PROFITABLE

Television Troubleshooting

A STEP-BY-STEP GUIDE TO EFFICIENT PROFESSIONAL SERVICING OF BLACK-AND-WHITE AND COLOR TELEVISION RECEIVERS

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Preface

This book is written to meet the practical needs of a man who knows radio servicing and would like to expand his capabilities profitably into television, including color sets. The book will also appeal to the television serviceman who wants to improve his basic understanding of the work. The information is arranged in a practical sequence which can be put to actual use as the reader goes along. It can thus be used equally well for home study, as a classroom text, or as the basis for an on-the-job training program.

The approach used in the book represents an entirely new attack for the problem of advancing a man from radio to television. It is the outgrowth of almost twenty years of personal experience in television—as a serviceman, a service manager, an engineer, and a practical teacher. All of this experience involved the very real requirement of earning a satisfactory living in the field of television servicing. The experience revealed consistently that there was a glaring weakness in standard approaches to the subject.

The typical book or course on television servicing assumes that the student must master the operation of all the circuits before he can start doing any real servicing work. The truth is, however, that such study is unnecessary and confusing.

The approach used in this book is definitely simple and practical. The subject is covered in layers, as it were. Each layer deals with the whole subject, but in limited depth, and provides a broad layer of knowledge. Information is then given on how this much knowledge can be used in practical servicing. After this the subject is covered again, broadly as before but in more depth so that another group of television receiver troubles can be fixed. These steps are repeated in cycles so that each step can be thoroughly digested and used before the next is started.

A quick glance at the arrangement of the subjects serves to illustrate this point. After an orienting introduction in Chapter 1, the technical aspects of television are introduced in Chapter 2. This chapter deals with background facts in conversational terms. It covers the things you ought to know about *television* itself, before you start worrying about television *receivers*. This first useful layer of knowledge will develop ability to talk about television to your customers. It will help you answer the questions they ask every day.

Chapter 3 is a natural follow-up. It explains how black-and-white television receivers use the principles covered in Chapter 2. Circuit detail is deliberately avoided. Instead, the receiver is studied exclusively from the standpoint of the functions which it performs. The chapter explains *what* a set does, not *how* the circuits are designed to do these things. This knowledge alone will permit you to do many service jobs without going any further in your study.

Chapters 4 through 9 deal with practical service work which can be done by applying your functional knowledge. These chapters cover installation, tuning, adjustment, how to make service calls and how to replace tubes and simple parts. This information will help you handle the majority of repair jobs which come your way.

Chapters 10 through 13 represent the next layer of knowledge, in that they cover the circuits which perform the basic functions of the television set. Here again, broad and uniform coverage is the objective. The information will permit a more analytical approach to tougher problems—the kind that are more easily solved if you know how the actual circuits work.

Chapter 14 deals with troubleshooting. It shows how circuit knowledge is applied to service work. Practical cases are given to add clarity. Tables are also included to help in the analysis of a wide range of trouble symptoms.

Chapter 15 deals with information about special television servicing instruments—the kind you would use as you gain competence. It explains how they work and how they are used, both for troubleshooting and alignment.

Chapter 16 delves into the problem of television interference. This chapter is especially valuable because it deals with this problem in practical down-to-earth terms.

The final four chapters expand the earlier information into the field of color television. Thus, another important layer of knowledge is unfolded. You quickly get a clear concept of how color television works, because each chapter concentrates on what is important. To illustrate this point, the confusing mathematics of color has been avoided because it adds little to basic understanding of color servicing problems.

Much of the information contained in this book has been provided through the direct help and cooperation of many individuals and organizations in the television industry. Wherever possible, credit is given under illustrations to identify the source. One of the major contributions was the fine collection of picture screen photographs supplied by the Allen B. Du Mont Laboratories and the General Electric Company. Many of the sketches in the final three chapters are based upon information provided by the Radio Corporation of America.

A special note of appreciation is extended to John Markus, not only for his critical review of the complete manuscript, but also for the patience, encouragement, and inspiration which he provided.

Finally, the most sincere thanks are due to my wife, Fran, without whose help, sympathy, and personal sacrifice these pages would be blank. The typing of the manuscript was hard work but not nearly as difficult as the task of getting me to start from scratch after I had completely scrapped the original manuscript.

Eugene Anthony

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1

Your Chances in Television Service

Television Service Offers Opportunity. The field of television service offers great opportunity to the ambitious serviceman. This opportunity stems not only out of the fact that millions of television receivers are in regular daily use, but also out of the fact that the television business continues to grow daily and rapidly. The popular adoption of color television ensures a long future of continued growth even after black and white television has reached a stable level.

More Servicemen Are Needed. That stable condition is not yet here. More servicemen will be needed to handle the growing load, and also to take the place of those who are unable to make the grade for one reason or another. This situation is to be expected while a business is in process of growth. It is not until after it has settled down for some time that the knock of opportunity becomes softer. Even though new servicemen are getting into the television service business every day, their number is not increasing as rapidly as is the need for their services.

Servicing Is Big Business. Some authorities claim that the radio and television service, as a combined business, is growing faster than any other in the country. This observation might be less surprising if it were limited to television service only because it is relatively new, having started virtually from scratch in 1946. But it includes radio service, a long-established business, along with television, so that the claim is thus all the more impressive. Radio service is included because of its natural association with television service; almost all television servicemen handle radio service as well, and consider the business to be a single package. You will probably do the same thing; it might be foolish to do otherwise.

Television Business Figures. As evidence of that growth, these figures are given: In the year 1939, every man, woman and child in the country, on a per capita basis, spent 70 cents per year for radio service. Big business? You bet! But look at what has happened since. In the year 1950, the per capita expenditure for radio and television service climbed to $4, almost six times what it was in 1939. By 1955, it had reached $9 per person, or more than double the 1950 rate. It would seem that with some well-directed effort, you should be able to get your share.

Other Attractions of Television. The field of television service offers something beyond simply the earning of a living. The very nature of the work is such that one can find a great deal of personal satisfaction in it. It also offers the opportunity for independence to those men who want it.

Personal Tips for Success. Your chances for success are better than good if you really sense an interest within yourself in the general field. If you like to read about television, to ponder over circuits, to use simple hand tools, and to talk to people, you have good reason to approach television service with a high degree of confidence. You have the assurance, at least, that you will be doing something that you can enjoy, and the work will be easier. Then, if you add a little common sense, patience, and good judgment, your chances of success will become extremely good.

Business success is encouraged further if you are earnest, sincere, and if you exercise good character. There is no substitute for personal character as a factor in establishing a good reputation for yourself in your community. When you have done that, you have a valuable competitive asset which will add greatly to your volume of business, to your profits, and to your personal satisfaction.

The average television service customer wants a serviceman who is honest as well as competent. Once he deals with a serviceman who has these qualities, he generally supports him strongly and loyally where it counts—with other prospective customers.

You can make these forces work in your favor if you follow two simple rules. First, make certain that you will always *deserve* your reputation; and second, make certain that you establish, as a firm objective, the deliberate development of this reputation. To express this second rule another way, don't assume or even hope that you will create a feeling of trust with your customers simply because you *are* honest; instead, make it a special point to reflect this quality in your total conduct without being obvious about it.

Getting Started in Television. A radio serviceman who contemplates getting into television service often fits into the picture better than he may realize. He may feel that he is at an overwhelming disadvantage—that nobody wants to deal with a beginner and that his services, as a consequence, are not worth much. That leaves him with little choice (he reasons) but to use low price as a bait, and that prospect does not sound promising.

There is little need to harbor such fears. Customers are not able, really, to rate a serviceman on his technical ability or experience when they first see him or speak to him. Instead, they rate a man in terms of his apparent confidence, or lack of it. The beginner has many good reasons to feel confident and thus to transmit that impression honestly to his customers.

Results Count. To illustrate the point, the beginner *can* provide a valuable service. There are many television service jobs which are basically simple to perform. He can perform these as competently as a man with years of experience—perhaps not always as quickly, but the results should be equally satisfactory to the customer. Examples of the kind of jobs that can be done competently right from the start are given in a few later paragraphs.

Don't Fear Competition. Although his competitors may be able to handle the tough jobs more quickly (a purely academic point because the practical repair situation never boils down to a competitive, side-by-side race) they have few secret weapons to use. This is especially true of the large service organization which, on the surface, may appear to be heavily armed.

Sheer size is not an advantage in itself, except perhaps to the owner of the business. When you get down to cases, there is little direct advantage that the customer can see; repair work cannot be mass-produced. Each job is necessarily a custom job, no matter how formal the organization may be.

Often, size creates disadvantages at the customer level, which gives you a fighting chance to compete effectively.

Drawbacks of a Large Organization. The larger organizations find it quite difficult, as a rule, to maintain the highest standards of personal relationships with customers. They often must compromise in the selection of servicemen. The financial problems which arise in slack periods invariably have their impact on the general manner in which calls are made. The servicemen frequently lack deep personal interest in their work and the lack is often sensed by the customer.

Criticism of the larger service organization is not intended. As a rule, they are honest, competent, and efficient, but the problems outlined above nevertheless exist.

Advantages of a Beginner. The beginner is in a favorable competitive position with other independent servicemen as well, because of the fact that the bulk of their respective expenses is essentially the same. For example, the matters of rent, telephone, parts, automobile, insurance, and so on, are no respecters of experience. For a given type of business, the expenses relative to these items are about the same for both; and they constitute the greater part of the cost, by far, in the performance of service work.

Beyond this, the enterprising beginner can often outsmart his experienced competitors by applying some good old-fashioned common sense. He can do this if he realizes how important the matter of good human relations is to the television repair business, and does a good job of following its principles.

By way of example, the simple matter of consistent neatness both in individual habits and appearance, as well as of shop and vehicle, can add dramatically to the success of a serviceman and can place him in higher esteem than other servicemen who have been in business much longer. Thus, the beginner on this score, too, is in a position to slug it out with most established pros on pretty fair terms.

Earn While You Learn. Television service is the kind of work that you can improve upon as you go along. You don't have to know it all at the start. You may not realize that a great many television servicemen presently in the business get by with only a minimum of technical knowledge and do a good part of their work "by feel," so to speak—but they are nevertheless capable of quality workmanship and of providing honest value for their customers.

With a little radio knowledge and repair experience as a background, you can fit into the television service picture without taking a back seat.

Many Television Service Jobs Are Simple. There are many television service jobs which can be done with virtually no previous television service experience. All you need is some practical experience with radio service and with radio service tools. There are other jobs which can be done after only a little initial study, such as is provided in the early chapters of this book. This includes installing antennas, adjusting sets, replacing tubes, and making other simple service calls. You will be able to tackle many of these jobs almost immediately. Later on, more detailed information is given to help you with some of the more complicated problems which come up from time to time.

Following are some illustrations of the simple types of repair jobs which comprise a large portion of the total jobs which you will have to do.

Replacing Tubes. Authoritative estimates of small-tube failures in television sets run around 30 per cent or more. This means that almost one out of every three jobs calls for the simple replacement of a tube, and generally nothing more. Replacing tubes in television sets is not quite as easy as in radio sets because there are more tubes and because some of them are a little harder to reach. Otherwise, the procedure is about the same.

Although it is possible to locate a defective tube by blind substitution, there are time-saving ways to simplify this procedure. Some concrete ideas are offered in this book. In any event, an inexperienced man can quickly learn to handle this kind of job, and thus will be able to fix about one-third of the service jobs which come up, even before he has studied further.

Antenna Service. An appreciable amount of television trouble develops out of problems in the antenna system. Broken wires, loose connections, corroded terminals, and mechanically damaged antennas are fairly common occurrences. Repairs of this nature call for little special experience and can be done at a profit. With ordinary care, a new man can do work at a quality level comparable with that of more experienced men. There is a wide variety of good accessories available for television antenna work which simplifies the problem greatly. The man from whom you buy these accessories may also be able to help you with useful suggestions as to how best to use them.

It is, of course, quite simple to put your finger on an antenna problem when the antenna is obviously in poor condition. It may be quickly apparent that the leads are broken or that the antenna itself is falling apart. Less obvious cases may be solved, however, if a practice is made of examining the antenna when a reasonable doubt as to its condition exists, and particularly if it has been in service for a few years. You may be surprised at the number of problems you can solve and the extra money you can earn in this way; it's a safe bet that you will pick up more antenna jobs than you would otherwise get.

Component Failures. Just as in radio, there are many component failures in television which are relatively easy to find—sore-thumb defects, as it were. An overheating power transformer is one case in point, an arcing sweep transformer is another. Such repairs are most easily made by a beginner when the manufacturer's original part is purchased, because no improvising is needed. A later chapter provides some practical information about this general type of work.

Complex Problems. Problems will arise from time to time which are beyond the scope of the inexperienced serviceman. These, however, need not prove to be a stone wall. In most areas, he can take the chassis to the shop of another, more experienced man, or perhaps to the shop of the set distributor, and pay to have the necessary repairs made. If he is lucky, he may find that one of these people will be willing simply to point out what the problem really is.

If he has to pay to get the set repaired, he won't make as much profit on the job, or he may just about break even, but that's a lot better than returning the set unrepaired. The serviceman would normally charge the customer for the repairs that he had to pay for, plus an appropriate charge to cover the original call, the pickup, delivery, and reinstallation in the cabinet.

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Getting Acquainted with Television

Two Stations in One. A television broadcast station, in effect, is composed of two completely separate broadcast stations, one for the sound and the other for the picture. They operate at different frequencies and can even use completely separate antenna systems. They operate as a *single* system only because the camera and microphones deal with the same subject; that is, the sound which is picked up by the microphones (or other audio pickup devices) is directly associated with the subject upon which the camera is trained. The general idea is illustrated in Fig. 1.

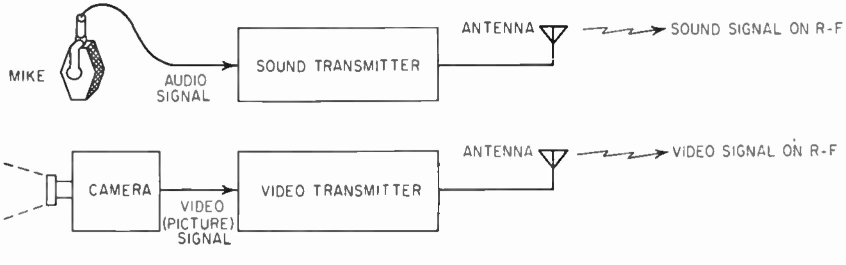


Fig. 1. Elementary diagram showing how the sound and pictures are handled as separate signals in a television station

At the receiving end of a television broadcast, it is entirely possible to pick up sound and picture with two separate receiving systems, although this practice would prove more costly and cumbersome than the familiar single-receiver system. The serviceman, however, should not let the use of a single receiver cause him to lose sight of the fact that the receiver deals with two separate signals. The nontechnical viewer, of course, is not concerned with this detail; he is satisfied that he is dealing with a single broadcast because he watches and hears the program as a single presentation.

Nature of Sound Signal. The audio portion of a television program is broadcast by means of frequency modulation (f-m) in much the same manner as conventional f-m broadcasting is carried on in the 88- to 108-mc band. The principal differences are in bandwidth and frequency assignment. Conventional f-m broadcasting employs a bandwidth of ±75 kc while the television sound channel is limited to ±25 kc. The f-m broadcast station frequency assignments are made in the 88- to 108-mc band, whereas each individual television sound transmitter is assigned to a specific frequency within its corresponding television channel. This will be explained in a little more detail later.

Although f-m is used for the television sound signal, the matter of servicing television sound circuits is much simpler than servicing conventional f-m receivers. There are a number of practical reasons for this, enough to indicate that you don't have to be an f-m expert to deal with the sound circuits of television sets.

One reason is that the alignment of the f-m circuits in a television set is much simpler to accomplish than in an f-m set. The narrower bandwidth is partly responsible but, even more important, the standards of performance for television sound are not nearly as exacting as are those for high quality f-m receivers.

A television receiver, by way of illustration, is not called upon to pick up very weak f-m signals (the weak picture becomes a problem before the sound performance suffers seriously). Ordinarily, the f-m sound signal in a television set is strong enough to compensate adequately for poor alignment, deterioration of tubes, etc.

Another important aspect is the psychological one; the average television viewer normally expects little more of his television sound than to have it reasonably clear and intelligible. The television viewer who seeks high-fidelity sound performance is the exception. As a matter of fact, the great majority of television receivers employ "utility" sound circuits because the popular table model leaves little effective space for a good speaker location anyway.

In spite of these things, the average television sound system is capable of good f-m performance, and especially so with regard to its noise-elimination properties. This is a particularly important advantage to the employment of the f-m system for television sound. As you will see later, the picture signal is amplitude-modulated and is located next to the sound signal in the spectrum, and thus is in an especially delicate relationship to the sound signal in terms of possible interference with it. As a matter of fact, the picture (video) signal is deliberately permitted to "interfere" with the sound signal in the intercarrier type of television receiver. This makes much circuit simplification possible; complete elimination of that interference is easily done at the proper time. As you will see, the intercarrier type of receiver with its many advantages would not be possible were it not for the fact that f-m is used for the television sound signal and a-m for the picture signal.

Nature of the Video Signal. The picture is transmitted by means of a radio carrier which is amplitude-modulated, just as in the conventional broadcasting carried on in the 500- to 1600-kc broadcast band. The signal, however, is quite different from ordinary sound broadcast signals because the nature of the intelligence which must be conveyed is radically different. The difference would be quickly apparent were you to tune a suitable short-wave receiver to listen in on a television signal. Two things would be immediately observed.

The first observation would be that there is a distinctive sound to the picture signal. You would hear a mixture of growls, whining sounds, whistles, and occasional rumbling. It is somehow suggestive of a busy machine shop with all of its equipment running full blast. Above all this jumble of sound you would hear a predominant 60-cycle hum.

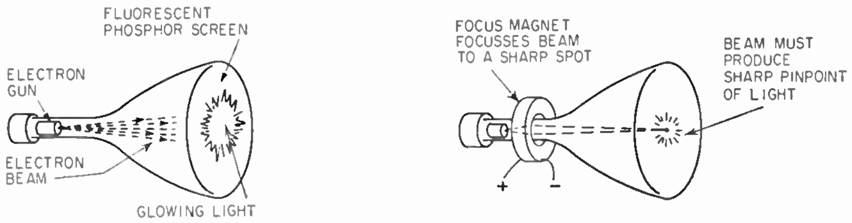
The second observation would be that the signal is extremely broad—it spreads out over a large portion of the tuning range. As a matter of fact, the signal spreads out over a spectrum wide enough to provide space for *over 200 a-m broadcast stations*, or for *more than 20 f-m stations!*

In order to be able to do a great part of the television service work with which you will be faced, it is necessary that you understand the composition of this unusual signal. That understanding is best obtained by pursuing a logical step-by-step approach to the related factors which enter into the transmission and reception of picture signals. The paragraphs which follow present such an approach and cover those basic facts which will provide you with a foundation for both monochrome and color television service and for future study.

Cathode-ray Tube. The basis of any practical television system is the device which will be used to display the picture. When the scanning disk was the only available device to do this job, television standards were very different. Not much was expected of the system because the scanning disk with its lamp and driving motor had its practical limitations. The development of the cathode-ray tube opened the door to today's high-quality television; our modern standards were developed to take advantage of the possibilities which the tube offered.

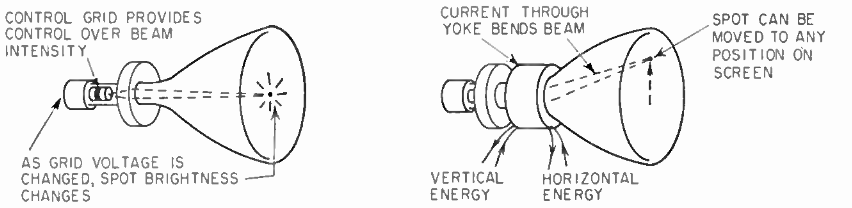
Despite the flowery phrases often used in lay circles to describe the miracle of the cathode-ray tube, it is basically a simple device. It performs a very simple function, but performs it well.

Fundamentally, a television picture tube is composed of two basic parts, a screen and an electron gun as shown in Fig. 2A. The screen is made of a fluorescent phosphor material which glows visibly when struck by electrons; the electron gun is a device which projects a beam of electrons toward that screen to make it glow.



(A) TWO BASIC PARTS

(B) ELECTRON BEAM REQUIREMENT



(C) CONTROL GRID ACTION

(D) BENDING THE BEAM

Fig. 2. Step-by-step illustration which shows how a picture is formed by a cathode-ray tube

Electron Beam Requirements. To be useful in television the electron beam must meet these three important conditions:

1. It must be extremely small so that it forms only a sharp pin point of light on the screen. The basic electron gun does not, of itself, do this, but rather, tends to form a fairly large blurred spot. Practical cathode-ray tubes use a focusing device either within the tube or around the outside (a focus magnet) to bring the beam to a sharp point. This is illustrated in Fig. 2B.

2. The beam must be controllable in intensity. That is to say, it must be possible to control the flow of electrons in the beam so that the brilliance of the spot of light can be varied. Picture tubes include a control grid in the gun which does this job, as in Fig. 2C. Smooth control is possible, from maximum brilliance down through the grays, until the spot disappears completely (the black condition).

3. The beam must be capable of being bent in any and all directions so that it can be made to strike the screen anywhere on its surface; and it must be capable of such movement at extremely high speeds. The electron beam meets these criteria perfectly. Being of very low mass, it can be bent about at incredible speeds; speeds which, in fact, exceed the needs of television. This is ordinarily done by means of coils placed outside of the tube which act upon the beam magnetically, and bend it about as in Fig. 2*D*. The cathode-ray tube is flared out like a funnel to provide free space through which the beam can travel, no matter in which direction it is bent.

Perhaps the most significant fact about the cathode-ray tube is that, at any given instant of time, it forms only a single pin point of light. It can no more produce a complete picture all at once than a typewriter can stamp out a full page at one stroke of the keys.

Getting a Complete Picture. Actually, the operation of the cathode-ray tube in a television receiver is analogous to that of an automatic typewriter located at the receiving end of a teletype system. The typewriter is capable of typing any combination and arrangement of characters, but it does so letter-by-letter according to the series of individual letter signals sent to it from the master typewriter. In addition to letter signals, the master typewriter sends special signals which tell the carriage when to return to the start of a new line.

The modern television system is similar in that the cathode-ray tube is capable of producing any picture on its screen, but does this by "printing" one dot of light after another and by arranging the dots in a series of horizontal lines on the screen. The general sequence is similar to that used in typing; the television system is designed to form a picture in a series of horizontal lines which are traced from left to right and which are placed one below the other until the full screen is covered. The cathode-ray beam is made to follow the line pattern as it progresses over the surface of the screen, and, while this is going on, its control grid is continuously under the control of the amplitude-modulated video signal. As a result, whites, grays, and blacks are made to appear in their correct physical positions; together, they form a complete picture.

Deflection Coils. The deflection yoke, as shown in Fig. 3, contains two pairs of coils. Each pair is series-connected so that it acts as a single coil. One pair is called the *horizontal deflection coil* because it is capable of bending the beam horizontally, along the "east-west" axis of the screen.

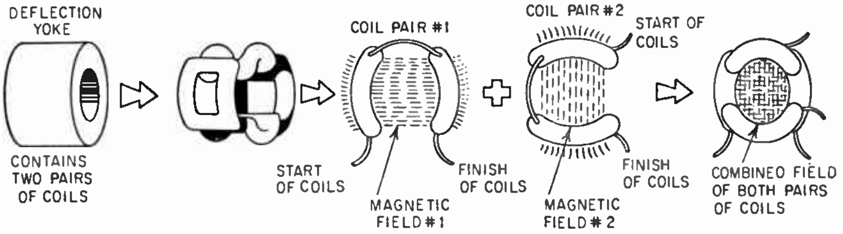


Fig. 3. Construction of a deflection yoke. The two pairs of coils are assembled as shown to provide for two magnetic fields at right angles to each other

The other pair is called the *vertical deflection coil* because it is capable of bending the beam vertically, along the "north-south" axis of the screen. Together, these coils can move the beam anywhere on the screen when suitable amounts of current are passed through each one.

The two deflection currents are fed to the yoke in a special combination of deflection speeds which causes the line pattern to be followed by the beam. This is illustrated in Fig. 4.

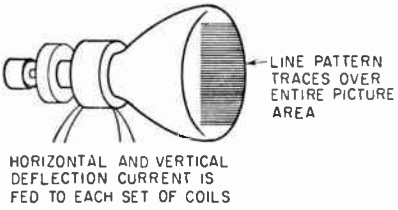


Fig. 4. The combination of slow vertical deflection energy and fast horizontal deflection energy results in a regular line pattern which fills a rectangular area of the screen

The process of forming a television picture, as you can see from the above, is basically simple. Unfortunately, it is not possible to slow up the action of a television set enough to *see* the process going on, but you can imagine it in your own mind. It is good mental exercise to do so because it helps immeasurably in giving you the real feel of television and it will help you to tie together the new things which you will learn as you go along.

Imagine, if you will, the slow progressive typing of a picture on a cathode-ray tube; then make it go faster and faster in your mind until the motion of the beam is so fast that you can no longer see it; you see only the full picture and it seems to be formed all at once. When you can do this successfully, you will have a clear, dynamic idea of how television works; you will recognize that the picture tube does a simple job, but that it does it too fast to let you see what's happening.

Fig. 5. Photograph of the essential parts of a deflection yoke. The coils have been pulled apart to show how they are made. (Allen B. Du Mont photo)

Number of Picture Elements. From the above you can see that each and every element of a picture must be transmitted individually in rapid sequence. The matter of *how many* elements there are in each line and *how many lines* are used in a full picture now becomes an important consideration.

Obviously, if there are only a few lines and few characters or elements per line, only a crude picture can be constructed. On the other hand, if millions of elements and perhaps thousands of lines are used, a picture of incredibly fine detail is possible. But remember this: each element must be transmitted individually, one after the other, and the more there are, the harder it is to do the job.

True, the cathode-ray tube is capable of operating at fantastic speeds, but the various coils, tubes, and circuits which act together to control the tube become more and more complicated and less and less efficient as their operating speeds are increased. Thus, a compromise was necessary when television standards were originally established.

It was recognized that the picture had to have enough elements to be a high-quality picture, but that it should not have so many that the system would become overly complex and inefficient. The commercial television standards finally settled upon a picture content of roughly 260,000 elements.

Frame Speed. Note that in the preceding paragraphs, consideration is limited to a *single picture*, or frame, as it is called. The next factor can now be taken up, and that is *how many* frames per second are required to create the illusion of continuous motion. In effect we have been dealing with a single frame in a reel of motion-picture film and have settled upon the quality (number of elements) of that individual frame. Now we must determine how fast the frames are to be displayed.

Here again, speed is an important consideration because as it increases, the system becomes more complicated and less efficient. Thus, there is an advantage in keeping the speed as low as possible.

Flicker Problem. There are two factors which cause difficulties when the frame speed is decreased. They are (1) the appearance of *flicker*, and (2) loss of smooth continuity of motion, which permits stuttering or jerkiness to be observed in moving objects. These effects were studied by motion-picture engineers long before the advent of television, and a very valuable discovery was made. The discovery is just as valuable to television as it was to motion pictures.

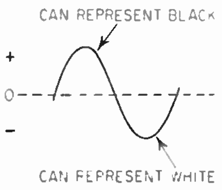
It was discovered that the illusion of smooth motion is obtained at frame speeds much lower than those required to eliminate flicker. To illustrate: At 24 frames per second, motion appears smooth, but there is very bad flicker. The frame speed has to be roughly doubled before the flicker disappears.

This discovery is valuable to the motion-picture industry because it made possible the effective *doubling* of film footage. Since only 24 frames per second are needed to create the illusion of smooth motion, only 24 scenes per second are photographed and printed. Then, to satisfy the need for 48 frames per second to eliminate flicker, each individual frame is displayed *twice* in the theatre.

The television system uses the same general principle to effect a similar saving. As you shall see later, the saving is in *bandwidth* and it is also a 2-to-1 saving. Here's how the idea is applied in television:

Flicker Speed. A flicker speed of 60 per second was selected as the most convenient value because of its numerical relationship to 60-cycle power-line frequencies. Using exactly 60 greatly reduces hum problems which might have been serious had the speed of 48 been used, or any other between 48 and 60. Without the motion-picture experience to fall back on, it might have been assumed that 60 *completely different pictures* would have to be transmitted each second.

A quick calculation reveals that if each picture has 260,000 elements and 60 are required each second, then 15,600,000 elements must be transmitted each second. That figure is high enough to call for careful study in terms of possible economy. To be transmitted by an a-m transmitter, it would require a bandwidth of at least 7,800,000 cycles per second or 7.8 mc. The bandwidth figure is *half* the number of elements because *each cycle* has a positive and a negative swing, consequently, it can serve to supply two picture elements in each cycle as shown in Fig. 6.



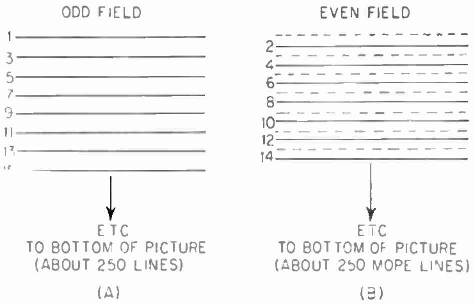


Fig. 6. (Left) A single cycle of alternating voltage permits two elements to be formed on a television picture. Thus there may be twice as many elements as there are a-c cycles

Fig. 7. Sketch showing how the odd (A) and even (B, solid lines) fields interlace in a full frame

Interlacing. To reduce the rate at which picture elements must be transmitted without sacrificing the advantages of 60 presentations per second, the principle of *interlace* was developed. In effect, it does what a motion-picture projector does when it repeats each picture twice—it creates a great saving through the simple expedient of fooling the eye.

The principle of interlace in television is incorporated through the display of only alternate lines of a picture in the first full screen presentation, after which those which were omitted in the first are displayed in the next presentation. Thus, two presentations are needed to display all lines. Each presentation is called a *field* and two fields are required to form a *frame,* as the full picture is called.

Lines per Picture. The full television picture is composed of roughly 500 lines. If we could trace the action from the start (in the upper left-hand corner of the screen) we would find that only 250 lines are formed by the cathode-ray beam on its first coverage of the screen surface and that a space is left between adjacent lines, as in Fig. 7A. If we call these the odd-numbered lines, we can then say that the odd *field* has just been completed.

Immediately upon completion of the odd field, the cathode-ray beam returns to the upper left-hand corner and starts tracing its second *field,* this time placing the lines of picture information *between* those of the odd field, as in Fig. 7B. These, then, are the even-numbered lines. When the second field is completed, all 500 lines of picture information have been displayed and a single *frame* has been completed. Thus, there appear to be 500 lines in the scene.

Field and Frame Speeds. The *field* speed is 60 per second, which is much too fast for the eye to discern—the eye sees steady illumination which is free of flicker. The *frame* speed is only 30 per second because two fields are needed to fill in a full frame, but the eye sees smooth continuity of motion. The net result is that only 30 *pictures* of 260,000 elements each must be transmitted each second. This calls for 7,800,000 elements per second instead of 15,600,000 and requires a bandwidth of only about 3,600,000 cycles per second or 3.6 mc. This is an appreciable improvement and is accomplished without sacrifice of picture quality.

Scanning. The line-by-line construction of the picture is a scanning process. The scanning is done in the same general sequence through which a typewriter covers a printed page. The typewriter prints characters in a straight horizontal line from left to right, at some practical rate. At the end of each line, the carriage is quickly returned to the start of the new line, below the first, and so on, until the bottom of the sheet is reached.

In order to simulate the effect of interlace, the typewritten sheet is returned to the starting position, but this time the sheet is slightly offset so that the characters are typed in the space *between* the first and second lines. If we continue to type, even without consciously trying to inter-space the lines, each new line will appear between the originals and the sheet will be solidly covered with characters when the bottom of the page is reached.

During this action, movement in two directions takes place: one is along each line from left to right and at a comparatively fast rate; the other is from top to bottom of the sheet at a relatively slow rate. To illustrate the point, if the typewriter forms say, 50 lines in each individual pass at the page, the left-to-right speed is 50 times as great as the top-to-bottom speed. Full coverage of the sheet of paper is, therefore, obtained by combining two rectangular movements, one horizontal and the other vertical, and these are fundamentally rhythmic in nature. Furthermore, the very nature of the process is such that one of the movements (the horizontal) is much faster than the other (the vertical).

Television Sweep Speeds. This relationship holds true in television. The movement of the beam is called scanning, or sweeping, and likewise is done in two directions which are at right angles to each other. The horizontal sweep speed is much faster than the vertical sweep speed.

It is important to know what numerical speeds are actually used in television and how they were chosen.

The vertical sweep speed has already been mentioned. Each vertical sweep accounts for a single field and there are 60 such fields per second. Thus, the vertical sweep speed is 60 cps.

Although the horizontal sweep speed was not mentioned, enough facts were given to permit you to make a rough guess as to what it might be. It was stated that there are about 250 lines per field and that 60 fields are formed per second. Using these figures, the horizontal speed would be 250 times 60, or 15,000 sweeps per second.

This figure is not accurate, because it is based on a convenient approximation for the number of lines, although it does illustrate the general principle. You ought to know the exact speed, however, and should have a little better idea as to how it was originally selected as a standard. The object, after all, is to display 260,000 picture elements most effectively, whether that requires 100 or 1,000 lines.

Exact Sweep Speeds. Here is a rough idea of how the proper number of lines per picture, and consequently the horizontal sweep speed, was established:

Assume that the picture which had already been established as having about 260,000 elements has those elements distributed uniformly over a square area. The elements can be visualized as being individual characters, set row upon row in checkerboard fashion. If this is done and they are then counted along the edges, there will be found to be about 525 rows each way. (That will give exactly 262,500 elements.) Since the lines are considered to be those rows which lie in the horizontal direction, there are 525 *lines* in the picture. Because the picture is interlaced, the full complement of lines calls for two scans, so that 525 lines are produced 30 times per second. Thus, there must be 30 times 525 lines scanned each second. This comes out to be 15,750 lines per second, which is the exact horizontal scanning speed used in television.

The mathematics involved is not quite as simple as shown here because the television picture is rectangular rather than square, but the basic idea is adequately illustrated in the example.

How Interlace Is Obtained. A few additional simple calculations will shed light upon the way in which line *interlace* takes place. Two fields are required to display the full quota of 525 lines. It follows then that each field contains 262 *and one-half* lines. It is because of this fractional relationship that interlace takes place—automatically. Two full fields are required to come out with an even number of lines; therefore, each second field will be identical. The ones in between will be offset by one-half line and will automatically cause the horizontal lines to interlace with each other.

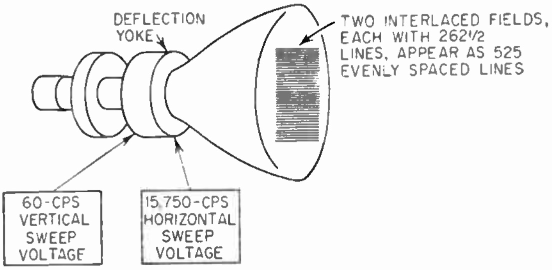


Fig. 8. Sketch showing the numerical relationship between horizontal and vertical scanning speeds which result in a properly interlaced raster

If this fails to make itself clear, you can try a simple experiment that will illustrate the point perfectly. Place any *odd* number of empty cups in a circle and then, starting with any one, drop a coin into *every second* cup. Continue this around the circle a few times. You will find that after the first circuit, the coins will be dropping into empty cups *between* cups which already have coins. After the second circuit, you will be dropping coins right on top of the first ones.

The experiment illustrates why no trick circuits or adjustments are needed to bring about interlace. It is the natural result of mixing two perfectly regular scanning speeds such that the higher (the horizontal) can be expressed as being so many *plus one-half* times the lower (vertical) speed. The horizontal speed is 262½ times the vertical speed, as indicated in Fig. 8.

Synchronization Problem. Thus far, these facts have been established or implied with respect to the signal which carries the picture information: The signal is composed of a continuous stream of amplitude-modulated intelligence which conveys element-by-element information about the picture. The elements may occur at speeds of up to seven to eight million per second. They are broken up into 15,750 lines of information each second and are arranged in fields of 262½ lines each.

The receiver must be able to decode the continuous stream of information in order to be able to place each *line* of information in its correct place on the screen of the cathode-ray tube. In order to do that, it must be able to sense at exactly what point each line starts, as well as to sense where those lines are to appear on the picture. It must then be able to apply that sensibility to circuits which can control the motion of the cathode-ray scanning beam so that it may reconstruct the picture on the screen; otherwise the picture information will appear as a meaningless mixed-up jumble of black, gray, and white specks.

Synchronizing Pulses. The process of placing each line where it belongs is called *synchronization*. The process requires that the transmitter include, along with the picture-element information, additional information to mark the point at which each line of picture elements begins, and the point at which each field (of lines) begins. These data are transmitted in the form of pulses (in amplitude), one type to serve as the line-marking pulse (called the *horizontal synchronizing pulse*) and another type to serve as the field-marking pulse (called the *vertical synchronizing pulse*).

Picture Signal. Bear in mind that these pulses are mixed in with the continuous stream of information picked up by the television receiver; but they are expected to perform a distinctly different job than is performed by the picture signal. The latter is intended to control the moment-to-moment *brightness* of the cathode-ray beam, while the synchronizing pulses are intended to control the *motion* of the beam; yet both the picture signal and the synchronizing pulses are essentially of the same character—they are both transmitted as amplitude excursions of the radio carrier.

Pulse-separating Problem. To operate successfully, the television receiver must be able to separate the sync (synchronizing) pulses from the picture signal so that these pulses may be used separately to do the synchronizing job which they are intended to perform. As a matter of fact, the receiver must be able to go one step further, and that is also to separate the horizontal from the vertical sync pulses, so that each may perform its particular function, one to control the horizontal spot motion, and the other, the vertical.

These criteria are met by assigning specific limits to the amplitude levels of both the picture signal and the synchronizing signal, as shown in Fig. 9. It is important to observe that as the carrier power goes up, the cathode-ray spot grows blacker; as it goes down, the spot grows whiter.

The transmitter is so adjusted that the whitest white causes the carrier power to drop down to the 25 per cent level. At no time does the signal drop below this level. The blackest black is adjusted to drive the carrier up to the 75 per cent level. Nothing in the picture can make it go higher.

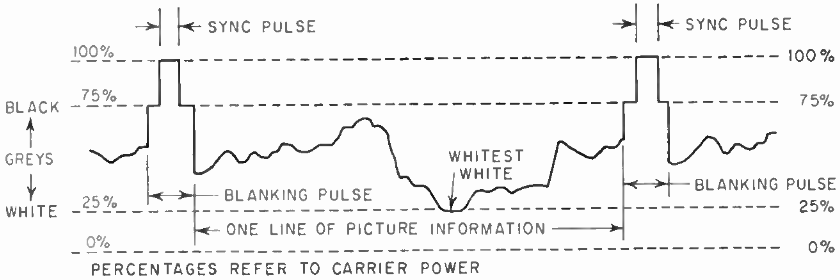


Fig. 9. A video waveform. The drawing shows a little more than one horizontal line. The pulses are horizontal pulses and contain one line of picture information between them

Horizontal Blanking Pulse. At the end of each line of picture information, the video signal is driven to the black level by the transmitter and held there for a short period of time. The black-level signal which does this is called the *horizontal blanking pulse,* and is shown in Fig. 10A. Its purpose is to extinguish the cathode-ray spot at the end of each line and to keep it extinguished while the beam retraces rapidly across the screen to start the next line. In the typewriter analogy, this is equivalent to the deliberate blocking of the keys while the carriage is returned to the left-hand margin of the page.

Horizontal Sychronizing Pulse. It is during the blanking pulse that the sync pulse is transmitted. It rises from the 75 per cent black level to the 100 per cent level, which region is called blacker-than-black (see Fig. 10*B*). Note that this pulse cannot be seen on the cathode-ray screen because it is an impulse which occurs in total darkness.

Pulse Clipper. Because the sync pulses are in the blacker-than-black region, that is, between the 75 and 100 per cent amplitude levels, they stand out above the rest of the signal, in the clear. No forces at the transmitter except sync pulses cause the amplitude to rise above 75 per cent. It is this very characteristic of the video signal which permits the television receiver to separate the sync signal from the picture signal.

Separation is done by means of a clipper which is biased-off heavily enough to permit nothing but about the uppermost 10 or 15 per cent of the signal to get through to the synchronizing circuits. The clipper, in other words, strips off the sync pulses cleanly from the video and uses them to synchronize the scanning action of the cathode-ray tube with the scanning action of the camera at the transmitter.

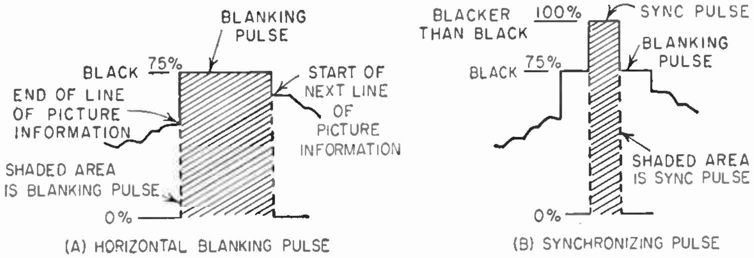


Fig. 10. The construction and positioning of the horizontal sync and blanking pulses which, together, appear as a composite pulse

Vertical Synchronizing Pulses. Thus far, specific reference has been made only to the horizontal pulses. Vertical synchronizing pulses are also transmitted, and in essentially the same manner. They occur at the end of each *field* so that there are 262½ horizontal sync pulses for each vertical pulse. The vertical pulse also occurs in the blacker-than-black region, but it is distinguished from the horizontal pulse by its duration. The horizontal pulses are about 6 microseconds long while the vertical pulses are about 500 microseconds long.

The great difference in character permits the separation of horizontals from verticals, both of which appear in the output of the sync clipper. The horizonal pulses are fed to the horizontal sweep circuit and serve to synchronize the horizontal scanning of the cathode-ray beam. The vertical pulses are fed to the vertical sweep circuit and serve to synchronize the vertical scanning of the cathode-ray beam.

Vertical Blanking Pulse. It should be pointed out that a vertical blanking pulse is employed and serves the same purpose during vertical retrace that the horizontal blanking pulse serves during horizontal retrace. It is proportionately longer to take care of the inherently longer retrace time of the vertical scanning system. The vertical blanking pulse is appreciably longer than the vertical synchronizing pulse and it is formed in the same general way, as shown in Fig. 10.

Scanning Action. The synchronizing pulses which are contained in the video signal serve only to *synchronize* their respective (horizontal and vertical) scanning circuits in the television receiver. Both circuits generate their own oscillations and feed them to their respective sets of deflection coils at the neck of the cathode-ray tube where they do the work of scanning the beam both horizontally and vertically.

The scanning circuits perform this function just so long as the television receiver is on, whether or not a television signal is being received. The difference is that when no signal is received, the two scanning oscillators run free of control. The vertical, for example, may be 58 or 59 instead of 60; the horizontal may be 16,000 instead of 15,750. When a television signal is tuned in, however, the sync signals are applied to the scanning circuits in such a way as to bring them into perfect step with the signal and the scanning speeds become exactly right.

What Synchronization Does. The object of synchronizing is not to make the scanning speeds exactly 60 and 15,750 per second but rather to make the scanning circuits *duplicate the scanning action* which is taking place in the transmitting camera. The numerical values are only average. At any given moment, the horizontal speed at the transmitter may really be 15,720 cps, for example, and the vertical 59.6. The synchronizing pulses, however, convey the exact action which is taking place at the camera in so far as scanning is concerned and cause the television receiver to duplicate the action perfectly.

Speed or Hold Adjusters. The synchronizing pulses are effective only when the television receiver is so adjusted that the two scanning circuits normally tend to run at approximately the correct speeds. When that is true, the pulses serve simply to alter the free-running speeds just enough to make them exactly right. That is why television receivers include some form of speed adjustment, one for the horizontal scanning circuit and the other for the vertical. They are usually identified as SPEED or HOLD adjusters.

The basic function which these adjusters perform is to permit variation of the natural speeds of their respective scanning circuits so that each wants to run at a speed which is very nearly correct. Then each circuit needs very little encouragement to shift into absolute synchronism.

Size Adjusters. There are two other kinds of adjusters associated with the scanning circuits. They are *size* and *linearity*. The size adjusters associated with horizontal scanning may be called WIDTH, SWEEP WIDTH, or HORIZONTAL SIZE adjusters. Those associated with vertical scanning may be called HEIGHT or VERTICAL SIZE adjusters. The linearity adjusters are usually called HORIZONTAL LINEARITY and VERTICAL LINEARITY adjusters.

The purpose of the size adjusters is self-evident. Each permits the picture dimension to be adjusted to fit the screen properly, one from top to bottom, and the other from side to side. What they really do is control the amount of scanning energy applied to the cathode-ray tube. As the energy is increased, so is the size of the picture, and vice versa.

Linearity Adjusters. The purpose of the linearity adjusters is not as readily evident, although they are important. Their purpose is to make possible the adjustment of the "smoothness" of the scanning action. Only when the action is "smooth" will the shapes of objects be properly presented on the screen.

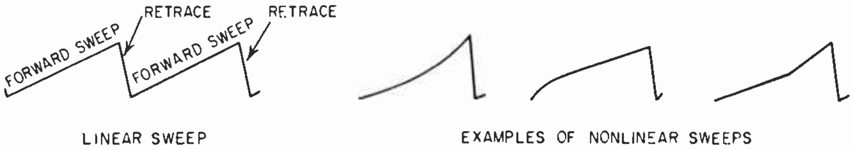


Fig. 11. Graphical representation of good sweep (linear) and examples of nonlinear sweeps. Nonlinear sweep causes the picture to be distorted by compressing or expanding portions of the scene

The term smoothness is used here to convey the idea of constant velocity of the scanning action. It is not enough to have each horizontal line start at the right instant and at the right physical location. The cathode-ray beam, in forming this line, must travel across the screen at a *uniform rate of speed*. The same is true of the vertical scanning; it, too, must move the beam downward at a uniform speed so that the horizontal lines will be spread out evenly all the way down the screen. Figure 11 shows what linear sweep looks like graphically.

Linearity adjusters are provided because practical scanning circuits, by nature, tend to be nonlinear, thus tend to develop nonuniform scanning action; adjustable compensation is needed to correct this. Figure 11 also shows examples of nonlinear scanning. No doubt you have seen the effect of poor linearity in a receiver. It is most quickly recognized in the vertical circuit. It causes performers to appear to have stubby legs, or stretched legs, or flattened heads, or compressed torsos. Poor horizontal linearity causes objects to appear wider or narrower than they should at certain places on the screen.

Linearity is most easily adjusted by using a test pattern as a guide. The method is described in a later chapter.

Bandwidth. Up to this point little has been said about the *radio signal* which carries the video signal except that it is an amplitude-modulated carrier. That r-f signal, however, differs from the more familiar amplitude-modulated radio broadcast signal in several important aspects. Unless you understand what these are, you may have a great deal of difficulty in tuning receivers properly or even in beginning to understand the why and wherefore of alignment.

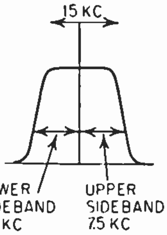


Fig. 12. Sidebands of an a-m broadcast signal

It was explained earlier that the video signal may include components as high as 3.8 mc, or 4 mc in round numbers. Compare this with the 7.5 *kilocycles* used in a-m broadcasting to get an idea of how much greater that is.

A-M Radio Uses Double-sideband Transmission. In a-m broadcasting, the carrier is modulated by the audio signal which has components as high as 7.5 kc, and the resultant modulated signal spreads out as far as 7.5 kc *each way*, as shown in Fig. 12. The total bandwidth is 15 kc. You can tell, in a rough way, that this is true when you tune through an a-m signal. It fades off in exactly the same way on each side of perfect tuning. This characteristic is called "double-sideband" transmission and it is almost universally used for audio transmission.

Double-sideband transmission, however, is wasteful of bandwidth because it employs twice the bandwidth represented by the modulating signal. Each sideband conveys the same intelligence; the two are simply "mirror images" of each other, one for each side of the carrier frequency. Double-sideband transmission, on the other hand, offers the important advantage of being extremely easy to tune—almost everyone can tune a broadcast receiver properly. It also simplifies both transmitter and receiver design.

Bandwidth Problem in Television. When it comes to television, these advantages are not worth nearly as much when the extremely wide sidebands are taken into account. With double-sideband transmission, the 4-mc video signal would result in an r-f signal 8 mc wide. This would reduce materially the number of television channels available for use and would also seriously impair the efficiency of r-f and i-f amplifier circuits.

The above comments might lead to the hasty conclusion that it would be best to eliminate one of the sidebands and employ the single-sideband system, which is used to a limited degree for some forms of voice communication. The objection to this, however, is that single-sideband receivers are complex and usually are extremely difficult to tune. It takes an expert to tune in a single-sideband signal properly and the equipment is critical of adjustment.

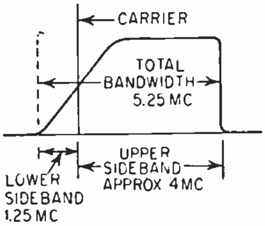


Fig. 13. Sideband distribution of a television video signal

Television Uses the Sesqui-sideband Method. A compromise method, called sesqui-sideband, or vestigial-sideband, is much more satisfactory since it makes possible material saving in bandwidth without making the receiving equipment unduly critical and difficult to adjust. This method is used in television.

The sesqui-sideband method of a-m transmission eliminates the greatest part of one of the sidebands while retaining the other fully. The saving in bandwidth which this makes possible is shown in Fig. 13. Note that it is almost cut in half from the 8-mc figure which double-sideband transmission would have required.

These facts have been stressed here because they bear directly upon the matter of television-receiver alignment. You may have already noticed that the television alignment instructions given by manufacturers call for locating the carrier "off-center," unlike those given for a-m radio, where perfect carrier centering is the rule. You can see from Fig. 13 that the sesqui-sideband method of transmission is an off-center system; consequently, the alignment of receivers must be correspondingly done in order to get proper results.

How to Tune a Television Set. For similar reasons, the tuning of a television receiver is different from a-m tuning. In the latter, correct tuning is indicated by the strongest signal. In television, this is not true. If the picture is tuned in where it is strongest, it appears badly smeared and blurry. Correct tuning is done down the slope, or what appears to be off the side of the signal. The signal gets a little weaker (although you may not notice it if the signal is strong and good automatic-gain-control action takes place) but it becomes very much better in quality.

Only one of the two sides produce these results. When you tune down the wrong side, the signal simply goes to pieces. The reason, of course, is that the receiver must be tuned to pick up that sideband which is transmitted and not the one which has been suppressed at the transmitter.

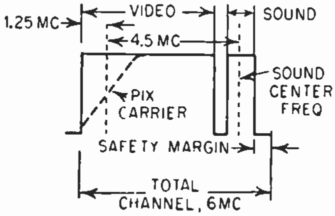


Fig. 14. Channel dimensions of a television signal with sound

Standard Television Channel. A television channel includes space for both the amplitude-modulated picture signal described above and for the frequency-modulated sound signal described earlier. The two signals are transmitted side by side. Such a channel is shown in Fig. 14.

The illustration is intended to show only dimensions and the relationship of the picture signal to the sound signal; consequently, specific signal frequencies are not included.

Note that the total channel is 6 mc wide. It provides for the picture and sound signals together with safety margins around the sound. The exact figures shown here need not be remembered. A general impression of the channel structure is enough to retain, with one exception: the sound carrier and picture carrier are exactly 4.5 mc apart. That is to say that if the picture carrier is at 100 mc, for example, the accompanying sound will be at 104.5 mc. (The sound is always on the *higher* frequency side.) This separation is important to remember because it forms a basis for the popular intercarrier type of television receiver which is described later in this book.

The exact frequencies assigned to the vhf channels are shown in the upper part of Fig. 15. Each of the channels conforms with the dimensions given in Fig. 14. Channel 2, for example, is 6 mc wide (54–60 mc). The picture, or video, carrier (55.25 mc) is exactly 4.5 mc below the sound carrier (59.75 mc). The same is true in each of the other channels.

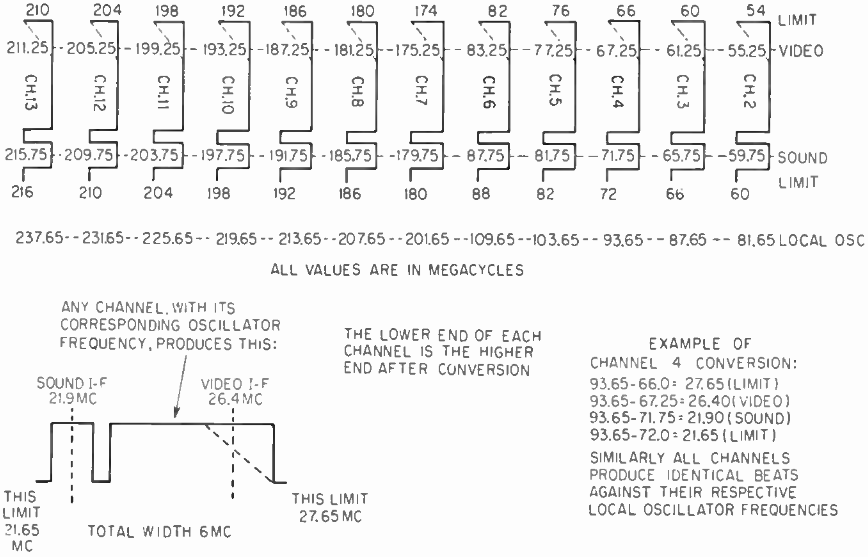


Fig. 15. Channel assignments of vhf stations and an example of frequency conversion to the i-f frequency. The local oscillator frequencies shown below the channel diagrams are the proper frequencies to convert the signals to the i-f frequencies on the lower portion of the diagram

You may notice that in the lower group of channels (2 through 6) the frequencies are not consecutive in that there is a gap from 72 to 76 mc not assigned to television. In the higher group (7 through 13) the frequencies run in consecutive order from 174 through 216 mc. The channels in the uhf group (channels 14 through 83) are similarly assigned in consecutive order from 470 through 890 mc. Channel 14 is assigned 470–476; channel 15, 476–482; and so on through channel 83, which is assigned 884–890 mc.

Television Receivers Are Superheterodynes. It was suggested earlier that because of the special characteristics of sesqui-sideband transmission, a special type of receiver alignment is needed to provide satisfactory results. Each television channel has exactly the same alignment requirement in terms of the dimensions shown in Fig. 14 although the channels fall at different r-f frequencies.

The only practical method of meeting these requirements is to use the superheterodyne circuit for television receivers. With this type of circuit it is possible to have an i-f amplifier which is accurately aligned to meet the standard television channel requirements as to bandwidth and shape, and then to convert each channel to that i-f frequency when it is to be received. Thus, each channel is provided with a carefully predetermined response characteristic. The r-f amplifiers employed before conversion are tuned rather broadly so that they play little part in shaping the selectivity of the receiver; their function is primarily amplification.

Frequency Conversion. Figure 15 illustrates the manner in which conversion occurs. This is no different from the operation of a conventional superheterodyne except that in the latter, only a single signal frequency is normally thought of, whereas with television, several different frequencies must be taken into account at the same time. Moreover, in broadcast superheterodynes, the signal with its sidebands is symmetrical so that there is no occasion to take into mental account which sideband comes out where, after conversion.

The point is that, in conventional broadcast superheterodynes, several frequency conversions may be taking place at the same time, but they are rarely taken into separate account when basic circuit operation is studied. Television superheterodynes work exactly the same way except that it is necessary to take each of the significant frequency conversions into account to see what really happens.

The basic principle of the superheterodyne is to beat a local-oscillator signal against an incoming signal so that two beats are produced, one being the sum of the two and the other, the difference. Then, an i-f amplifier is tuned to either one of the beats, which it amplifies at this new and more convenient frequency.

Oscillator Runs High. In television, the low beat is almost invariably employed (the oscillator is higher than the signal frequency). In the example shown in Fig. 15, the i-f frequency range is 21.65 to 27.65 mc. In order to have the channel 4 signal fit exactly into this "slot," the local-oscillator frequency is set at 93.65 mc. Then the 66-mc low limit of the channel subtracted from 93.65 produces the 27.65-mc *high limit* of the i-f channel. Similarly, the 72-mc high limit of the channel, subtracted from the same 93.65-mc oscillator signal, produces the 21.65-mc *low limit* of the i-f "channel." By the same method, the sound carrier of 71.75 mc becomes the 21.9-mc i-f sound carrier and the 67.25-mc video carrier becomes the 26.4-mc i-f video carrier. The fact that the i-f is reversed in frequency (the sound carrier is now on the *low* side of the video) is of no particular importance except that this effect is anticipated in the design of the receiver and the i-f is aligned accordingly.

The arithmetic involved in the conversion of channel 4 to the i-f passband is shown in Fig. 15. Similar events take place in all other channels, so long as the correct local-oscillator frequency is used. Correct oscillator frequencies are shown for all vhf channels below the channel representations, to correspond with the particular i-f characteristic used in the illustration.

In practical television receivers, the local-oscillator frequency is tunable over a range by means of the TUNING control so that the user is required to set it properly.

Tuning Older Split-carrier Receivers. In the earlier split-carrier type of receiver the control is tuned by listening to the sound. When the sound is heard properly, the oscillator adjustment is known to be correct and the video i-f frequencies are, therefore, also assumed to be correct. In this type of receiver the sound i-f circuit is permanently tuned to 21.9 mc (if the receiver uses the particular i-f characteristics shown in Fig. 15) so that when the sound is heard properly the sound i-f signal must obviously be at 21.9 mc. Then, all other i-f frequencies correspond with those shown in Fig. 15.

Tuning Modern Intercarrier Receivers. In the more popular intercarrier type of receiver, the sound is *always* correct (for reasons to be explained in the next chapter) so that the tuning control is tuned by watching the picture instead of by listening to the sound. The setting which provides the most pleasing picture is the one which is then used. This provides more latitude than the type of receiver described above because the owner does not have to take what he gets in terms of picture tuning. He can mistune the receiver one way or the other to compensate for some deficiency in antenna, alignment, or signal, although he is not ordinarily aware that he is doing this. He simply tunes for what, in his estimation, is the best-looking picture.

Because of these factors, the alignment of split-carrier receivers is much fussier than that of intercarrier receivers, as you will see when you reach the point of doing i-f alignment work.

Summary. The preceding paragraphs covered some of the basic things you ought to know before you start thinking in terms of a complete, operating television receiver. The highlights are summarized as follows:

1. The television receiver must pick up two separate signals—an f-m sound signal and an a-m picture signal.
2. The picture is formed on the screen of a cathode-ray tube.
3. The cathode-ray tube includes an electron gun and a fluorescent screen which glows when the electron beam from the gun strikes it.
4. Some sort of focusing device is used with the cathode-ray tube to focus the beam to a sharp point.
5. A control element in the gun permits the intensity of the cathode-ray beam to be controlled from brightest white, through the grays, to black (beam cutoff).
6. A deflection system is used to move the beam about so that it can cover the full useful surface of the screen.
7. The deflection system is composed of a horizontal sweep and a vertical sweep section, which together move the beam in a regular rhythmic motion so as to cover the total picture area, line by line.
8. The horizontal sweep speed is nominally 15,750 per second while the vertical is nominally 60 per second. The mathematical relationship between the two results in interlacing.
9. The video signal, being amplitude-modulated, varies in amplitude and thereby conveys information relative to the picture. The variation is from 25 per cent carrier power for white to 75 per cent for black. It is used to control the intensity of the cathode-ray beam.
10. The video signal includes sync pulses for synchronizing both the horizontal and vertical sweep circuits. These pulses rise to 100 per cent carrier power (blacker-than-black) and are not visible on the screen.
11. The sync pulses are extracted from the video signal by means of a clipper which clips the pulses cleanly off the video signal.
12. A separator is used to separate the horizontal from the vertical pulses so that each may be used separately in its respective circuit.
13. The video signal is transmitted next to the sound signal so that both may be picked up simultaneously.
14. The video signal is less than 6 mc wide and is transmitted by the sesqui-sideband system in order to conserve bandwidth. The receiver

is aligned with a similar characteristic in order to respond to the signal properly.

15. Television receivers are superheterodynes.

QUESTIONS

1. What kind of modulation is used for the television sound signal? The video signal?
2. What are the basic parts of a cathode-ray tube? What components are used around the neck to make it work?
3. What does a deflection yoke contain and how does it work?
4. What is meant by *field* and *frame* speeds and what are these speeds?
5. Make a sketch showing the principle of interlaced scanning. Approximately what is the total number of lines in the picture?
6. What are the scanning speeds?
7. Make a rough sketch of a video waveform including a horizontal blanking pulse and a sync pulse. Label the parts.
8. What is the significance of the 25 per cent and 75 per cent levels of the video signal? What takes place between 75 per cent and 100 per cent?
9. What is the purpose of the clipper? Of the separator?
10. What is the difference between horizontal and vertical sync pulses? What is their purpose?
11. What is meant by linearity of sweep? Express the answer graphically and in terms of picture appearance.
12. What are the principal differences between the signals of an a-m broadcast station signal and a television picture signal?
13. Why is it incorrect to tune a television set simply for the strongest picture?
14. If your customer has owned a split-carrier set and has just bought a new intercarrier set, what would you tell him about the difference in tuning?

3

How Television Receivers Work

Learning Step by Step. The preceding chapter explains some of the important basic concepts regarding television. The concepts were discussed pretty much as individual factors which play a part in television as we know it today. No serious attempt was made to relate them to each other in terms of a complete television receiver. Instead, they were treated as a collection of ground rules which are better covered in advance, before a play-by-play description of a television set is taken up.

In this chapter, those ground rules will be put together and a functional block diagram of a television set will be built up. This will be done in a step-by-step fashion, starting with the familiar a-m broadcast receiver as a base. Each step will add a new function until the complete block diagram of a practical television set is obtained.

The coverage is called *functional* because little emphasis will be placed on circuitry, and no circuit diagrams will be used. The object is to show *what* the circuits do, not *how* specific circuits accomplish these tasks. Once you have a clear *functional* picture of a television set in mind, you are ready to think about circuits in greater depth; but before you do that, much of this functional knowledge can be put to practical work.

A-M Broadcast Receiver. The block diagram of an a-m broadcast receiver is shown in Fig. 1. It will be recognized as a conventional superheterodyne with an r-f stage.

The r-f amplifier, the mixer, and the local oscillator are tuned simultaneously with a ganged tuning condenser, represented by 1*D*. The output of the mixer is at 175 kc, 456 kc, 465 kc, or whatever i-f frequency is used in the particular receiver. The tuning mechanism covers the broadcast band from 550 to 1600 kc.

Radio Tuner. A dashed box is shown around the r-f amplifier, converter, and oscillator in order to treat this group of circuits as a single item, identified as the *tuner*. This is done principally to employ terms which are common to television language. The important point to keep in mind is that the tuner performs one basic job: It takes any one of the many signals which come down from the antenna and converts it to a given i-f frequency. The signal can then be amplified at this i-f frequency, detected, amplified further, and finally heard through the speaker. The desired station is selected by the tuning control. The output of the tuner is fed to the i-f amplifier.

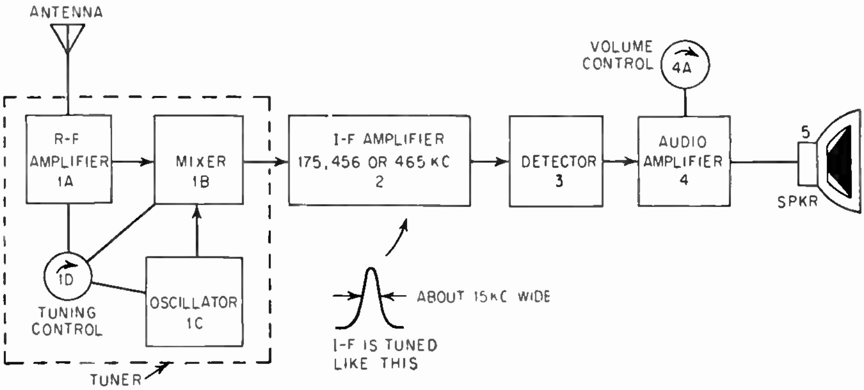


Fig. 1. Block diagram of an a-m broadcast receiver

I-F Amplifier. The i-f amplifier in box 2 of Fig. 1 may consist of one, two, or three stages of amplification, each with its own i-f coil or transformer. The function of the i-f amplifier is twofold; it provides the amplification needed to bring the signal up to a higher power level, and it provides the desired selectivity characteristic.

Selectivity. Some receivers employ very *sharply tuned i-f stages* to provide knife-like selectivity so that they can tune in stations very close to each other without getting interference. When this is done, fidelity is sacrificed because the very narrow i-f bandwidth cuts out the higher sidebands which contain the high-frequency audio components, and they are not heard. The gain, however, is very high when sharply tuned circuits are used.

Fidelity. Other receivers employ *broad i-f tuning* in order to permit higher fidelity; the broader tuning permits the higher sidebands to get through. This is done, of course, at a sacrifice in selectivity, and the receiver may not perform well with stations which are close together. A sacrifice in gain is also made and the receiver may be poorer on very weak stations unless more amplifier stages are used.

The average general-purpose broadcast receiver is a compromise between these limits; a bandwidth of about 15 kc is common and is represented on the diagram below the i-f amplifier.

Detector. The output of the i-f amplifier is fed to the detector, which may employ a tube or a crystal. The principal function of the detector is to extract the modulation from the i-f signal. The intermediate-frequency signal, as such, is filtered out and discarded, while the audio-frequency component is retained. The output of the detector is audio, but at too low a level to be applied directly to the speaker.

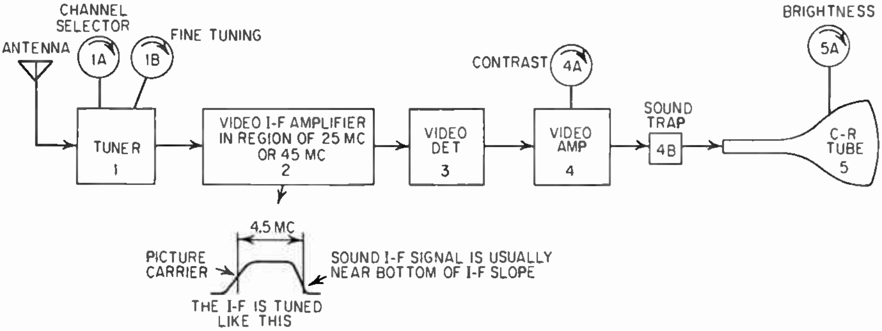


Fig. 2. Block diagram of the basic video functions in a television set

Audio Amplifier. The low-level audio is fed to an audio amplifier, whose principal function is to amplify the signal to a high enough level to be fed to the speaker. The amplifier may use one or more stages, depending upon the audio power desired. The typical receiver employs two stages, one a voltage amplifier, and the other a power amplifier which feeds the speaker through an output transformer.

A volume control is included somewhere in the audio amplifier to permit the listener to adjust the audio level to suit his particular requirements.

Basic Diagram of Television Set. Figure 2 shows the basic video functions of a television set. Note the similarity to the block diagram of a broadcast receiver. Not only do the diagrams look somewhat alike, but the functions are also quite similar. The most striking difference is the fact that a cathode-ray tube rather than a speaker is used at the output end.

Television Tuner. The antenna feeds its signals into a tuner which consists of an r-f amplifier, a mixer, and a local oscillator, individually shown in Fig. 3. Basically, they are the same as their counterparts in the broadcast receiver and they perform the same functions. The tuning mechanism, however, is somewhat different. Rather than a continuous tuning mechanism as on most broadcast receivers, switching is used. This is not unlike pushbutton broadcast receivers, which may employ from 5 to 10 or 12 pretuned sets of coils which are brought into use separately by means of a pushbutton switch.

The television tuner employs 12 sets of pretuned coils, each set tuned to a different television channel. They are brought into use separately by means of a rotary channel-selector switch.

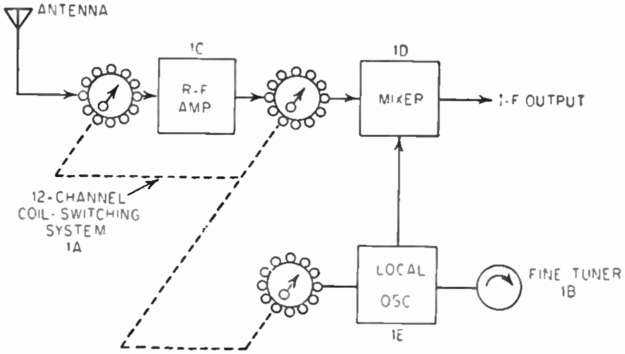


Fig. 3. Block diagram of the basic circuits of a typical television tuner

Continuous or dial tuning is rarely used in vhf television because the stations are not located one after the other in frequency sequence. (There is a gap from 72 to 76 mc and from 88 to 174 mc.) In the case of uhf channels, assignments are made in sequence from channel 14 through 81, and continuous dial tuners are common. The basic receiver under consideration, however, is a vhf receiver, intended to receive channels 2 through 13.

Fine Tuning. In addition to the channel-selector switch, the typical television tuner employs a fine-tuning control, commonly labeled TUNING. This is simply a vernier control which permits the oscillator frequency to be tuned a little way above and below the correct frequency. It permits the user to adjust the set so as to compensate for his particular receiving conditions and preferences. More important, it simplifies tremendously the design of the receiver and its internal adjustment because it makes it unnecessary to set it up in advance so that it is exactly right; it permits compensation for normal drift which is difficult to eliminate, especially the kind that takes place slowly as the receiver ages.

The channel-selector switch and fine-tuning control are shown in Fig. 2, directly above the tuner. The output of the tuner, as in the case of the broadcast receiver, is at the applicable i-f frequency. Most television receivers employ a video i-f frequency in the neighborhood of either 25 or 45 mc, the latter being more popular in modern sets.

The i-f signal contains both the video signal and the sound signal because they are transmitted adjacent to each other. Both signals get through the tuner in much the same way that two adjacent broadcast stations are sometimes picked up and heard simultaneously.

Video I-F Amplifier. The video i-f amplifier in Fig. 2 serves the same purpose as its counterpart serves in the broadcast set; it provides amplification and the desired selectivity characteristic. In television, however, the term selectivity is not usually employed, because the i-f amplifier is not selective in the usual sense. Instead, it is very broadly tuned so that it can pass all the sidebands of the video signal, which sidebands are very much broader than those involved in audio work. A typical television i-f amplifier may be from 3 to almost 4 mc wide. In addition, the i-f coils are carefully aligned so that the i-f amplifier will respond properly to the sesqui-sideband transmission characteristic employed in television. A rough idea of the i-f passband is shown below the video i-f amplifier block.

Ordinarily, more stages of amplification are used in television sets than in broadcast sets because the gain per stage is lower. (It was pointed out above that when the i-f amplifier is more broadly tuned, the gain is lower.) From two to five stages of amplification may be used to bring the video signal up to a suitable level.

The f-m sound signal is amplified along with the video signal although not nearly as much, because it appears near the bottom of the slope of the video i-f passband, as indicated in the illustration.

Video Detector. The output of the video i-f is fed to the video detector, shown in box 3 of Fig. 2, which serves to extract the *video signal* from the *video i-f signal*. The detector may employ a diode or a crystal. Its output is composed of the picture information originally picked up by the transmitting camera. Because the f-m sound i-f signal also appears at the detector along with the video i-f signal, the output of the detector includes, in addition to video, a *beat signal* between the video and sound signals. This beat occurs at 4.5 mc because the sound and video carriers are exactly that far apart in frequency.

The beat between these carriers, called the *intercarrier* beat, may be likened to the whistle which you sometimes hear when you are listening to a broadcast station on one frequency and the carrier of an interfering station is near that frequency. You hear the audio perfectly well except that there is a constant annoying whistle in the background. The same is true of the signal delivered by the video detector; the video signal is detected in perfectly useful form, but a beat with the sound signal rides along with it. The beat cannot be called a whistle in the case of television because it is at a frequency of 4.5 mc, which is too high to hear, but it is nevertheless there.

As will be explained later, the intercarrier beat is useful in some respects and undesirable in others. For the moment, its presence is purely incidental, although it should be noted for future reference; the significant output of the detector, at this point in the discussion, is the video, or picture, signal.

Video Amplifier. As in the case of the broadcast set, the detector output is too low for direct use, so it is further amplified by the video amplifier of Fig. 2, where it is built up to a more suitable level. The amplifier may employ one or two stages. Special means are used to extend its frequency response from nearly zero to about 4 mc to provide faithful reproduction of the complex video signal.

Picture Tube. The output of the video amplifier is fed directly to the control element in the gun of the cathode-ray tube, where it controls the intensity of the cathode-ray beam. As the video signal swings up and down in voltage to convey information about the shading of the individual picture elements, the cathode-ray beam varies in intensity correspondingly, duplicating the black-gray-white information accurately from one instant to the next. Fluctuations from black to white may occur as rapidly as from three to four million times per second, or as slowly as only one or two times per second (or slower) depending upon the scene being transmitted. The voltage range from black to white is perfectly smooth, so that any intermediate shade of gray can be accurately reproduced. White is represented by 25 per cent of peak signal output while black is 75 per cent. The grays run the gamut between these values.

The video signal contains both picture information and synchronizing pulses, with the latter appearing at 100 per cent amplitude. They exceed the 75 per cent black level and therefore are blacker-than-black and are not visible on the cathode-ray screen. Thus, for all practical purposes, only the picture portion of the signal may be considered to appear at the cathode-ray tube.

Sound Trap. The intercarrier beat (the whistle) also appears in the video amplifier and, unless filtered out in some manner, appears at the cathode-ray tube where it may be seen as visible interference. It would be seen as a fine meshwork or graining in the picture, and would impair its quality. Most television sets incorporate some sort of trap to keep this beat signal from reaching the tube. It is tuned to reject 4.5 mc, the frequency at which the beat occurs.

The sound trap is often located at box 4*B* of Fig. 2, directly between the video amplifier and the cathode-ray tube, although it may be located anywhere in the video amplifier circuit between its input and output. The trap is composed of a small coil and condenser, with one or the other variable so as to permit alignment to exactly 4.5 mc.

Brightness Control. Associated with the cathode-ray tube is a BRIGHTNESS control, which permits the user to adjust the average brightness of the picture to suit his needs. In a brightly lighted room, the brightness must be advanced appreciably, otherwise the picture appears dim. Conversely, in a darkened room, the picture brightness must be reduced, otherwise the picture will appear to glare too brightly.

Contrast Control. Associated with the video amplifier is a CONTRAST control. This control is analogous to the volume control in the broadcast set in that it controls the output level of the signal. More specifically, the contrast control permits adjustment of the level of the video signal which is fed to the cathode-ray tube. It permits the user of the set to use the correct "volume" of video to suit the brightness level of the tube. Higher brightness requires more video, hence an advance in contrast, and vice versa. Contrast controls are sometimes called PICTURE controls.

Automatic Gain Control. Most television sets, like broadcast sets, use some form of agc (automatic gain control). Note that in television it is not called avc, which means automatic *volume* control. The general idea, however, is much the same. The agc circuit tends to keep the level of all television stations about equal at the video detector so that a minimum amount of adjustment is called for on the part of the user when he changes from station to station. The agc system is omitted from the block diagram in order to maintain simplicity.

In summary, there is a great deal of similarity between a broadcast superheterodyne and the basic video portion of a television set just described. In the former case, an audio signal is picked up and made to move the cone of a loudspeaker; in the latter, a video signal is picked up and made to control the moment-to-moment intensity of the electron beam in a cathode-ray tube.

Making the Spot Move. The television set shown in block diagram form in Fig. 2 is incomplete and thus is useless as it stands. The only result which it can produce is to cause a stationary blob light on the screen of the picture tube to vary in brightness. Before that action can be useful, the blob of light must be concentrated into a sharp pin point and then deflected about in the fashion described in the preceding chapter. In other words, the beam must be *focused* and *scanned.*

(As a matter of fact, the picture tube in Fig. 2 would not light up at all because no high-voltage supply is shown for the cathode-ray tube. To simplify matters, it is assumed that this power is somehow provided. A little later, the high-voltage supply will be shown, when its description fits into the discussion better.)

The functions which serve the purposes of focusing and deflection are shown in Fig. 4, which is identical with Fig. 2 except for these new additions.

Focusing. The matter of focusing the spot to a sharp point may be accomplished fairly simply by one of several practical methods. A common one, shown in Fig. 4, employs an adjustable magnet around the neck of the cathode-ray tube (and thus around the cathode-ray beam itself).

Electromagnetic Focusing. The magnet may be an electromagnet, which utilizes a form made of a magnetically permeable metal (soft iron, for example) which is magnetized by passing current through a coil of wire around the form. The intensity of the magnetic field (coil current) is controlled by means of a FOCUS control. When the intensity is just right, the cathode-ray beam converges to a pin point at the screen. When it is too high or too low, the spot is out of focus, and it appears blurry.

Permanent-magnet Focusing. Some television sets employ a permanent-magnet device for focus control. It is made of a stationary section and an adjustable section so that an adjustable magnetic gap is obtained. A mechanical-drive assembly is used to vary the gap and thus provide control of focus. The control is sometimes hooked up to a flexible shaft so that the adjuster knob may be located at the back of the cabinet. With many sets, it is necessary to take the back off the cabinet to get at the adjuster.

Self-focusing. Some television sets use cathode-ray tubes which are internally focused when they are built. These are generally known as the self-focus type. When this type of tube is used there is no visible focusing device nor is there need for an adjuster.

Deflection Yoke. Scanning of the beam is accomplished through the deflection yoke, shown at 5*D* in Fig. 4. This yoke is composed of two principal sections, one being a horizontal deflection coil system and the other a vertical deflection coil system. When sufficient electrical force of the correct character is applied to each, the line structure for the picture is obtained. The flickering spot of light then comes to life, for it paints a recognizable scene.

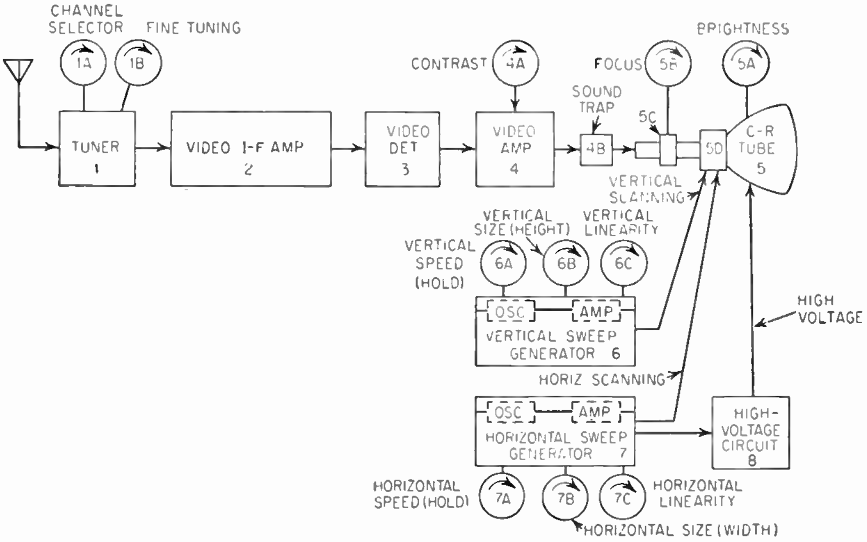


Fig. 4. Block diagram showing how the focusing, deflection, and high voltage circuits are added to the basic circuits shown in Fig. 2

Vertical Sweep Generator. The vertical deflection coil calls for a 60-cps sawtooth current to operate properly. That is provided by the vertical sweep generator, in box 6 of Fig. 4. The circuit may involve two or more tubes, or sections of dual tubes. It is composed of two principal parts: a vertical sweep *oscillator* and a vertical sweep *amplifier*.

The former is an oscillator of some form, designed to produce a sawtooth voltage at a nominal frequency of 60 cps, and adjustable over a convenient range above and below 60. It is followed by a sweep amplifier whose principal function is to build the sweep signal up to a power level high enough to deflect the cathode-ray beam fully from the top to the bottom of the screen. The sweep amplifier also performs some of the functions of shaping the oscillator waveform into as nearly perfect a sawtooth as possible. It includes some means for controlling amplitude, or vertical sweep amplitude, so that picture height may be adjusted to fit the screen accurately.

Sweep Adjusters. The adjusters associated with the vertical scanning circuit are shown on the diagram as 6*A*, 6*B*, and 6*C*. The first, 6*A*, is the speed adjuster (VERTICAL HOLD OR VERTICAL SPEED) which permits the speed of the sweep oscillator to be adjusted to the required 60-sweeps-per-second rate. The second, 6*B*, is the VERTICAL SIZE OR HEIGHT adjuster which controls the amplitude of the signal fed to the deflection coils as just explained. The third, 6*C*, is the VERTICAL LINEARITY adjuster, which provides for adjustment of the shape of the sweep waveform to obtain a good sawtooth characteristic.

Horizontal Sweep Generator. The horizontal scanning circuit is essentially the same except that it feeds energy to the horizontal deflection coils and it operates at a sweep frequency of 15,750 per second. Like the vertical sweep section, it employs an oscillator and an amplifier.

In a practical sense, there is an appreciable difference between the horizontal and vertical scanning circuits because the higher speeds of the horizontal circuit involve much more power than the vertical. Higher voltages and currents are used in the horizontal circuit. The horizontal sweep amplifier tube is usually a tube of appreciable power-handling ability.

The horizontal scanning circuit incorporates a SPEED control, 7*A*, a SIZE control, 7*B*, and a LINEARITY control, 7*C*, which are similar to their vertical counterparts.

A characteristic of the horizontal sweep amplifier, due to its high power and speed, is that it generates high voltages as a normal consequence of its operation. Ordinarily these high voltages might be considered a necessary evil of the circuit, were it not for the fact that very high voltages are needed for illuminating the cathode-ray tube; the horizontal sweep amplifier is a natural and economical source of supply for these voltages.

High-voltage Circuit. The ordinary cathode-ray tube requires d-c voltage in the order of 10,000 to 15,000 volts. An a-c voltage of this order is easily obtained from the horizontal sweep output transformer. This a-c voltage is rectified by a special high-voltage rectifier tube and filtered to provide pure direct current. Such a rectifier with its filter is represented by block

8 in Fig. 4. The high voltage is applied to the side terminal (high-voltage terminal) of the picture tube where it serves to give the cathode-ray electron beam the high velocity which it needs to make the fluorescent screen glow brightly.

The high voltage supplied to the cathode-ray tube is really a by-product of horizontal sweep. This should be remembered because it will serve you well and often when you troubleshoot certain television failures. It will help a lot to remember that when the horizontal sweep circuit fails, the high voltage fails, and no light is seen on the picture tube.

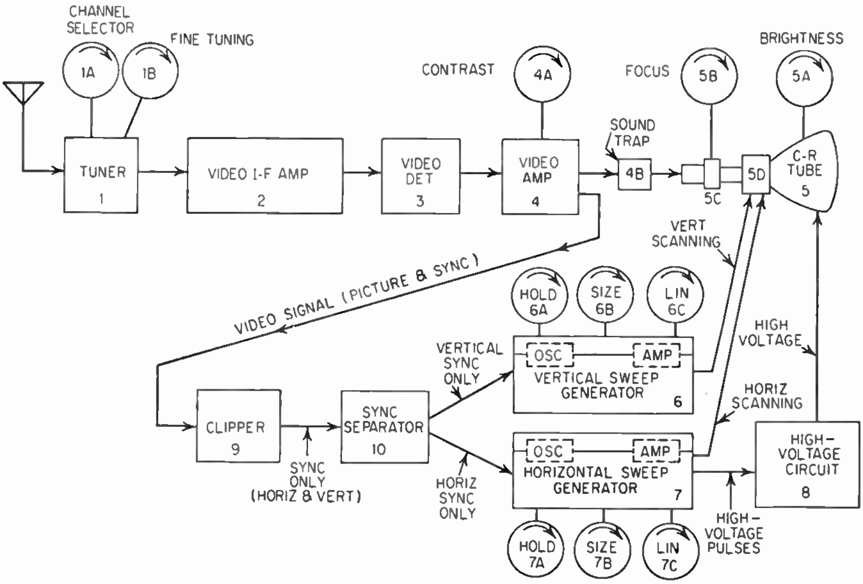


Fig. 5. Block diagram showing how the synchronizing circuits are added to the circuits shown in Fig. 4

Synchronizing Functions. Blocks 9 and 10 in Fig. 5 provide the horizontal and vertical sync pulses that must be used to synchronize the two scanning circuits.

Clipper. The clipper is used to extract the synchronizing signals from the video signals. The video signal may be obtained as shown, directly from the output of the video amplifier, or it may be obtained at some earlier point, perhaps at the detector or from a point within the video amplifier. The signal fed into the clipper is consequently the same video signal that is fed to the control element of the cathode-ray tube although it need not necessarily be at the same amplitude.

The clipper circuit resembles a standard resistance-coupled amplifier but it operates differently. Instead of amplifying the video signal, it clips it, and passes only the uppermost part of the waveform, the blacker-than-black part, which contains the sync pulses.

Sync Separator. The sync signal at the output of block 9 contains both horizontal and vertical pulses, but these are quite different from each other in character. The horizontal pulse is only about 6 microseconds long while the vertical pulse is about 500 microseconds long. This difference permits them to be individually recognized and separated from each other in the sync separator, shown as block 10.

The typical separator is composed of a network of resistors and condensers. The vertical part of the network is really a form of low-pass filter and it permits only the long, low-frequency vertical sync pulses to get through to block 6. The horizontal sync part of the network is really a form of high-pass filter and it permits only the short, high-frequency horizontal sync pulses to get through to block 7.

The two sync pulse signals are so applied as to control the timing of their respective sweep oscillators, thereby bringing about perfect synchronism of the television receiver with the transmitter.

Sound Circuits. The block diagram of Fig. 5 represents a complete television set with one obvious exception—it has no sound circuits. These are added in Fig. 6 to make the set complete. The diagram is that of an *intercarrier* receiver and it applies to the vast majority of modern television sets.

Intercarrier Receiver. The set represented by this diagram is called an intercarrier set because of the manner in which the sound signal is obtained in the circuit. It utilizes the beat between the video and sound carriers to good advantage. This beat appears at the output of the video detector (block 3).

The beat occurs at exactly 4.5 mc because that is the frequency difference between the sound and picture carriers. It is a mixture of the f-m sound signal and the a-m picture signal.

The video signal is branched off from the video detector and fed to the input of the first *sound* i-f amplifier, in block 11. This stage, like those represented by blocks 12 and 13, is tuned to exactly 4.5 mc.

Intercarrier Tuning. Items 11 through 15 are very much like a fixed-tuned f-m receiver, fixed-tuned to 4.5 mc. Block 11 is an amplifier, block 12 is a limiter, block 13 an f-m detector, block 14 an audio amplifier, and 15 is the loudspeaker. A conventional volume control, 14A, is used to permit the user to adjust the volume of the sound to suit his needs.

The intercarrier beat is not a clean f-m signal in any sense of the word, because of the large amount of video signal which is mixed with it. The video signal, however, is *a-m*, which an f-m receiver is designed to reject. For all practical purposes, the video signal may be considered to be nothing more than severe noise interference.

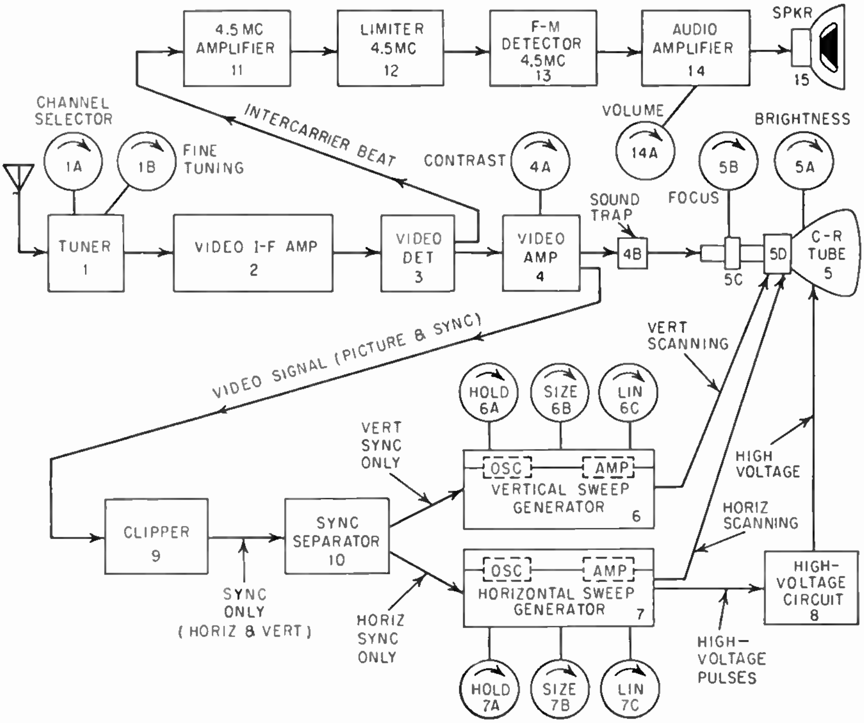


Fig. 6. Complete block diagram of an intercarrier television set. The diagram has been completed by adding the sound circuits to the circuits shown in Fig. 5

Limiter. The limiter cuts off the a-m component of the signal, leaving a relatively clean f-m sound signal. The f-m detector completes the job; it responds only to f-m so that it detects only the sound signal. Thus, the output of the detector is clean audio, and the listener need not be aware of the fact that it started out as a badly mixed signal.

Advantage of Intercarrier. The principal advantage of using the intercarrier beat for the sound signal is that the sound circuits of the receiver are always tuned exactly right, no matter how the user tunes the set. This is true because no matter what channel is tuned in, or how the local oscillator (fine tuning) is adjusted, the *frequency difference* between carriers is always 4.5 mc; the carriers are transmitted with that frequency difference and it *remains* fixed.

Here is an example. Suppose that at correct tuning for a desired station the picture carrier is 26.4 mc and the sound carrier 21.9. The difference is 4.5 mc. Now, if the local-oscillator frequency is shifted 0.5 mc so that the picture carrier becomes 26.9 mc, then the sound carrier shifts to 22.4, and the difference is still 4.5 mc.

Because of these facts, an intercarrier television set is easier to tune and generally provides better results. The user simply adjusts the set to give him the picture he likes best, knowing that the sound will be correct. Should the set drift in frequency, as many sets do, particularly on the higher channels, the effect will not be noticeable until the drift is so severe that the picture suffers, but the sound will remain unaffected. Some manufacturers refer to the intercarrier circuit as automatic sound tuning when describing the features of their sets.

Noise Elimination. The intercarrier idea offers other advantages which are important both to the owner and the serviceman. The two most important are that this type of set is almost completely free of channel-switch noise and is rarely bothered by microphonic local-oscillator tubes in the tuner. Both of these problems may be quite severe in split-carrier sets, as the other type of set is called.

A really bad channel switch will, of course, give trouble in any set, but the garden variety of dirty-contact noises is not heard in the intercarrier set. The reason for this phenomenon is that ordinary worn or dirty contacts do not really make and break when they are wiggled or moved, but rather, permit the point of contact to shift in position or pressure; this makes the oscillator frequency jump about. In split-carrier television sets this produces severe scratching noise; in intercarrier sets, both carriers jump about together, and no detectable change occurs in the frequency of the beat or in the audio.

The same general reasons prevail for the immunity to microphonics in oscillator tubes in intercarrier sets. The common microphonic condition in these tubes is a frequency-microphonic, meaning that a bonging sound is heard when the tube is bumped or otherwise disturbed physically. This effect, however, does not show up in the intercarrier set because both i-f signals (video and sound) wobble together and remain spaced at 4.5 mc. A microphonic oscillator tube, on the other hand, can be quite a problem in a split-carrier set, causing violent howling or at least bonging from time to time.

The block diagram given in Fig. 6 is the complete functional block diagram of an intercarrier television set. Once you understand it fully and have it clearly in mind, it will help you greatly in television troubleshooting work.

Split-carrier Sets. Not all sets use the intercarrier principle. As a matter of fact, none of the first television sets produced immediately after World War II used it. It was not until about 1948 that the intercarrier circuit started to come into use. Today, almost all sets use this circuit.

The original type of set was once called the conventional set but as its popularity waned it became known as the split-carrier type. It is called split-carrier because the two carriers delivered by the tuner to the i-f are used separately, one for the video and the other for the sound. The split-carrier set is shown in block diagram form in Fig. 7.

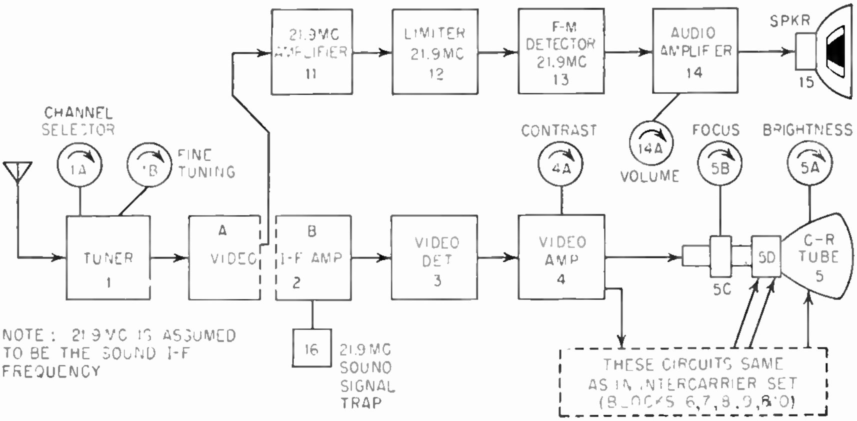


Fig. 7. Block diagram showing how the sound circuits are arranged in split-carrier television sets

Where Split-carrier Differs. The diagram of the split-carrier set is almost identical with that of the intercarrier set. The difference is in the frequency of the sound i-f channel and the point in the circuit from which the sound signal is picked up.

Split-carrier I-F. In order to understand how this type of set works, it is helpful to know exactly what i-f frequencies are used. Assume that the set is aligned for a video i-f frequency of 26.4 mc. The sound i-f frequency is thus 21.9 mc. The video i-f amplifier, 2, is aligned in much the same way as in the case of the intercarrier set; the complete video channel, blocks 2, 3, 4, and 5 of Fig. 7, works just about the same. In fact, even an intercarrier beat occurs at the detector, although it is not used.

There are some small differences in alignment and in operation of the video i-f circuits, but these are not particularly important at this time, and they will be explained later.

Split-carrier Sound. The signal for the *sound* i-f amplifier is picked up somewhere in the *video i-f* amplifier, and *before* the detector. The exact place is incidental; some sets pick it up right after the tuner, another may pick it up in the first, second, or even third video i-f amplifier. The important point is that the sound signal is picked up *before* the detector, thus, before the point at which intercarrier mixing occurs. The sound signal appears in the video i-f stages as a clean f-m sound signal at a frequency of 21.9 mc.

The sound i-f circuits are aligned to 21.9 mc, instead of 4.5 mc. As a consequence, the television set must be tuned by the user, using the sound as a guide. If the set is slightly mistuned, the audio goes to pieces. The user has no choice as to picture tuning because at only one setting of the tuning control will the sound signal be 21.9 mc, which it must be in order to be heard properly. Should the set drift during operation, it must be retuned to restore proper sound reproduction.

Despite the disadvantages, many split-carrier sets were built and you should be familiar with the functional diagram given in Fig. 7.

Failure of Picture Transmitter. There is an interesting feature of the split-carrier set which may be considered an advantage under special circumstances. Because the sound and video circuits are relatively independent of each other, the set will work on the sound signal alone, in the event that the picture transmitter should fail. The sound will still be there, at 21.9 mc, or whatever other sound frequency is used in the set, even when the video signal is absent. The intercarrier set, on the other hand, depends upon the video carrier to beat with the sound signal to produce the 4.5-mc intercarrier sound signal. If the video transmitter fails, the intercarrier beat also fails, and no sound is heard (and no picture is seen).

Both sets will continue to produce a picture if only the sound transmitter fails.

Troubleshooting Tips. Keep these facts in mind because they will help you in general troubleshooting work. They will tell you, for example, that you would not expect to hear any sound on an intercarrier set if a failure should occur in the video i-f amplifier; if the set produces no sound or picture it is probable that the sound circuit is O.K. and that troubleshooting should be done first in the video i-f circuits.

Sound-trap Action. The principal difference in video i-f circuits between both types of sets is due to the difference in the methods used to keep the sound from interfering with the picture. In the intercarrier set this is done with a 4.5-mc trap, such as *4B* in Fig. 6, placed somewhere in the video amplifier, after the detector. This method is used because the sound signal necessarily appears at the detector, thus it beats with the video; still it must not be permitted to pass on to the picture tube where it would be seen.

This same method can be used with split-carrier sets (and has been) although a different approach is generally used. Since there is no need to have the sound i-f signal reach the detector in the first place, it is usually trapped out completely before the detector and after the point at which the sound is branched off to the sound i-f amplifier. Such a trap is represented by block 16 in Fig. 7. One or more sound traps may be used, and each is tuned to 21.9 mc (or whatever sound i-f frequency is used in the set). They are generally connected into the video i-f transformers in such a way that they absorb the sound i-f signal and thus prevent it from being passed on to the next amplifier stage, or to the detector.

Thus, the split-carrier set usually traps out the sound interference at the sound i-f carrier frequency, *before* that signal reaches the detector; the intercarrier set traps out the sound interference at 4.5 mc, *after* it beats with the video in the detector.

How to Identify Intercarrier Sets. You can very quickly distinguish one type of set from another if it is operating. Just tune it, and note what happens to the sound. If the tuning is critical, that is, if it is like tuning in a regular f-m set, the set is a split-carrier receiver. If the sound tunes very broadly and seems to be correct over the major part of the tuning range, the set is an intercarrier receiver.

This can be expressed in another way: If the set obviously requires that the *sound* be deliberately tuned in to be heard, it is a split-carrier set. If the set may be tuned so that the picture can be affected without material effect on the sound, the set is of the intercarrier type.

Identifying a Dead Set. When the television set is not operating, it is not quite as easy to determine which type it is, and you may want to know. There are two ways to do this.

The first is to refer to any service data or specifications which the manufacturer has prepared. The set will probably not be identified as one type or the other, but you can tell by finding out the frequency of the sound i-f. The frequency may be marked on the circuit diagram or the alignment chart. If the sound i-f coils are tuned to 4.5 mc, the set is certainly an intercarrier set. If the coils are tuned *to any other* frequency, it is a split-carrier set.

The second way to find out is to ask the owner how he tunes the set. Does he tune for sound or picture? Is the sound always O.K.? After two or three questions you should be able to find out the type of set in question. This method, by the way, is not completely reliable because customers may sometimes become confused when asked questions of a technical nature and may provide misleading answers.

Commercial Television Receiver Block Diagram. The basic block diagram of an intercarrier set (Fig. 6) which has been built up step by step in this chapter comes quite close to the published block diagrams of many commercial television receivers. The latter differ from the basic diagram principally in that they are usually more detailed and tend to follow their respective circuit diagrams more closely.

An example of a commercial block diagram is shown in Fig. 8. It represents a General Electric receiver which, for convenience (the chassis covers a series of models), will be referred to as the E chassis.

The tuner includes two r-f amplifier stages, V101 and V102, a mixer, V103B, and an oscillator, V103A. Signals from the antenna are fed into the first r-f amplifier, while the mixer delivers an i-f signal to the video i-f amplifier.

The video i-f amplifier is represented by three blocks—V104, V105, and V106—which represent individual amplifier stages. The video detector is a single block, Y151, as in the basic diagram of Fig. 6.

The video amplifier, block 4, is represented by blocks V107A and V107B in Fig. 8 because the video amplifier of the E chassis is a two-stage amplifier using both sections of a dual tube.

The cathode-ray tube is V108 and, as in the basic diagram, is shown to be provided with a signal from the video amplifier.

The sound section of the receiver is almost identical in the two block diagrams. The one shown in Fig. 8 simply shows an extra audio amplifier stage, V111B.

In the basic diagram, the clipper 9 is shown to get its signal from the output of the video amplifier. In the E chassis, the signal is taken instead from the video detector where it is essentially of the same character, but

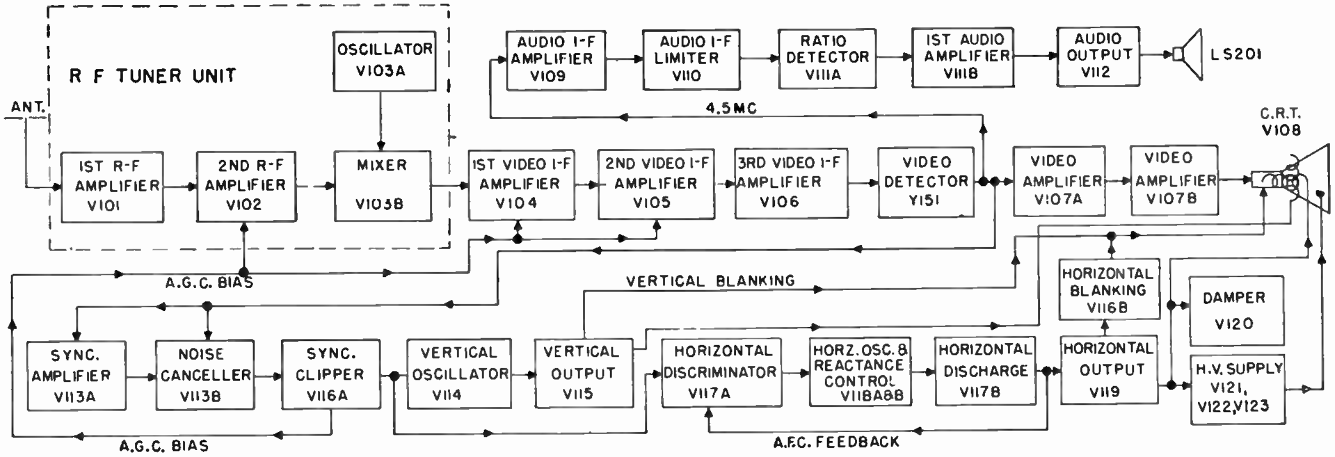


Fig. 8. Block diagram of a commercial television receiver. This is the General Electric E chassis

lower in level. An amplifier stage, V113A, is therefore used to build up the level of the signal before it is fed to the clipper. This stage is called a sync amplifier.

Refinements. A noise-canceler circuit, V113B, is inserted between the sync amplifier and the clipper to make the sync circuits work better under severe noise conditions. The circuit will be described in a later chapter. These functions are not shown on the basic block diagram because they are not basic receiver functions. They are refinements found in the E chassis. Some sets, in fact, do not employ these functions.

The clipper is block V116A. It provides vertical and horizontal sync signals to the respective sweep circuits. Note that the separator, block 10 in the basic block diagram, is not shown in Fig. 8. This was omitted only because of the difficulty of identifying the exact components used to do this job on the circuit of the E chassis; it involves a number of resistors and condensers scattered through the circuit. The function of separation is, nevertheless, performed and it will be explained in a later chapter when the actual circuit is described.

The vertical sweep circuit is composed of the vertical oscillator, V114, and vertical sweep amplifier, V115, exactly as explained earlier. The amplifier delivers a sweep signal directly to the deflection yoke represented by the two overlapping coils at the cathode-ray tube. The amplifier also delivers an extra signal, identified as *vertical blanking,* which serves to do a more reliable job of blanking the vertical retrace on the cathode-ray tube than is done by the vertical blanking pulse of the video signal. This, too, is simply a refinement in the E chassis and is not a basic function.

The horizontal sweep circuit is somewhat more involved than the one described earlier, although it does the same job. The new items, identified as horizontal discriminator V117A and reactance control V118A (a *part* of a block), are simply more elaborate circuits which serve to improve the accuracy of horizontal synchronization. This is also a circuit refinement, but one which is almost universally employed in one form or another in all television sets.

The horizontal oscillator V118B (the other part of the shared block) together with the horizontal discharge, V117B, compromise the horizontal scanning generator. The horizontal sweep amplifier, V119, is the same as the one in Fig. 6.

Another refinement in the E set is represented by block V116B, the horizontal blanking circuit. It serves to improve horizontal retrace blanking.

The damper, V120, is also a new item, although it is really a part of the horizontal sweep output circuit in terms of basic functions. That is why it was not shown as a separate block in the basic block diagram, Fig. 6. It is shown separately in Fig. 8 primarily because a separate tube, V120, is employed to do the damping job.

The high-voltage supply is identified with three tubes, V121, V122, and V123, which perform the same function as was previously described for block 8 in Fig. 6.

QUESTIONS

1. What are the functions of a television tuner and what panel controls does it include?
2. Roughly, how broad is the response of the video i-f amplifier?
3. What is the difference between the picture signal handled by the video *i-f* amplifier and the video amplifier?
4. How does a video amplifier differ from an audio amplifier? Why is this difference important?
5. How does the video signal act at the cathode-ray tube? Express this specifically in terms of 25 per cent, 75 per cent, and 100 per cent amplitude.
6. What function does the sound trap perform?
7. Where does the vertical sweep signal originate? Where is it finally used?
8. What is the source of energy for the high-voltage supply?
9. What is the frequency of the intercarrier signal and how is it developed?
10. What is the principal advantage of an intercarrier set? Compare the advantage with a split-carrier set.
11. How would you determine whether a set uses the intercarrier circuit or not—if it is operating—if it is dead?
12. Draw a block diagram of an intercarrier set showing at least these items:

a. Sound limiter
b. Horizontal oscillator
c. Antenna
d. Video detector
e. Speaker
f. Video amplifier
g. Vertical oscillator
h. Clipper
i. High-voltage supply
j. Sound detector
k. Tuner
l. Sync separator
m. Cathode-ray tube
n. Horizontal amplifier
o. Video i-f amplifier
p. Deflection yoke
q. Vertical amplifier
r. Audio amplifier

4

How to Tune and Adjust Sets

General Controls and Adjusters. There is a general set of controls and adjusters which every television set must have in order to permit the serviceman to set it up and to permit the owner to tune it in properly; but all sets do not have exactly the same controls at the front panel. Because of different circuit design, some sets call for front-panel adjustment for certain things while others provide only an internal adjuster to be set up by a serviceman. Consequently, you will find some variation in panel controls from set to set. Almost every manufacturer identifies the controls by name, right on the panel of the set.

There is even less uniformity between television sets in the kinds of *adjusters* provided. (The term adjuster is used to identify a screwdriver control or other permanent setup adjuster.) Different methods are used to center pictures, for example, or to adjust horizontal size.

In order to simplify the problem of learning how to use controls and adjusters, they are separated in this chapter into three distinct groups. These are: (1) primary operating controls; (2) secondary operating controls; and (3) internal adjusters.

Primary operating controls are those which are usually located on the front panel of a television set. They represent controls which the *owner* must understand and be able to operate correctly.

Secondary operating controls or primary adjusters are sometimes located at the panel for the owner to use, or in a concealed location for the serviceman to adjust. When they are at the panel they are considered *secondary controls* in that they play only a secondary role in tuning the set; when they are accessible only to the serviceman they are considered *primary adjusters* because they are the ones which most frequently require checking and readjustment. In fact, these adjusters should be checked whenever the set is serviced, unless it is obviously operating excellently—at least with respect to the functions which are affected by these adjusters.

Internal adjusters comprise the adjusters which are almost always located where only a technician can reach them. They constitute the adjusters by means of which a television receiver is originally set up for normal operation and which may require adjustment from time to time.

Primary Operating Controls. The primary operating controls are shown in Fig. 1. The illustration gives the functional title for each and shows the circuit which it controls. The basic diagram applies equally to the split-carrier or intercarrier receiver, as noted in dotted lines.

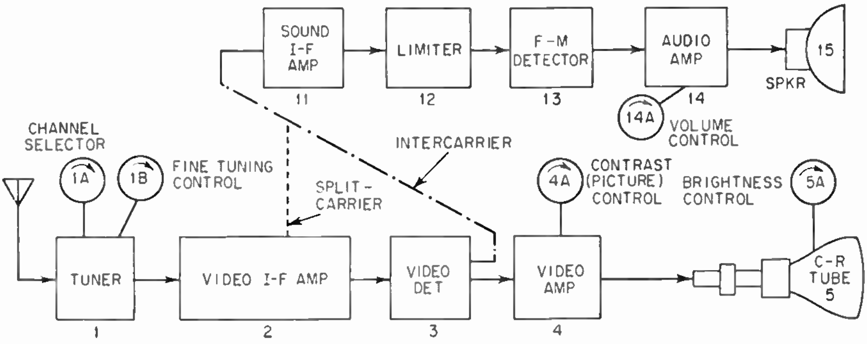


Fig. 1. Primary operating controls of a television set

Each control will be described individually, along with the general facts regarding its practical form in commercial television sets. This information can be helpful to you even though you may feel that you know how to tune most sets properly. There may be some detail, here or there, that you may not have known. Furthermore, part of your job as a serviceman is to explain the use of these controls to your customers and you must be able to do this clearly and concisely. You will probably find some useful ideas here to make this job easier.

Channel Selector. This control is almost always a rotary selector switch, with one stop position for each television channel. The knob may have the channel numbers marked on its circumference or the knob may have an index of some sort on it, while the channel numbers are on the panel.

It might appear that there is little to be said about the use of the channel selector, but despite its simple purpose, it is frequently employed either carelessly or improperly by the set owner, particularly on channels 7 through 13. The principal cause for misuse develops out of the manner in which the physical markings of channels are made, together with the fact that often no illumination is provided for the selector.

It is possible, through the effect of parallax, to misread many types of channel-selector knobs. When the knob is set on channel 10, for example, it may be read from some angle either as 9 or 11. Frequently the indexing in the set itself fails to correspond accurately with the panel markings, or the shaft may be off-center with respect to the markings. The net result is that the channel indication is not always as positive as it might be.

The set owner is generally aware of this but sometimes fails to turn the switch to its proper position. He may turn it to 12 to get channel 11 without realizing it. Then, when he tunes in the station and he *sees* channel 11, he assumes that he has set the selector properly. Unfortunately, this is not always true.

It is possible with a great many sets to tune in up to *three* channels in some channel-selector positions. They are: the channel selected, the one above it, and the one below. Thus, the channel 12 position can bring in channel 12, if it is in local service, channel 13, or channel 11. Perhaps some users may consider this convenient, but it does not lead to the best reception. When the wrong channel index is used it can result in blurry or snowy pictures.

The reason is that the selector switch selects the proper *r-f coils in addition to oscillator coils* for each channel; the r-f coils are pretuned for each individual channel. No amount of tuning adjustment by means of panel controls can change that. The panel *tuning* control changes only the *oscillator* frequency and its range can be great enough to lap over into adjacent channels; but the r-f coils remain *fixed* in tuning.

Set owners should be instructed to select channels carefully, perhaps by showing them how an improper selection can be made. They should be shown how the picture is either blurry or weaker, if these effects are very noticeable, and should be told that the chances of outside interference are much greater when they have not indexed the dial at the proper channel number.

Tuning Control. This control permits the frequency of the local oscillator to be adjusted to produce best results. It is used differently in split-carrier and intercarrier sets.

Its function is more clearly understood by the set owner with the former type of set. The control is simply tuned to provide good, clear sound, and it is left at that position regardless of whether or not another position seems to produce a better picture. The manufacturer aligns the i-f circuits in his set for a specific sound i-f frequency and for a specific video i-f characteristic; the owner must tune the set so that the sound i-f frequency corresponds with the sound alignment and no further choice exists as to picture tuning; the preadjusted video i-f characteristic prevails.

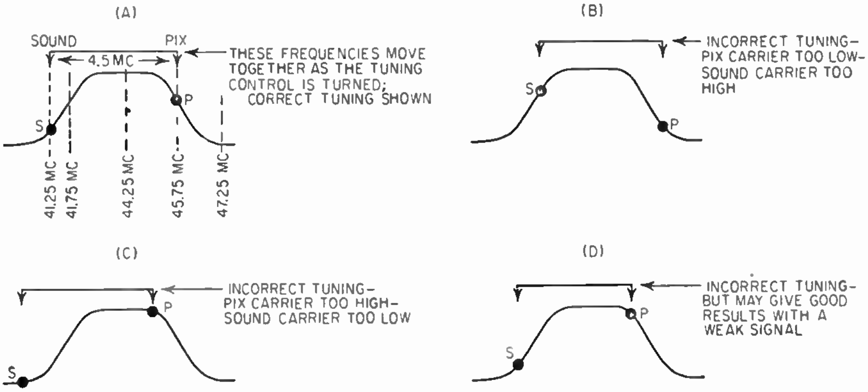


Fig. 2. These diagrams show how the tuning control moves the sound and picture carriers through the i-f response of the receiver. Correct tuning is illustrated at the upper left

Intercarrier Tuning Control. Intercarrier sets are easier to tune in that good sound reproduction is obtained at almost any setting of the tuning control, and the effect of that control on the picture is rather gradual. As a matter of fact, tuning is so broad that the majority of set owners neglect to tune the control unless they have to. If the picture comes in when they select the channel, the control is not touched. As a result, they often watch blurry pictures, or pictures with occasional interference patterns marring their quality.

There is a specific tuning point at which the picture is best. You should be able to recognize that point and to instruct your customers to do the same thing.

Intercarrier Response Curves. The principles involved in the tuning of an intercarrier set are illustrated in Fig. 2. The curves in the illustration are all the same. They show the video i-f characteristic curve (or response curve, as it is also called) of a typical set. This response is built into the set, the i-f coils having been aligned for this curve at the factory. In the event that the set is realigned at a future date by a serviceman, the manufacturer's instructions specify the same characteristic.

The frequencies relating to the response are shown along the bottom. The response curve of this particular set runs roughly from 41.25 to 47.25 mc although there is nothing sacred about these particular frequencies. Other sets may use different frequencies which the manufacturer prefers. The general shape of the curve, however, is roughly the same, and is about as wide in terms of bandwidth.

The heavy dots on the curve in part *A*, marked *P* and *S*, show the correct positions for the picture and sound carriers respectively. The set is designed for the two carriers to occupy those positions and best all-around performance is obtained when they do. They will occupy those positions when the sound carrier after conversion is 41.25 mc, and the video carrier after conversion is 45.75 mc. (Note again that these are 4.5 mc apart.)

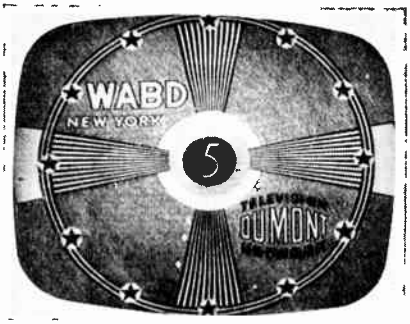


Fig. 3. Picture at normal tuning—condition *A* in Fig. 2. (Allen B. Du Mont photo)

Intercarrier Oscillator Action. Figure 2*A* also illustrates, in a rough way, how the local oscillator fixes the *two* frequencies *simultaneously*. It shows the two carriers at the correct positions on the curve. Figure 3 shows how the picture should appear at normal tuning.

Figure 2*B* shows what happens when the local oscillator is mistuned toward the right. Both carriers move together (they remain 4.5 mc apart) so that the sound is too high up one slope and the video is too far down the other. The results are these: the sound is amplified excessively and interferes with the picture—it causes interference patterns to appear; the video carrier is too low and the picture becomes distorted—it loses its proper gradation from black to white and shows severe fringes, or overshoot. This happens because the response of the set no longer matches the sesqui-sideband characteristic of the transmitter. The low-frequency picture components are suppressed and the high-frequency components are exaggerated. This makes the picture look as though it might be stamped out in relief on solid metal—like a coin—as shown in Fig. 4.

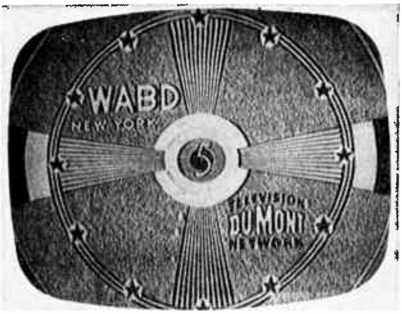


Fig. 4. Picture tuned with carrier too low—condition B in Fig. 2. (Allen B. Du Mont photo)

Figure 2C shows what happens when the local oscillator is mistuned too far in the opposite direction. In this case, the sound carrier slides down almost to nothing and the picture carrier climbs too far up the slope. The sound may continue to perform properly but the picture becomes smeary, as shown in Fig. 5. It loses its definition severely. This is so because now the low-frequency picture components are exaggerated, causing smear, and the high-frequency components (which provide detail) are suppressed, making the smear appear ever worse.

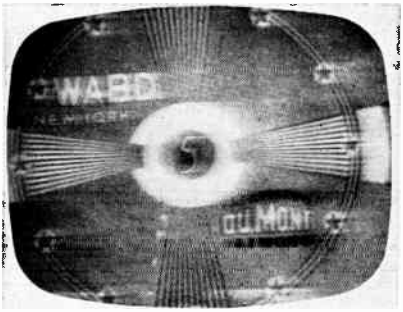


Fig. 5. Picture tuned with carrier too high—condition C in Fig. 2. (Allen B. Du Mont photo)

Intercarrier Tuning for Fringe Reception. Figure 2D illustrates one of the practical compromises in tuning which has its uses. Here, the local oscillator is a little too far to the left of its correct position, but not so far that the picture detail is entirely destroyed. It would look something like Fig. 6. Ordinarily, this setting would not be used because the picture appears to be somewhat blurred compared with Fig. 3. If the signal is very weak, however, as in the case of fringe reception, the improper setting may give much better all-around results. It produces a stronger video signal and may permit acceptable reception of a signal which is so weak as to be badly marred by snow and interference when the carrier is at the theoretically proper level.

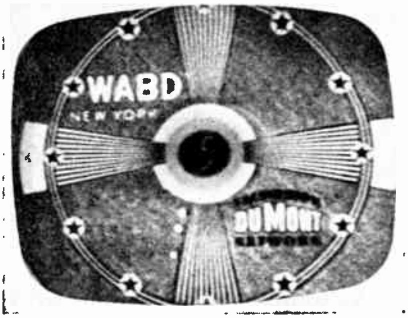


Fig. 6. Picture tuned to compromise detail in order to improve strength of weak signal—condition D in Fig. 2. (Allen B. Du Mont photo)

Practical Summary of Tuning. Perhaps tuning action sounds exceedingly complicated and well it may be, because many things happen at once when the tuning control is turned. It is not necessary to remember all of these details when you tune an intercarrier set, nor could you hope to explain them to your customers; but there is one general idea which you must remember and be able to convey. It is this: as the tuning control is turned, a gradual change continues to take place in terms of picture quality. There is a setting at which the picture comes to life, as it were, and reflects the best performance that the set can provide. It is the position at which picture detail almost suddenly seems to sharpen up, without loss in good shading. At other settings, the picture may be blurry or too hard. If your customer will look for this effect and learn to recognize it, he will enjoy better reception.

There are times when getting good picture detail is less important than simply getting a picture. The case of the weak signal is one such situation, but there are others. Most common are the cases of outside interference of some sort which cause annoying crosshatch patterns to obscure the picture. Frequently, mistuning the set will result in the elimination of the interference and will thus permit enjoyable reception even though the picture may be a little blurry.

Volume Control. There is little of special nature to be explained relative to the volume control in television sets. It is used simply to adjust volume as in broadcast receivers. The power switch is usually combined with the volume control, not only because users are accustomed to this combination from their radio experience, but also because no other television control adapts itself so well to this dual function.

Contrast Control. The contrast control is really a video gain control. It is identified by some manufacturers as the PICTURE control. It serves to adjust the amplitude of the video signal which is fed to the picture tube.

There is no one setting of the contrast control which is always right. The amount of contrast needed for good picture quality depends partly upon the strength of the incoming signal but primarily upon the amount of brightness being used. In general, the higher the brightness, the more the necessary contrast, and vice versa.

When too much contrast is used, the picture appears harsh, excessively black where only soft shadows should appear, and noise can be seen sputtering all over the surface of the screen. The last effect is sometimes described as a busy background.

Insufficient contrast produces a dull, washed-out picture, very much like an underexposed photograph.

At correct contrast, the picture includes its widest range of shades from black to white and thus provides greatest clarity.

Some television sets employ agc circuits which work better than others, consequently do not require frequent changes in contrast setting. Other sets may require that the contrast be readjusted almost with every change in channel setting.

Brightness Control. The brightness control permits the user to adjust the brilliance of the picture to suit room conditions. In a dark room, very little brightness is needed to give satisfactory results; as a matter of fact, low brightness is to be preferred in this case. More brightness is needed in a well-lighted room.

The brightness control is actually a grid-bias control for the cathode-ray tube. It governs the average amount of beam current, just as variation in grid bias governs the amount of plate current in an ordinary amplifier tube. At high grid bias, very low beam current flows from the electron gun, and low brightness is obtained. At lower bias voltages, the beam current is higher and the screen glows with correspondingly higher brilliance.

It is advisable to use the lowest brightness which produces a satisfactory picture, not only because this prolongs the life of the cathode-ray tube, but also because it provides better picture quality. The reason for the latter statement is that when excessive beam current flows, the spot formed by the beam goes out of focus—it becomes too large to permit good picture quality. The effect is noticeable on highlights only, because it is only at those portions of the picture that the video signal permits the beam current to reach its highest values. The highlights appear to be badly blurred and devoid of detail—they seem to glow almost as though the subject itself were giving off light. The effect is called blooming. The cure, of course, is to use less brightness, and to reduce the contrast control proportionately.

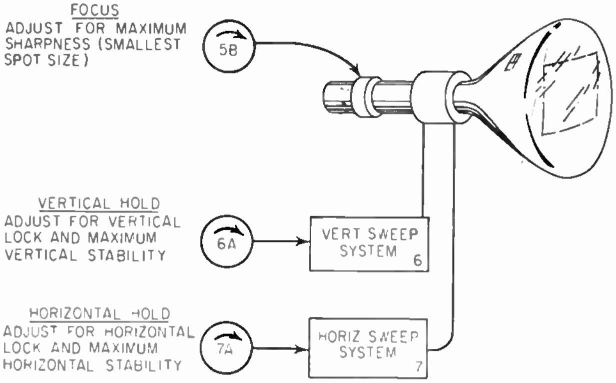


Fig. 7. Secondary operating controls of a television set

Secondary Operating Controls. The secondard operating controls of a television set are shown in Fig. 7. They comprise the two scanning speed controls and the focus control, when such a control is located where the user can reach it conveniently.

Vertical Hold Control. This control may be identified on the set as VERTICAL HOLD, VERTICAL SPEED, or VERTICAL SYNCHRONIZING. Its basic function is a speed or frequency adjuster for the vertical sweep generator. In terms of television reception, it is used to synchronize the vertical scanning with that of the transmitted picture.

As a matter of academic interest, the correct setting is the one which makes the vertical sweep generator, *without* synchronization, run just a little *slower* in speed than the picture. The synchronizing pulses then give the extra push to make the speed just right.

When the speed control is set to run faster than the picture, it rolls by with a fairly smooth motion. When the control is set to run much slower, the synchronizing pulses are unable to drive the speed hard enough to come into synchronization, and the speed jumps free. The picture then bobbles violently about. There is a fairly broad range over which synchronization holds well.

The best setting is the one which holds most steadily during electrical disturbances. You should explain this to your customers because many of them watch jumpy pictures only because they don't realize that further adjustment can help. They may set the receiver for a steady picture on a strong signal, or when no noise interference is present. Then, when they switch to a weaker station, or when a neighbor turns on a vacuum cleaner or electric drill, the picture starts to jiggle. A little further adjustment will often steady it.

Interlace. There is one other effect of vertical speed adjustment which may be observed on some sets, and that is the effect on *interlace*. Sometimes, changing the setting of the speed, changes the accuracy of interlace. At some particular setting, the interlace may be perfect. That setting will produce the best picture and should be used. Chances are, if your customer owns a set that acts this way, he is not aware of it, and consequently does not always get the best picture.

When the interlace is in error, the number of lines in the picture seem to become fewer in number (actually, one-half) and they become more prominent; the line structure is then clearly evident from a distance and the picture appears coarse in some respects. When interlace is correct, the reverse happens. The lines seem to double in number and are very thin, and they cannot be seen as distinct lines except up close to the picture. If you watch the line structure carefully as you turn the vertical speed control, you can see this, unless the set is one which is *always* interlaced, or one which can *never* interlace. These are not typical, however. The typical set shows some change in interlace with vertical speed adjustment.

Pairing. The effect is illustrated in Figs. 8 and 9. The photographs are of an enlarged portion of the screen. In Fig. 8, good interlace is illustrated. The line structure appears to be very fine. In Fig. 9, poor interlace is illustrated. The lines are coarse and exhibit an effect called pairing. Even up close you can distinguish only half the normal number of lines, while the black spaces between lines are excessively wide. This produces a fairly poor picture and permits the lines to be seen even from normal viewing distances.

Many sets run through these conditions during adjustment of the vertical speed control. Watch for it—have your customer look for it. Obviously, the better condition is the one shown in Fig. 8.

Fig. 8. Enlarged portion of picture showing good interlace. (Allen B. Du Mont photo)

Some sets may drift in and out of interlace without anyone's touching the control. If you come across this kind of set, there is not much you can do with adjustment except to set it where it appears to be interlaced most of the time. Perhaps it might be advisable in this case to say nothing about interlace to the owner.

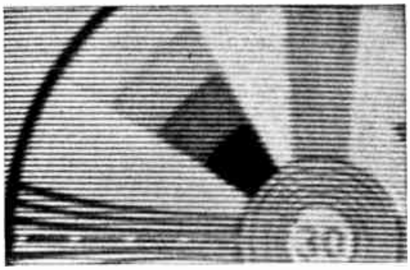


Fig. 9. Enlarged portion of picture showing poor interlace. The lines are pairing. (General Electric photo)

Horizontal Hold Control. This control may be identified on the set as HORIZONTAL HOLD, HORIZONTAL SPEED, or HORIZONTAL SYNCHRONIZING. It performs the same purpose in the horizontal scanning circuit as the vertical speed control performs in the vertical. The control, however, has no effect on interlacing.

The horizontal speed control appears to be more elastic than the vertical in adjustment. It holds over a wider range and when it finally drops out of synchronization, the speed is usually far from normal. The picture might then look like Fig. 10. When it is brought back toward synchronization, the picture continues to change gradually and looks something like Fig. 11 just before it pulls back into synchronization.

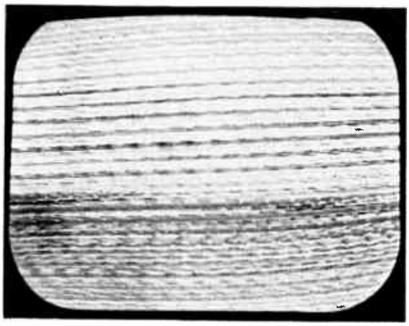


Fig. 10. Appearance of screen when the horizontal is out of sync and far from normal speed. (General Electric photo)

With many sets it is impossible to make the horizontal speed jump out of synchronization, after it is set correctly, so long as a picture is received. Consequently, it is difficult to tell when the speed is set correctly. An incorrect setting, however, may permit the speed to drop out of synchronization occasionally due to noise, changes in power-line voltages, or other causes. The best way to adjust the speed correctly is to turn the channel switch to a dead channel for a few moments and then back to a channel

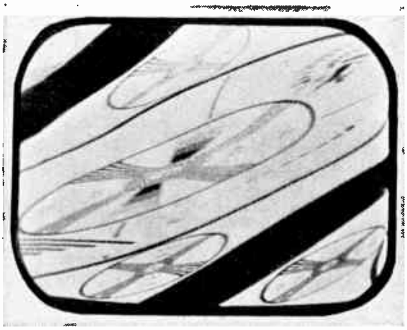


Fig. 11. Appearance of screen when the horizontal speed is almost in sync. (General Electric photo)

which is on the air. If the horizontal speed control is not right the picture might look like Fig. 10. The control should then be reset to synchronize and the operation repeated.

After just a few tries, the control will be so set that as channels are switched, each picture jumps almost instantly into perfect synchronization. Such a setting is the proper one and the control need not be touched again unless it shows evidence of needing readjustment in the future.

Focus Control. As explained earlier, all sets do not have focus controls, and when they do, they may be either a simple potentiometer or a mechanical device around the neck of the picture tube. Only the former will be considered here, that is, the simple potentiometer type.

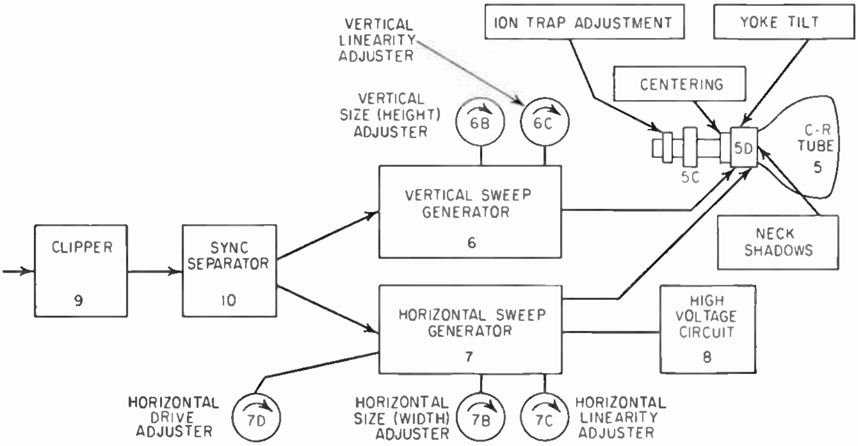


Fig. 12. Diagram of internal adjustments of a television receiver

Not much can be explained with respect to the adjustment of the focus control which does not suggest itself to the user almost instinctively. The purpose of the control is, of course, to permit adjustment of the picture for the sharpest detail. What the control does is make the cathode-ray spot as small as possible; when it is smallest, the picture is sharpest.

The best way to adjust the control is to look at the picture itself, not at the scanning lines. The sharpest *lines* do not necessarily produce the sharpest *picture*. Moreover, the focus may not be good in all areas of the picture at the same time. When the center is sharpest, the edges may be blurry. In setting the control try to get a good picture about halfway between center and edge and adjust for the sharpest grain. When you have done that you will get the best all-around focus that the set can provide.

Internal Adjustments. The common internal adjusters are shown in block diagram form in Fig. 12. Their adjustment will be explained in the general order in which they should be made if a set is completely out of adjustment.

Ion Trap. Most but not all television sets employ an ion trap; it depends upon the type of cathode-ray tube used. Certain of the aluminized tubes, for example, do not require them.

There is no choice in the matter—a given cathode-ray tube is either designed for an ion trap or not. If it is, you must use one; if it is not, you may not add one.

The usual ion trap consists of some form of permanent magnet assembly which clips onto the cathode-ray tube, near its base. It is identified in Fig. 13, which shows a typical assembly of components on the neck of a cathode-ray tube.

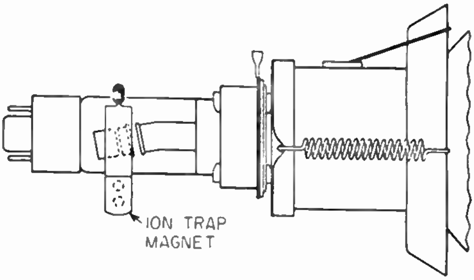


Fig. 13. Typical assembly on the neck of a cathode-ray tube. The ion-trap magnet is identified

Before you proceed to adjust the trap, you ought to know roughly why it is used and how it works.

Cathode-ray Tube Facts. When a cathode-ray tube is manufactured, the electron beam, which is emitted by the gun, is purposely bent away from the axis of the tube so that the beam cannot reach the screen. This is usually done by assembling the gun with a tilt in its structure. If you examine Fig. 13 closely, you will see that tilt. The gun is called a bent gun.

A trap system is used because the gun emits ions along with electrons. If the ions are permitted to reach the screen, they destroy the phosphor after only a short time. The damage shows up as a fairly large round dark spot on the screen, from about one-quarter of an inch to possibly several inches in diameter. This kind of damage was common in early cathode-ray tubes, which employed no ion protection for the screen.

The bent gun directs the ions away from the screen, along with the electrons, so that they cannot do damage.

How Ion Traps Work. The ion-trap magnet is a device which, when placed around the gun, bends the electron beam but *not the ion beam;* the ions continue to travel along a path which takes them away from the screen. When the ion-trap magnet is adjusted properly so that it counteracts exactly the bending produced by the gun, the electron beam, once again, travels directly toward the screen and does the job which it was intended to do.

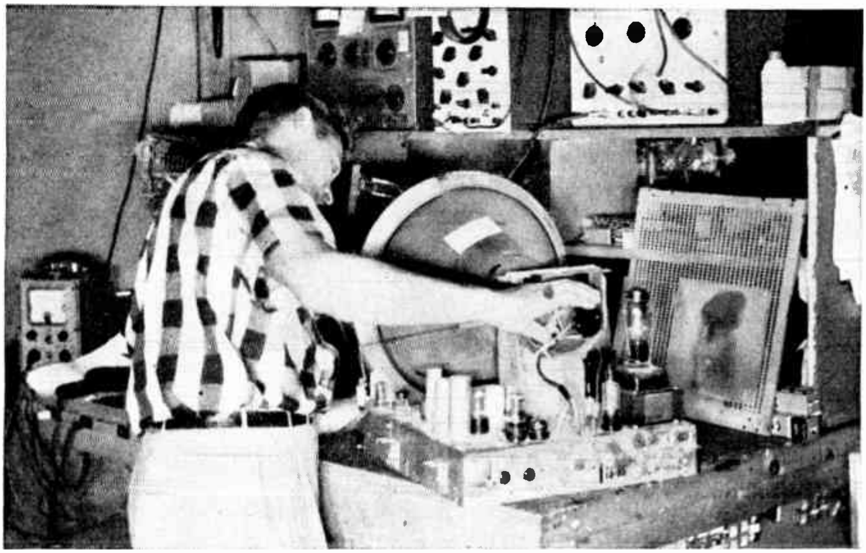


Fig. 14. Adjusting the ion-trap magnet. A comfortable position is assumed before power is turned on. Then the set is turned on with the left hand, leaving the right one in position to make the adjustment quickly as the set warms up

There is no exact rule as to how to adjust the ion-trap magnet. The correct position must be found experimentally by watching the screen during adjustment. The magnet may be rotated around the neck of the tube, and moved forward and backward, nearer to or further from the base. The object of the adjustment is, first, to get the picture tube to light up, and, second, to get maximum brightness. When the position is found at which maximum brightness occurs, the bend of the gun and the bending effect of the ion-trap magnet are perfectly balanced.

Warning. When you first turn on a set of which you have reason to believe that the ion-trap magnet is not properly adjusted, you should adjust it as quickly as you can, within a minute or two at most; otherwise the cathode-ray tube may be injured. The electrons will be trapped in the gun and may cause the tube to overheat. You can save time if, before you turn on the set, you get into a comfortable position with one hand on the magnet and so that you can see the screen. This is illustrated in Fig. 14.

How to Adjust Ion Traps. After turning on the set and allowing warm-up time, start rotating the ion-trap magnet around and around the neck of the tube, with each revolution moving the magnet to a new position, either forward or backward. The brightness should, of course, be turned up so that there will be something to be seen when the trap comes into proper adjustment. You should be able to get the screen to light up within four or five seconds after you start adjustment and should be able to get the approximate point of maximum brightness in four or five more.

Fig. 15. A tilted picture. This condition is caused by a tilt of the deflection yoke, not by a tilt of the picture tube. (Allen B. Du Mont photo)

Once you see the screen light up, turn the brightness control down, so that you can see the effects of further and more accurate adjustment.

When you service sets and have occasion to remove the back cover, it is a good idea to touch up the setting of the ion-trap magnet. Many sets will be found to be *nearly* right but not perfect. The adjustment which you make can increase the brightness considerably.

Yoke Tilt. This adjustment permits the picture as a whole to be rotated, just like a picture on a stiff card which is pinned through the center. The purpose of the adjuster is to permit the picture to be leveled with respect to the frame or mask.

A tilted picture is shown in Fig. 15.

Tilt adjustment is made by rotating the deflection yoke. The yoke is identified in Fig. 16. In many cases this requires that you loosen whatever clamp holds the yoke in position. Grasp the yoke in your hand, and rotate it while you watch the picture. Figure 17 shows this adjustment being made on a chassis.

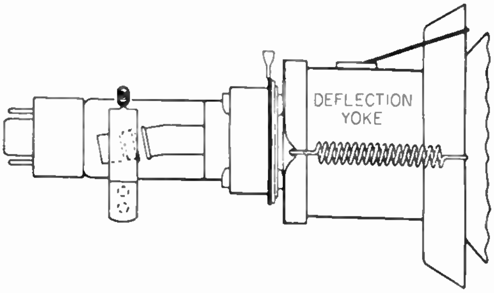


Fig. 16. Typical assembly on the neck of a cathode-ray tube. The deflection yoke is identified

Fig. 17. Adjusting the deflection yoke to correct picture tilt. The yoke assembly is rotated while watching the picture

You must be particularly careful when making this adjustment because some yokes have, at the front of the assembly, exposed terminals carrying plate voltage. To play safe, make certain that you touch only the case. If you are not sure that you can avoid the terminals, look at the picture, determine the direction of rotation needed, and estimate the amount. Turn off the set, rotate the yoke, then turn it on again and check your results. After a few tries you will get it right.

Some sets provide a tilt lever on the yoke to make tilt adjustment easier. It is simply pushed one way or another to adjust tilt. A wing nut generally is employed and must be loosened to permit rotation, then tightened after the adjustment is completed.

After adjustment of both the ion-trap magnet and the tilt of the deflection yoke, the set should be tuned in properly before you proceed with further adjustment. That is, the regular operating controls should be set up to provide as good a picture as you can get. Then the balance of the adjusters can be set up.

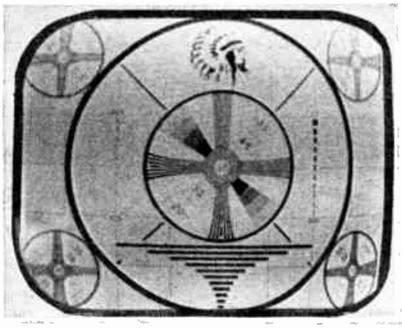


Fig. 18. Poor horizontal linearity. The left side of the picture is expanded and the right side compressed. (General Electric photo)

Horizontal Drive. The horizontal drive adjustment may be set up first after tuning in a picture, if the set has such an adjuster. In general, it is set up to produce *maximum picture width.* Individual sets have their own special qualifications as to what other effects should be obtained. You must get these from the manufacturer's setup instructions. If you do not have them, it will be sufficient to set the control only for maximum width. If further adjustment is needed, it will become evident when you set up the *width* and *horizontal linearity* adjusters.

Horizontal Linearity. This adjuster is set up to produce even distribution of the picture from left to right. An example of poor horizontal distribution is shown in Fig. 18. Note that the left side of the picture appears larger than the right, which is compressed.

The horizontal linearity adjuster is turned to get perfectly even distribution, as shown in Fig. 19. This adjustment is difficult to make without a test pattern; the pattern shows clearly the condition of linearity which is hard to see in ordinary scenes. You can, however, feel your way if there is no pattern available. The adjustment must be made so that subjects on the screen appear to be properly proportioned in width whether they appear at the left side, the right side, or in the center of the screen.

It is most important that you consider *only the left-to-right, or horizontal, linearity* when making this adjustment, no matter what the shape of the picture is in the vertical direction. No amount of adjustment of horizontal linearity will affect the vertical linearity, and vice versa.

Do not despair if you cannot get the linearity perfect; some sets are not capable of it—but you should be able to make it reasonably good and certainly better than the condition shown in Fig. 18. Should you have trouble getting it good enough, you can try some readjustment of the horizontal drive adjuster, which may help. Do not, however, adjust the drive so that the width is materially reduced, unless you find later, when you adjust width, that you have plenty to spare.

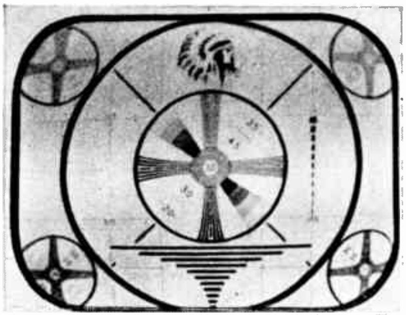


Fig. 19. A properly adjusted picture. Linearity and size are correctly adjusted both horizontally and vertically. (General Electric photo)

Vertical Linearity. This adjuster serves the same purpose in the vertical direction that the horizontal adjuster serves in the horizontal direction. An example of poor vertical linearity is shown in Fig. 20.

It will help when making this adjustment to keep the height of the picture approximately correct, because most sets exhibit some interaction between vertical linearity and height, more so than with the horizontal adjusters.

The control is adjusted simply to get an even vertical distribution of the picture such as is shown in Fig. 19. Here again, the adjustment is simplified if a test pattern is available. If it is not, you can feel your way as recommended above, this time observing the *vertical* distribution of the picture. It is easier to feel your way with the vertical control because the effect of poor vertical linearity is very quickly seen on full-length human subjects. Poor vertical linearity, in fact, makes human subjects look rather ridiculous because it gives them flat heads or disproportionate torsos or legs.

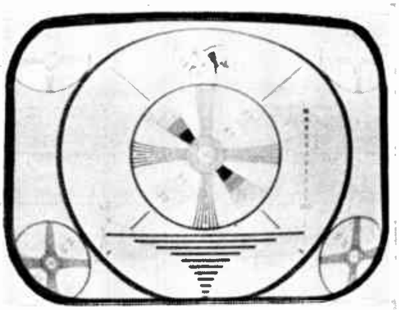


Fig. 20. Poor vertical linearity. The upper part of the picture is compressed. Compare this with Fig. 19. (General Electric photo)

Width and Height. Once linearity is good, the width and height of the picture may be adjusted to fill the screen properly. The width should be adjusted first, because it usually affects height to some extent, whereas

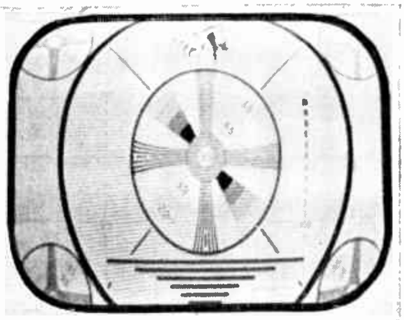


Fig. 21. Excessive height. The picture fits properly from left to right but is too large from top to bottom. Objects appear tall and thin. Compare with Fig. 19. (General Electric photo)

the reverse is not true. Width and height should be adjusted so that they exceed the dimensions of the screen by a small amount; then, normal size variations will not expose black borders. Such variations generally occur with line-voltage changes.

The test pattern is also useful for these adjustments because only when they are correct with respect to each other will a round object, for example, really appear round. Otherwise, it would be oval, being larger in one direction or the other. It is not difficult, however, to guess the correct settings in the absence of a pattern because the mask dimensions on the set serve as a fairly good guide. The effect of poor height and width adjustments is shown in Figs. 21 and 22.

Ordinarily, the adjustment of height and width cannot be done as directly as suggested above on a set which is badly out of adjustment; it usually becomes evident that the picture is off-center, and thus cannot be adjusted for size properly. If this should be the case, do the best you can, preferably leaving the picture a little *undersized* (so that you can see the edges) and proceed to center it as described below. When you have done that, you can come back to the adjustment of width and height and complete the job.

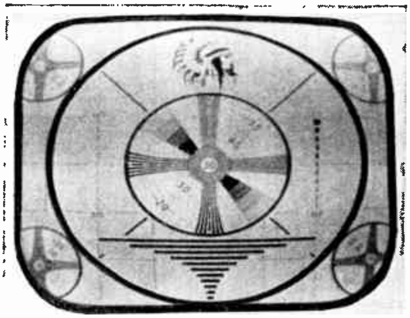


Fig. 22. Excessive width. The height is proper but the picture stretches out beyond the sides of the mask. Objects appear short and squatty. Compare with Fig. 19. (General Electric photo)

Centering. Some television sets employ potentiometers for centering, which makes the operation very simple indeed. The adjusters are simply turned so as to move the picture up and down and sideways, to locate it properly in the screen. Adjusters of this form come in pairs; one is provided for vertical movement (called VERTICAL CENTERING or VERTICAL POSITION) while the other is provided for horizontal movement (identified as a HORIZONTAL CENTERING or HORIZONTAL POSITION).

The more common form of centering mechanism is a mechanical device associated with the focus magnet. That magnet is located around the neck of the tube and between the deflection yoke and the ion-trap magnet. Figure 23 shows a typical assembly. In this form of centering device, the matter of coarse focusing is also involved. Fine focusing is done by means of a vernier adjuster of some form, through control shaft *E* in the assembly in Fig 23.

Wobble Plate for Centering Picture. The assembly in Fig. 23 has an added convenience not found in all focus-centering devices. It has a device called a wobble plate which literally can be wobbled to move the picture about. It can be pushed forward, pulled back, or rotated to affect the picture position. The focus magnet is then required primarily to provide good focus and plays a lesser part in picture centering.

Focus Magnet. Many sets are provided with a simple focus magnet (or focus coil) which serves not only to focus the beam but also to fix the picture position on the screen. The magnet is usually supported by a pair of slotted brackets like the one in Fig. 23. You can see one of the brackets

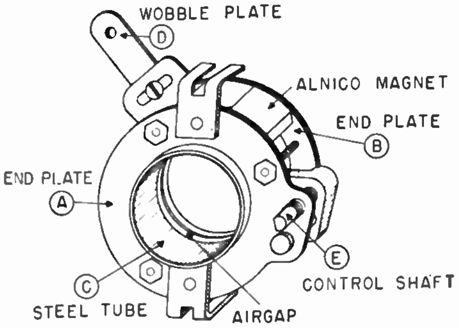


Fig. 23. A combined centering and focus adjustment assembly. Centering is adjusted by means of wobble plate D. Focus is adjusted by turning shaft E

on top, near the letter D. Another is located on the bottom. The mounting screws pass through the longitudinal slots in the mounting bracket so that a universal mounting is obtained. The focus magnet can be turned on the axis of the screws. One of the screws can be pushed forward of the other so as to tilt the magnet, or both can be moved forward or backward together so as to move the whole focus magnet along the neck of the tube.

Adjusting Focus Magnets. In adjusting the magnet, forward and back movement affects focus primarily. The tilting of the magnet from its natural plane affects picture centering. The usual procedure for adjustment is first to find the longitudinal position which provides best focus with the fine-focus adjuster (if there is one) in the center of its range, and then to wobble the magnet about in that approximate location to center the picture.

You will have to feel your way as you go along—the manner in which the picture moves in response to tilting of the focus magnet usually appears to make little sense. You may tilt it upward and the picture may move sideways. By experimenting, you can get it right. When you do, tighten the screws which hold the assembly in place.

Don't Forget the Ion Trap. When you have made any adjustment of the focus magnet, always check the adjustment of the ion-trap magnet because interaction does occur. Keep readjusting the ion trap for maximum brightness as you go along, because that adjustment also affects picture centering to some extent.

Example of Centering Adjuster. Figure 24 shows the location of the picture-centering device, *A*, used with the assembly illustrated earlier. The centering unit employs two tabs, *B*, one of which can be seen in the illustration. The tabs can be pushed together or spread apart and the whole device can be rotated. These adjustments, in combination, provide a wide range of picture-centering control.

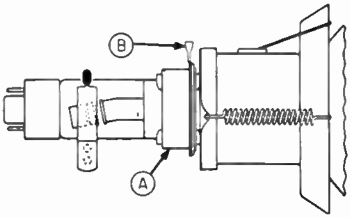


Fig. 24. Typical assembly on the neck of a cathode-ray tube. The centering device *A* is identified. Adjustment is made by means of two tabs, *B*, only one of which is visible. The other is directly behind the one you can see

Neck Shadows. Although there are no neck-shadow adjusters as such, you will frequently be required to adjust neck shadows. A neck-shadow condition is illustrated in Fig 25. It is not always as bad as shown—it may only black out a small part of one or perhaps two corners of the picture.

The condition is caused by the fact that when the electron beam in the cathode-ray tube is bent severely by the deflection yoke, as it must be to reach the corners of the picture, it runs the risk of striking the glass envelope just before the point at which the neck flares out. This is illustrated in Fig 26. When this happens, a corresponding part of the picture is blacked out.

The answer to the basic problem may seem to be simply to have the cathode-ray tube manufacturer flare out the neck more gradually, but this is not so; the neck must be narrow just before the flare because the deflection yoke must be located at that point and the diameter of the opening in the yoke must be as small as is reasonably possible.

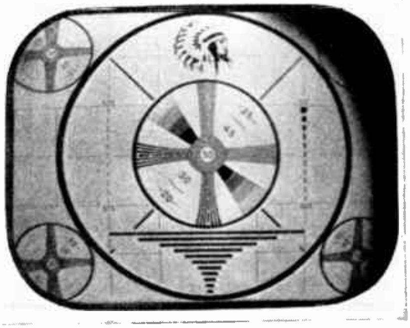


Fig. 25. An example of neck shadow on a picture. Sometimes only a small corner area is affected. (General Electric photo)

Eliminating Neck Shadows. The cause for neck shadow, in most cases, is that the deflection yoke is not all the way forward, against the bell of the tube. This makes the beam bend too soon inside the neck of the tube, hence the shadow. The cure is to push the yoke, with reasonable force, snugly against the tube, after you have loosened the screws which hold it in place. In the process, you must be careful not to tilt the yoke or you will have to readjust that again. You must also observe the precautions outlined earlier with respect to possible live terminals on the yoke.

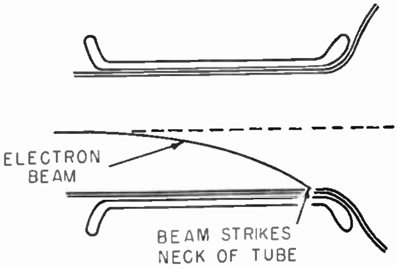


Fig. 26. Cross section of a tube neck where it passes through the deflection yoke, showing the cause of neck shadow

Neck shadow can also be cured by readjustment of the focus magnet and ion trap. These are numerous combinations of the latter two adjustments which can produce good focus, maximum brightness, and proper centering. Some of those combinations may result in neck shadows, others may not. It is your job to find the latter through repeated adjustment if you have a tough neck-shadow case.

If nothing seems to cure neck shadow and you are dealing with a chassis out of its cabinet, you may find that the shadow will disappear when the set is installed in the cabinet. This can happen because the mask against which the picture tube rests may add just enough pressure against the yoke to bring it up snugly enough to clear up the problem.

If even this fails, your customer may have to live with the problem or get another picture tube. It may help you to know that his tube may work perfectly well in another set, because each set is a little different in its geometry and in the nature of the magnetic fields of the yoke, focus magnet, and ion trap—even sets of exactly the same make and model.

QUESTIONS

1. What common mistakes are made by television-set owners regarding the channel selector and the fine tuner on intercarrier sets?
2. Describe the effects on the picture when the picture carrier is tuned too high or too low.
3. How is tuning compromised for the reception of weak stations? How should the customer be instructed?
4. What is another popular name for the CONTRAST CONTROL and precisely what does it do?
5. How does the BRIGHTNESS CONTROL work?
6. What influence may the VERTICAL HOLD CONTROL have on the picture beyond bringing it into sync?
7. How should the HORIZONTAL HOLD CONTROL be adjusted for best results?
8. What should you seek when you adjust the FOCUS CONTROL?
9. Why does the screen of a cathode-ray tube refuse to light when its ion-trap magnet is maladjusted or missing?
10. How should an ion trap be adjusted?
11. Is the picture rotated, or tilted, by (*a*) rotating the picture tube or (*b*) by rotating the yoke? Explain why one does and the other does not have this effect.
12. Describe a procedure for adjusting size and linearity if a test pattern is on the air.
13. Describe the adjustment of a mechanical picture-centering device.
14. What are the cause and the cure for neck shadows?

5

Using Television Service Data

An important tool. Television service information is carefully prepared by television manufacturers for the sets which they build. This information is one of the more valuable tools in a service shop. Few servicemen work without it, even after they are familiar with the sets which they service. There are some jobs which they would not attempt without that information—alignment, for example.

Manufacturers' Service Manuals. Most manufacturers publish service manuals or service notes, as they are sometimes called. They generally do this separately for each model or group of models which they manufacture. Some of these manuals are quite elaborate, running as high as 50 to 100 pages for a single set. They are usually available from the time the first set of the particular model is placed on the market.

In some cases, the manufacturer maintains a mailing list at his factory through which his manuals are mailed when they are available. Generally, this service is provided for at a fixed annual fee.

Other manufacturers ship their manuals in bulk to their set distributors throughout the country and the distributors, in turn, either mail them through local mailing lists, or simply make them available upon request at their parts departments. Here again it is common practice to charge for the manuals. Many distributors provide their retail dealers with copies as they become available, either free of charge or at a fixed annual fee.

Manufacturers' Volumes. In addition, some manufacturers prepare larger volumes of service manuals from time to time and in some form of durable binding. Figure 1 shows such a set of volumes. These volumes are essentially collections of individual service manuals. The latter may be collected by the year or at more or less frequent intervals, depending upon the manufacturer's plan of operation. The volumes almost always contain the most up-to-date revisions of the individual manuals.

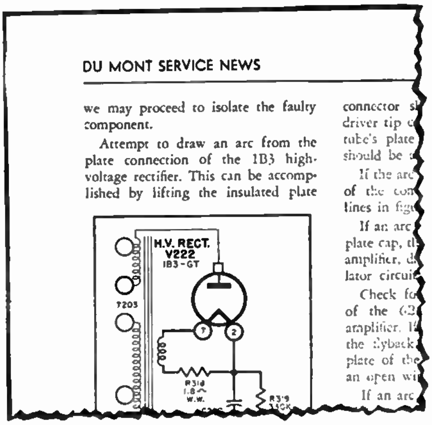
The manufacturers' volumes are rarely distributed in the same way as the individual manuals. Most often, they are treated as a sales item for replacement parts departments and are available where parts for the manufacturer's sets are sold.

Fig. 1. A set of manufacturer's service volumes. Each volume contains information on a series of models. (General Electric photo)

Manufacturers' Service Guides. There is another form of publication produced by television manufacturers, sometimes referred to as a service guide or by some other title which serves to distinguish it from the regular service manuals or volumes of manuals. The guide is usually a condensation of information contained in previously published manuals. It may contain only schematic diagrams, tube-layout diagrams, and parts lists. This kind of guide is useful primarily to servicemen with extensive knowledge and experience since it includes only the minimum of information relative to each set. Until you feel you have more experience, you should not depend solely upon these guides.

Publishers' Manuals. Because of the large number of television manufacturers in business, collecting service manuals from all of them may prove to be expensive and may take a great deal of time and effort. As an aid to servicemen, certain independent publishers do the work of collecting and organizing the television service manuals of most manufacturers and offer them for sale in a package. Examples of such publishers are John F. Rider in New York City and Howard B. Sams in Cincinnati, Ohio. Some of their manuals are direct reprints of manufacturers' manuals, while others add further useful data. Many servicemen consider the purchase of these manuals a worthwhile investment, not only because of the convenience, but also because they are assured of having data on virtually every television set manufactured up to the time of the publisher's release. The value of this service is reflected in the fact that this type of manual has been used by radio servicemen for over twenty years.

Manufacturers' Information. In addition to the service manuals which provide data for specific models of television sets, some manufacturers publish general information of interest to television servicemen. Many of these booklets are extremely helpful and informative. They frequently provide extra data about the manufacturer's sets or general data relating to the servicing of all sets. One of the features of these publications is the presentation of service tips which cover either recurring problems or special problems calling for circuit changes in specific sets. An example of a general-information publication is the Du Mont "Service News" published by the Teleset Service Control Department of Allen B. Du Mont Laboratories. A section of one of the pages is shown in Fig. 2 to give you an idea of its editorial form.



DU MONT SERVICE NEWS

we may proceed to isolate the faulty component.

Attempt to draw an arc from the plate connection of the 1B3 high-voltage rectifier. This can be accomplished by lifting the insulated plate

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Fig. 2. A section of a page from Du Mont "Service News"

On occasion, manufacturers prepare special publications for the serviceman. An example is the publication titled "Successful Service Management" prepared by the Tube Department, Electronics Division of the

General Electric Company. This publication provides valuable information regarding business practices, merchandising, and servicing. The business-practice section covers the various aspects of simple accounting for a radio or television service business.

Special Reference Books. Private publishers also develop special books designed especially for the television serviceman. Some provide, in one binder, *tube-layout diagrams* for a large number of popular television sets together with a short description of the function of each tube. Another form of publication provides a series of *picture-tube photographs* showing various television *faults* together with appropriate information relative to analysis of the faults. A third type of publication lists *common troubles and cures* in specific television sets. These are normally a collection of manufacturers' tips or recommendations gathered from individual manufacturers' publications or through solicitation of the manufacturer for such information.

The value of these publications must be judged individually by the user. You may find some of them extremely helpful. They will not, however, replace the manufacturers' service manuals or the manuals prepared by private publishers. In general, they offer only portions of the same information contained in the manuals, but in handier form. The general publications of manufacturers, on the other hand, are usually extremely helpful, although they, too, do not replace the service manuals themselves; they are intended to augment those manuals, not to replace them.

How to Get Service Manuals. As suggested above, there are two principal sources for service manuals—the manufacturer and the private publisher. Both offer their own particular advantages. If you are interested in the television sets of only a few manufacturers, it may be less expensive to get only those specific manuals. If you are interested in getting manuals of all brands of sets, the private publisher may be your best bet.

Service Manuals of Private Publishers. These manuals are sold by most radio parts distributors who handle multiple brands of radio parts. Your local parts jobber probably has them in stock or can give you whatever information you need to get them. The chances are that he will be glad to let you look them over before you buy, if he has them in stock.

If there is no parts jobber of this description in your town, you can find the manuals listed in the catalogs of mail-order radio parts suppliers located throughout the country.

Before you buy the manuals, it would be helpful to get the advice of another serviceman. There are so many different kinds of packages available, some of which are expensive, that it would be wise to find out what particular publications have been most useful to someone who has had frequent occasion to use them.

Manufacturers' Manual Sources. The best place to get information about the service manuals for particular brands of sets is from the local distributor of those sets. Most of these distributors will have them right in stock and will be able to tell you how you can receive them regularly as they are issued. The distributors will probably also have back numbers for older sets.

You can almost always find the distributor listed in your telephone directory under the manufacturer's name. Look for the listing of the brand name in the classified directory and then for the organization given as the distributor for that brand. Usually you will find only one or two names. If you are close enough, you can telephone or drop in personally to their replacement parts depot. Otherwise, you can write to the distributor, addressing your letter to the "Product Service Department."

When looking up the name in the directory, be careful that you do not confuse the distributor with retail dealers. Distributors sell sets to the retail dealers. The latter are rarely able to provide you with service manuals. A possible exception is the manufacturer who sells directly to retail dealers without distributors, but you will quickly find out which they are when you try to locate the distributor.

If you are unable to find the proper distributor in your telephone book, you can get his name and address from any retail dealer who sells his brand of sets. Retail dealers know who the distributor is because they buy their sets from him. The retail dealer will also be able to tell you whether he buys his sets directly from the factory, in which case you may have to contact the factory for manuals.

Getting Service Manual Volumes. The preceding information applies equally to the service manual *volumes* prepared by the manufacturer. These volumes may contain the service manuals issued in a calendar year, or in some other convenient grouping. The volume may sell for as little as a dollar for the set or may run as high as several dollars. Before you buy it, ask the distributor whether the volume is a collection of the *same* type of manuals which were issued *individually* for each set or whether it is a *condensation* of the individual manuals. If the latter is true, the volume will not be nearly as complete as you may want it to be. The type of manual which generally is a collection of *condensed* material is the kind which contains *every* set made by the manufacturer for five or more years.

The special books covering general television service information can be found in book stores or in radio parts houses. Those prepared by manufacturers are usually available at the distributor's parts counter.

Information in Service Manuals. Although each manufacturer uses his own ideas in his service manuals, they do follow a similar pattern. The basic information is similar and there are some things, like alignment procedures and schematic diagrams, which they all contain. Moreover, they all appear to be written for an average serviceman with some television experience and with a fairly good understanding of radio circuits. It is assumed, in the preparation of the manuals, that the user has a clear understanding of basic television functions.

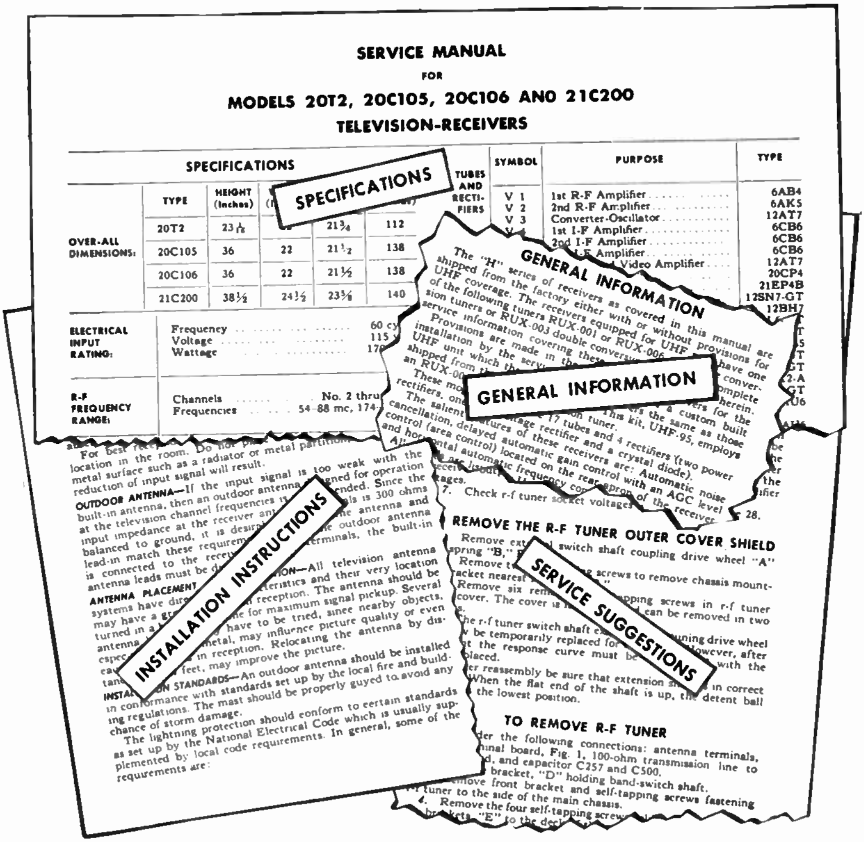
Following is a description of the type of information given in typical manufacturers' service manuals and which is reproduced in some of the independent publishers' service manual packages.

Model Identification. The service manual lists the various model numbers or names to which the manual applies (see Fig. 3). Often, photographs are given so that you may recognize the sets from the appearance of the cabinet. In some cases a manual may apply to six or more separate models and it is not unusual to have it apply to all models of a given brand which are sold during the same period. This can be done in many instances because the manufacturer may have only one basic chassis in production during a given year, with the differences in models being a difference in quality and style of cabinets.

Operating Data. The manual may contain a brief description of how the set is to be installed and operated. It may include an illustration of the operating controls together with an explanation of their proper use. It may also contain data such as type of antenna to be used, power required, audio power output, and physical dimensions.

The operating instructions are supplied for the information of the serviceman particularly and are not included to serve as the owner's instructions—it is not expected that nontechnical owners will read the service manual. In most cases, a separate booklet is supplied with the set for the owner. The booklet describes, in less technical language and perhaps in more detail, how to operate the set.

Setup Adjustments. The manual contains either helpful hints or detailed instructions on how to set up each of the adjustments provided for this purpose. The instructions include such things as centering, ion-trap magnet adjustment, linearity, etc. The manufacturer's instructions are naturally more accurate than the general data already given in this book so far as specific adjusters are concerned. It is not unusual, however, for the manufacturer to assume that you are familiar with general data and to include in his instructions only those special things which make his set different.



SERVICE MANUAL
FOR
MODELS 20T2, 20C105, 20C106 AND 21C200
TELEVISION-RECEIVERS

SPECIFICATIONS

	TYPE	HEIGHT (Inches)	(I		)
OVER-ALL DIMENSIONS:	20T2	23 1/16		21¾	112
	20C105	36	22	21½	138
	20C106	36	22	21½	138
	21C200	38½	24½	23⅝	140

ELECTRICAL INPUT RATING: Frequency …… 60 cy; Voltage …… 115; Wattage …… 17

R-F FREQUENCY RANGE: Channels …… No. 2 thru; Frequencies …… 54-88 mc, 174-

TUBES AND RECTIFIERS SYMBOL	PURPOSE	TYPE
V 1	1st R-F Amplifier	6AB4
V 2	2nd R-F Amplifier	6AK5
V 3	Converter-Oscillator	12AT7
V	1st I-F Amplifier	6CB6
	2nd I-F Amplifier	6CB6
	I-F Amplifier	6CB6
	Video Amplifier	12AT7
		20CP4
		21EP4B
		12SN7-GT
		12BH7

SPECIFICATIONS

GENERAL INFORMATION

The "H" series of receivers as covered in this manual are shipped from the factory either with or without provisions for UHF coverage. The receivers equipped for UHF have one of the following tuners RUX-001 or RUX-006 … conver-sion tuners or RUX-003 double convers… complete service information covering these … herein.
Provisions are made in the … for the installation by the serv… custom built UHF unit which th… This kit, UHF-95, employs shipped from th… the same as those an RUX-00… tuner.
These mo… 17 tubes and 4 rectifiers (two power rectifiers, one … rectifier and a crystal diode).
The salient features of these receivers are: Automatic noise cancellation, delayed automatic gain control with an AGC level control (area control) located on the rear apron of the receiver and horizontal automatic frequency co…
All …

GENERAL INFORMATION

For best recep… Do not pl… metal partition location in the room. … metal surface such as a radiator or … reduction of input signal will result.

OUTDOOR ANTENNA—If the input signal is too weak with the built-in antenna, then an outdoor antenna … gned for operation at the television channel frequencies is … ended. Since the input impedance at the receiver ant… ls is 300 ohms balanced to ground, it is desira… the antenna and lead-in match these requirem… he outdoor antenna is connected to the recei… terminals, the built-in antenna leads must be d…

ANTENNA PLACEMENT … ION—All television antenna systems have dir… teristics and their very location may have a gr… reception. The antenna should be turned in a … for maximum signal pickup. Several antenna … have to be tried, since nearby objects, espec… metal, may influence picture quality or even ca… in reception. Relocating the antenna by dis-tanc… feet, may improve the picture.

INSTAL… ON STANDARDS—An outdoor antenna should be installed in conformance with standards set up by the local fire and build-ing regulations. The mast should be properly guyed to avoid any chance of storm damage.

The lightning protection should conform to certain standards as set up by the National Electrical Code which is usually sup-plemented by local code requirements. In general, some of the requirements are:

INSTALLATION INSTRUCTIONS

7. Check r-f tuner socket voltages … 28.

REMOVE THE R-F TUNER OUTER COVER SHIELD

Remove ext… switch shaft coupling drive wheel "A" spring "B," …
Remove t… screws to remove chassis mount-… acket nearest …
Remove six rem… pping screws in r-f tuner cover. The cover is … can be removed in two …
The r-f tuner switch shaft ex… uning drive wheel … be temporarily replaced for … However, after … the response curve must be … with the … placed.
…er reassembly be sure that extension sh… in correct … When the flat end of the shaft is up, the detent ball … the lowest position.

TO REMOVE R-F TUNER

…der the following connections: antenna terminals, …inal board, Fig. 1, 100-ohm transmission line to …d, and capacitor C257 and C500.
… bracket, "D" holding band-switch shaft.
…move front bracket and self-tapping screws fastening … tuner to the side of the main chassis.
4. Remove the four self-tapping screws … brackets "E" to the deck …

SERVICE SUGGESTIONS

Fig. 3. Clippings from a typical service manual showing the kinds of special information it may contain

Sometimes the setup information includes little more than the location of the hard-to-find adjusters by means of drawings or photographs, together with a simple statement of the function of these adjusters.

Schematic Diagram. The manual includes at least one schematic diagram of the set, giving the complete circuit. Sometimes several are provided, one for general reference, and additional diagrams showing functional groupings something like a block diagram, or waveforms such as would be seen in making tests with an oscilloscope.

Television schematic diagrams identify the various tubes with some form of title to indicate roughly the function which each performs. These titles help you recognize quickly the functions of the circuits.

Like radio schematics, television schematics also identify each individual component with a symbol number so that textual references can be made and so that parts can be identified in a parts list.

Parts-location Drawings. The manual includes one or more illustrations showing the physical location of the more important components. This includes tubes; they are almost always identified by the schematic symbol number in addition to the type number. Significant adjusters and alignment screws are also located.

Operating Voltages. The manual shows the normal operating voltages which appear in all significant points in the circuit. These may be shown on the schematic diagram, on a separate drawing provided exclusively for this purpose, or in a table. The voltages are extremely useful in testing defective sets. Often they permit you to locate faulty components which may be otherwise difficult to find.

Circuit Descriptions. Some manufacturers provide a technical explanation of special circuits in their service manuals. Usually this is done when it is believed that the particular circuit is not generally understood, or when it is entirely new. These circuit descriptions normally start where the general information, such as is contained in this book, leaves off.

To illustrate the point, there are many types of noise-canceling circuits and keyed agc circuits used which are very different from each other. Their variety is so wide that they cannot be covered very readily in a general treatment of television. The typical manufacturer is aware of this and tries to fill that gap in his service manual.

Sometimes the manufacturer will supply a special functional block diagram for the particular set covered in his manual, to clarify its general circuitry.

Alignment Instructions. Detailed alignment instructions are provided in the manual for all tunable circuits. These are usually given in a detailed step-by-step procedure and are ordinarily comprehensive enough to permit most servicemen to do a good alignment job if they have the necessary test equipment.

Although the step-by-step tables seem to make the job very simple, alignment should not be attempted without adequate equipment and not unless you understand that equipment fully.

The procedure is usually broken into three or four parts: sound (or audio) i-f alignment, video i-f alignment, r-f alignment, and local-oscillator alignment. The last two are sometimes combined in one table.

Of these, a radio serviceman or an inexperienced television serviceman will be able to do the first (sound i-f alignment) and last (local-oscillator alignment) with little difficulty, and he can expect to get good results. Video i-f alignment is more difficult and requires an intimate knowledge of sweep-alignment equipment, while r-f alignment is most difficult and requires the greatest amount of experience.

These statements are necessarily generalities. Some sets are so designed that one or another of the alignment procedures is considerably easier, or in special cases, particularly difficult. These qualities prevail, not so much because of the kind of instructions provided, but rather because of the special design features built into the sets.

Waveforms. Because of the increasing popularity of the oscilloscope as a service instrument, more recent service manuals give diagrams of proper oscillograms which should be obtained at specific points in the circuit.

These waveforms are of little value if you do not understand the operation of your oscilloscope. The same signal can produce many shapes and patterns simply by changing the adjustment of the oscilloscope. If you know how to use it and how to interpret what you see, the manufacturer's waveforms will be extremely helpful in diagnosing difficult service jobs. You may find that you will be using this method in preference to others (voltage tests, for example) in checking sync or sweep-circuit operation.

Because of the increasing popularity of this type of diagnosis, you may find it helpful, when you feel you have reached this point, to purchase one of the special texts devoted to the use of the oscilloscope as a service instrument.

If you own an oscilloscope, study its instructions and use it as often as you can. When you have a set in your service shop along with the manufacturer's waveform data for that set, try them out. Practice using them; you will find that they will begin to take on real meaning.

Service Suggestions. The service manual frequently contains troubleshooting suggestions for the particular set. These may be given in table form, through the use of picture-tube photographs, or by a combination of these.

Some of the suggestions are based upon the past experience of the manufacturer with the particular set or with earlier sets using similar circuitry and parts. These are often lifesavers in tough cases.

Parts List. The service manual contains a parts list giving the manufacturer's catalog numbers for the various parts. Some manufacturers also describe standard components fully so that you can supply your own substitute should you need one.

The catalog numbers are those which the parts distributor uses to identify the parts; distributors rarely, if ever, use the circuit symbol numbers for this purpose. Keep this in mind when you order replacement parts.

Fig. 4. The service manual is an indispensable tool on the service bench. It sometimes saves hours of work in checking circuits for faults

Some parts lists include a list of prices. These may be net or they may be list prices. In either case, the parts distributor will probably extend to you the discount which applies to the trade once you establish your identity as a professional serviceman. You can learn in advance what your discount is, if any, from the manufacturer's parts distributor from whom you may be getting your service manuals.

In any event, the individual who supplies the manuals is also in a position to advise you of the discount structure or from whom that may be obtained. When you find out what it is, write it down in your service manuals so that you can compute your costs more accurately.

How to Use Service Manuals. Service manuals are useful as basic study material. You will probably find that most of them provide helpful and interesting material. Look them over in your spare time. Try to follow the circuits through and to identify them with a basic block diagram previously studied. This will provide excellent practice and will also give you a greater degree of familiarity with each set you study when you come across one on a service job.

A good rule to follow is this one when the circumstances permit: When you get a service request, try to have the customer give you the brand and model number of his set, or at least the approximate age of the set. Just before you make the call, read through the service manuals which you think may apply. Then when you make the call you will fumble less and create a much better impression than you would if you had to start from scratch to figure the set out in front of your customer. Remember, he is paying for your time and he may be inwardly critical of whatever time you take out of actual work to study his set. Some reference to notes will frequently be necessary on the job but they ought to be as short as possible.

The principal use of a service manual, of course, is as a guide when you are actually servicing a set. Use it as much as you can.

Practical Advice. If you come across an obvious, sore-thumb defect such as a burnt-up resistor, for example, look it up on the schematic diagram. Find out where it is located and make a mental note of how the set acted when it failed. Experiences such as these, if they are thought through, will begin to add up and will give you clues later on as to the probable circuit involved in a defect, when there is no sore-thumb defect to flag your attention. The suggestions regarding waveforms made above should also be followed if you own an oscilloscope.

When making live tests of an exposed chassis, be especially careful to avoid bodily contact with live circuits. Television sets pack a lot more wallop than most radio sets and call for greater care. Look especially for cautionary advice given by the manufacturer in the manual.

Voltage Data. When comparing voltages with those given in the service manual, always try to find out under what conditions they were originally measured. Wherever a specific condition is significant, this information will usually be provided along with the voltage diagrams or tables. The manual may tell you, for example, that the tests are made with a signal tuned in, in which case you should try to get one before you make your tests. The set may not be working in all respects but you can, at least, be reasonably certain that you have adjusted the panel controls in such a manner that a signal would come in if the set were working.

The conditions also specify the type of meter used to make the checks.

A 1,000-ohm-per-volt, 20,000-ohm-per-volt, or a vacuum-tube voltmeter may be called for. When no such information is provided, it is a reasonably safe bet that the readings were made with the popular 20,000-ohm-per-volt instrument.

You may not have all the instruments called for—a vacuum-tube voltmeter, for example. In that case you may read the voltage with your meter but you can use it only as a rough check. The readings may not agree, but that should be expected. Usually, vacuum-tube voltmeters are specified only for one or two special points, so that the lack of one will not handicap you very much. Most data are based on the use of the popular 20,000-ohm-per-volt multimeter. If you own one, as you should, you will be able to use the basic data given in virtually all service manuals.

Troubleshooting Tips. Look through the manual to see whether it offers troubleshooting suggestions. If it does, see if the symptoms of the defective set are listed in the manual and follow the suggestions. When you do this, however, bear in mind that the manufacturer can list only a few specific faults for each symptom. His real purpose is not so much to give you an *inventory* of possible defective components, but rather, to suggest to you the general area in the set in which the defect can be located.

As an illustration, the following is an excerpt from an actual service manual, and is listed under troubleshooting:

Symptom: No vertical deflection (single white horizontal line on screen).
Possible Causes:
Suggestion 1. Open deflection coil, D301.
Suggestion 2. Defective sweep output transformer, T301.
Suggestion 3. Sweep generator V109 and V110 defective, no plate voltage to V110, open R312 or shorted C310.

By means of symbol numbers the manufacturer puts his finger on certain specific parts in the set; but what he *really* means is something more like this:

Suggestion 1. Inspect the circuit involving the deflection coil. It may be open either in the coil, in the cable leading to it, or in the plugs used to connect it to the chassis. Perhaps the socket into which the yoke plug fits is loose or is damaged.

Suggestion 2. Check all connections to this transformer. There may be a bad connection involved or the output winding may be shorted *outside* of the transformer; the insulation on its leads may be cut or damaged.

Suggestion 3. These (items listed in suggestion 3, above) are the tubes and some of the principal parts which are involved in providing vertical deflection. Many other things, however, could be wrong. The tube socket could be bad or there could be a loose heater connection. There may be a drop of solder shorting out some of the tube pins or a strand of wire may be shorting something out in this circuit. Perhaps both the tube and a resistor are bad.

Practical Use of Manuals. The illustration given above is admittedly a simple one and may be quite obvious. The point, however, is that all of the probable causes given by the manufacturer may not suggest, just as obviously, that there could be many other associated defects. It is a good rule always to consider the suggestions primarily as a means of pointing out the general area of the defects by giving you certain specific examples of what might cause the problem. When components are identified as the possible culprits, look them up on the schematic diagram and find out what other components are also involved, and check them.

As pointed out earlier, the alignment data given in service manuals are based upon the premise that you know how to use alignment equipment. The information is usually tabular in form and explains little about the technique. You will not *learn* how to align sets properly from most service manuals. You will have to get that special information from separate texts on the subject and from the instructional material provided by alignment-equipment manufacturers for their particular instruments.

Interpreting Oscillograms. The same is essentially true in using the waveforms, or oscillograms, provided in the manual. Ordinarily the manual simply expresses peak voltages and oscilloscope sweep speeds, and gives you a picture of what the oscillogram should look like.

There is more to using an oscilloscope than simply setting up sweep speeds, estimating peak voltages, and looking at the presentation. To be useful to the user, the oscilloscope must be understood and it must be studied separately. Chances are you won't always get exactly the same pattern as the manual shows anyway, because there is a fair amount of variation from set to set, even of a given model, and because different oscilloscopes act differently. The real trick in using this instrument is in learning how to *interpret* the patterns. The service manual simply presents basic patterns on the assumption that the serviceman who uses them is fully familiar with the personality of his oscilloscope.

QUESTIONS

1. What is the difference between manufacturers' service *manuals* and service *guides?*
2. Why should the beginner avoid depending on service guides?
3. What are the sources of service data? What are the advantages of one over the other?
4. What is the principal value of circuit descriptions given in service manuals?
5. How are alignment instructions usually subdivided in service manuals?
6. What portions of the alignment procedure call for special equipment and experience? What portions are readily done by a television service beginner with previous radio experience?
7. How should you prepare yourself to take advantage of waveform diagrams given in service manuals?
8. What meter sensitivity may be assumed if this is not marked on voltage charts or tables?
9. What are the limitations of troubleshooting suggestions given in service manuals?

6

Making Service Calls

Selling Yourself to Your Customer. Some servicemen find that they are kept busy all the time, because service calls keep coming in steadily. Others find them hard to get. Oddly enough it isn't always the real crackerjack who gets the calls, nor is it always the relatively green man who finds himself sitting and waiting for his telephone to ring. Sometimes it's the other way around.

The reason is that very few of your customers are really able to judge a serviceman properly in terms of his technical knowledge or competence. Instead, they rate a serviceman in accord with the general impression which he creates as an individual.

Cigars Give a Poor Impression. A top-notch serviceman who habitually is unkempt and unshaven and who carries a chewed-up cigar in his mouth has a tough time getting business through recommendations. His burden is unnecessarily heavy; if he is really successful it is probably due to an unusually appealing personality which offsets the initial impression.

How to Act. On the other hand, the serviceman who always looks and acts as carefully as if he were fixing the President's own set makes things a lot easier for himself. In order to *complete* a most satisfactory impression in his customer's mind, he has only to do the additional thing that all other servicemen are *expected* to do anyway—fix the set so that it works.

Each of his customers may really believe he is doing his neighbors a good turn by recommending that serviceman to them. Inwardly, many of that serviceman's customers may take pride in having discovered him. That kind of advertising simply can't be bought.

The point is that perhaps the most important thing which you have to sell is *yourself*. You are, in effect, performing on a stage, except that you deal with your audience one at a time. During the course of every service call you are watched most carefully, although your customer may not be obvious about it and may not even be conscious that he is doing so.

Personal Appearance. Your first rule should be to maintain as good a personal appearance as you can while you are on the job. Keep your hair neatly trimmed and combed and always keep well shaven. If you are a smoker, do not smoke while you are working in a customer's home, even if your customer is smoking. Don't chew gum—some people dislike the practice intensely.

Choosing Work Clothes. If you prefer to use some form of work clothes, purchase several changes of one of the many styles which are sold in department stores. Get the kind that provides a matching winter jacket and which includes a neat work shirt, bow tie, and hat. Most important, get the kind of clothes which can be washed in a standard washing machine. Several changes are recommended so that you will always be able to wear one which is clean and neat. Work clothes manufacturers such as Sweet-Orr make clothing of this sort. The work and expense of keeping your work clothes clean ought to be treated as one of the necessary expenses of your business. You should be able to deduct these expenses on your Federal Income Tax return.

Keep Your Truck Clean. The same general principles hold true for your car or truck. Keep it washed and have unsightly dents repaired if you should be unfortunate enough to get them. If you have a truck, have it lettered in as professional a manner as you can afford.

The things which you carry should also be kept neat and clean. These include your toolbox, your meter, and your business cards.

Courtesy Rules. Treat your customers as courteously as you can but don't talk too much. Don't talk about personal things unless the customer gives you no choice. Don't try to impress him with how much you know or with your prowess as a brilliant conversationalist. Save these activities for your personal associations.

There are some rules concerning courteous and considerate treatment of customers which you cannot violate without getting into trouble. Here are some of the more important ones:

Always keep your promises relative to appointments. If you find that you must break a promise, *telephone your customer,* advise him of the fact, offer your explanation and apology, and make another date. Don't, under any avoidable circumstances, make your customer wait for you in vain.

If you give your customer a firm price to do a job—*stick to it*. Don't change your mind because you found that *you* made a mistake, unless you feel that the circumstances requiring greater expense are outside the original basis of your agreement. If you find that you have lost money on a particular job because of your mistake, accept the loss gracefully as your own responsibility. There is no harm in advising your customer of his gain if you make certain that your explanation cannot be construed as an attempt to gain his sympathy or to make him feel responsible for your tough luck.

Don't make calls on your customer's telephone, especially if the call has no direct connection with the customer himself. If there is need to make a call on his behalf, request his permission. If it requires a toll call, request an account of the charges from the operator, and pay that to your customer, or better yet, have the charges applied to your own telephone bill.

Don't jump to the conclusion that your customer is a regular guy and assume, therefore, that you can become personal with him. If you try to poke a little good-natured fun at him or carry on a debate with him in order to cement relations, you may have a rude awakening. No matter how regular he may appear, he still expects you to conduct yourself as a professional businessman, if he resembles the typical customer. He may feel perfectly free to exercise *his* humor, but may inwardly resent the same from you.

In short, the success of your business depends as much upon yourself as an individual as it does on the more concrete things. Don't make the mistake of overlooking that fact, otherwise you may find yourself sitting in your shop and waiting for the telephone to ring.

Your Service Vehicle. You will, of course, need a vehicle. It may be a passenger car, a station wagon, or a light truck. Of the three, the station wagon is claimed to have the greatest utility for service work. Most types offer a large amount of load space and are easy to load and unload.

Your Tools. The ordinary tools used for radio service work are needed for television service. These should include a quick-heating soldering iron, and the special tools needed for antenna-installation work. The frequently used small tools should be carried in a neat toolbox, along with a dropcloth on which to place them while you are working on the set.

It is good practice to carry a furniture touchup kit with which you can repair scratches, and a good grade of furniture polish and polishing cloth. With these you can put the finishing touch on a service job instead of leaving handprints on the cabinet. Do not use the polish without asking your customer's permission.

You should carry in your car some protective container in which you can transport cathode-ray tubes should you find it necessary to handle one separately from a chassis. The container should not only be well padded, but should employ a soft, clean cushion on which the face of the tube can rest without getting scratched.

Along with your tool kit, carry the standard types of jumper cords which can be plugged into the television chassis after you have removed the built-in cord. These cords are carried by radio and television parts distributors.

Carry a mirror in the car. The kind which is used in medicine-cabinet doors is excellent and can be stored in little space. The mirror should be of good quality, without noticeable ripples so that it can reflect an accurate image of the television screen; otherwise it may be almost useless for adjusting linearity.

For ordinary work, a small mirror such as is made for a ladies handbag is handy to have in your pocket. It serves well for the adjustment of ion traps, for example, or for making other adjustments and checks at the back of the cabinet when only a portion of the picture need be seen.

Instruments. If portable instruments must be limited to a single one, that one should be a general-purpose 20,000-ohm-per-volt multimeter. A second instrument could very well be a tube tester, to help you find bad tubes and to help you sell tubes to replace weak ones which might otherwise not be detected. You can use the tester to good advantage by offering to test the tubes of radio sets in the home while you are on a television job. You may be able to pick up some extra sales in this way, and sometimes some extra radio repair jobs.

There is little need to go beyond these instruments for ordinary service work in the home. There is one, however, which you may wish to consider later. It is one of the forms of special pattern-generators which permit you to make accurate linearity adjustments when no test patterns are on the air. These generators develop bar patterns or crosshatch patterns. Several inexpensive instruments of this kind are presently available.

Tubes. Carry as many different kinds of tubes used in television sets as you can—this will more than pay for itself in a short time. Keep them in a special case in the car, one which will protect the original cartons both from dirt and damage.

The complement should be brought up to date from time to time to take care of new tube types as they come into use. A good guide as to what types to carry, if you have no past experience to help you, is your set of service manuals. Look up the tables showing the quantity and types of tubes used in television sets and mark them down on a tally sheet. With this information you can make up a fairly good starting list.

You can improve on that list as you go along if you keep a record of usage. Keep a card in the case with the tubes and mark down the types as you use them, along with the date. You may start a new card each month if you choose. After three months or so, you can get an idea of which types are simply going along for the ride and which are in demand. The stock of very slow movers may be cut down to one or may be cut out completely if your records show this to be wise, leaving more room for new types or for very active types.

It is probably unwise to carry new picture tubes on the chance that you may need one. There is the possibility that it may be damaged through too much vibration. When a new tube is needed, the price is high enough to warrant a trip back to the service shop to pick it up.

Ladder. If you can, you should carry a light ladder which you can use for general antenna service work, even if you decide not to do antenna-installation work. It may be carried on a car-top carrier along with replacement antennas.

Accessories. There are many accessories offered for sale by radio parts distributors which are natural sales items for servicemen. If you can afford to do it you should consider the opportunity carefully. Among these are special furniture polish, new antennas and television transmission line to replace old ones, indoor antennas, lightning arresters, etc.

In fringe areas, the demonstration of a booster may result in a sale. In other areas, an antenna rotator may be a good sales item. During the summer months, portable radio batteries can frequently be sold on the simple basis of a reminder to your customer that he may need one and that you have some new ones in your car. Additional extension power cords are easily sold when you find cords in dangerous condition or when your customer doesn't have enough.

Don't miss these bets. They can add many dollars to your income over a period of time.

Parts. You should carry enough of the small standard parts to take care of simple service jobs. These should include a variety of carbon resistors and molded plastic condensers. It is not possible to prescribe a stock of other repair parts because the requirements may vary widely from year to year and also with the types of television receivers in your area. If you specialize in one or two brands, however, you may find it wise to carry some of the more commonly needed items for those sets.

Making Your Initial Visit. An important difference between radio and television service is that most radio service is done in the shop on sets which the customer carries in, whereas most television service calls are made in the home. Consequently, there are many radio servicemen with little experience in this type of service call. The relationship between customer and serviceman is entirely different.

When you make your initial visit to a customer's home, be as courteous and considerate as you can. Make sure that after you ring the bell, the customer finds you there at the door ready to introduce yourself, rather than ready to walk inside. Do not enter the house until you are invited in.

Let the Customer Talk. Before examining the television set, ask your customer to explain the television difficulty he is having. Have him demonstrate the set to you and watch him carefully as he does so. In the meantime, make your own observations. If he fails to mention something which appears obviously wrong to you, ask him whether he intended to disregard it. You may notice bad flashes on the picture, for example, to which he makes no reference. When you call his attention to it, he may tell you that it was always that way and thought it was normal in his area, or he may tell you that it is caused by a neighbor's sewing machine. In any event, you can find out how he feels about the matter and whether or not you should consider doing anything about it.

Beware Ancient Troubles. Until you have more experience, do not commit yourself to correcting the kind of problem that has existed for some time—there may be little if anything that you can do about it. Try to confine your immediate work to the particular problem which has just recently developed and about which he called you. Keep the others in the back of your mind and see if you can solve them as you go along.

When your customer is through explaining the difficulty, check the set over. Tune in the various channels and try the set out. See if anything about its faulty operation is suggested by the way it acts when *you* operate the controls.

Then, when you are satisfied as to the nature of the problem, turn the set away from the wall, lay out your tools on a dropcloth and remove the back.

Removing the Back. Before removing the back completely, disconnect the antenna wires so that they will not interfere. Then, holding the back in place with one hand, remove the screws with the other. Hold the back firmly in place until both hands are free to take it out of the way. The reason for this precaution is to prevent accidental damage to the cathode-ray tube. In most sets, the base of the tube extends into some form of compartment in the back cover (to keep the cabinet as shallow as possible). An example is shown in Fig. 1. If the back is permitted to drop straight downward it may strike the tube base and break the neck.

When the back is out of the way, put the antenna leads back in place and connect power into the set by means of your own power cord if necessary.

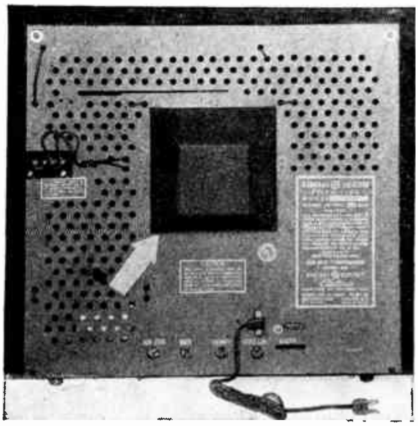


Fig. 1. A typical cabinet back showing the extended compartment into which the picture-tube base projects. (General Electric photo)

Preliminary Checks. After the set has warmed up, look to see if there is anything obviously wrong. If you are not familiar with the set do not get your hands into any blind spots where there might be exposed terminals.

See if all tubes are lit. If any of them appear to be gassy or otherwise suspect, get the proper types from your car. Use the ideas given in the chapter on testing and replacing tubes. According to most authorities on the subject, this will take care of about one out of three problems. They estimate that well over 30 per cent of all service calls are due to faulty tubes.

High-voltage Compartment. The horizontal sweep and high-voltage rectifier tubes are almost always enclosed in a shielded compartment. If you have reason to suspect one of those tubes, open the compartment and check them. Some sets use a power interlock on the compartment so that you cannot operate the set when it is opened. If this is true, and the interlock acts to remove the power cord, you can plug your own cord in to operate the set with the compartment open. Do this only to permit yourself to *watch* the tubes in operation, for light, for flashovers, or for gas. *Do not put your hand inside while power is on.* Most of these compartments contain exposed terminals and there is danger of getting a painful shock.

Don't Burn Your Fingers. Before trying to remove a tube, touch it carefully to see how hot it is. Some tubes get much too hot to touch and will burn you if you grasp them with your bare hands.

Fig. 2. Removing the horizontal sweep tube from a chassis. This tube along with the high-voltage rectifier and damper are usually located within a cage similar to the one shown

Don't Brag Too Soon. If everything appears to be normal and the complaint suggests a possible defect in the antenna system, trace the transmission line as far as you can, and see if you can find any breaks or poor splices. Look particularly in corners, where chair legs can damage the line, and under windows. If you find a break, repair it before you tell the customer that you found the difficulty, to avoid the possibility of looking a little foolish. You may be embarrassed to find that the break has only a secondary effect on reception and that its repair does not solve the problem.

To illustrate the point, it is not uncommon for servicemen to find breaks in antenna systems which are quite old. Sometimes the break simply reduces the quality of the picture but not enough for the owner to call a serviceman. The owner may attribute the change to some other cause in the locality. Not until the set fails in some other respect, and repair is obviously necessary, is the break discovered but its repair does not solve the immediate problem. When the television repair is completed and the antenna system is also repaired, the owner will be pleased to find that his set is once more operating like new.

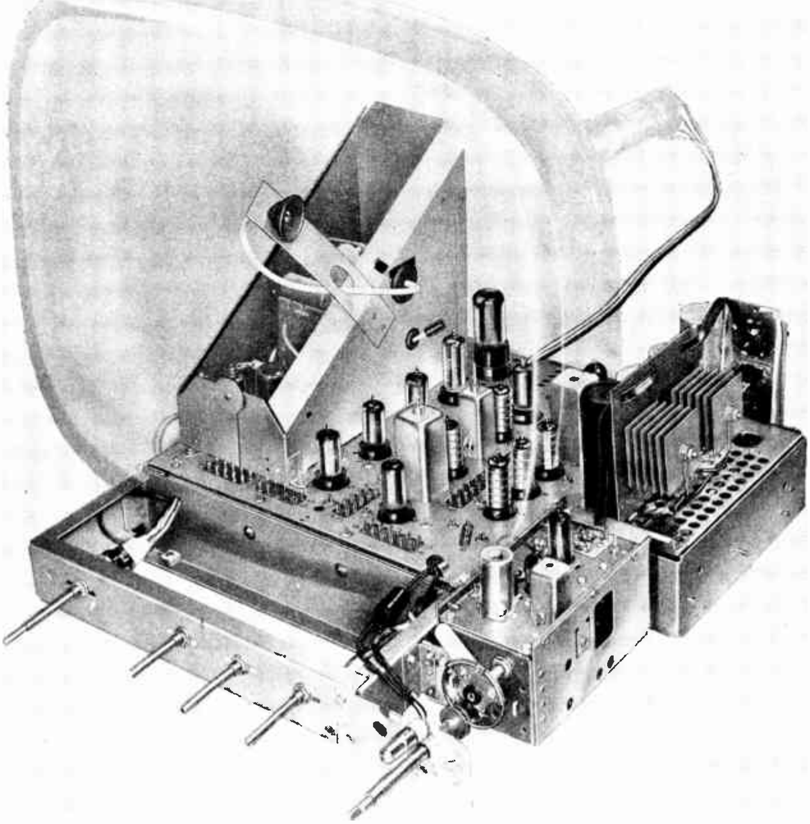


Fig. 3. A typical single-unit television receiver chassis. The picture tube is shown in phantom to let you see the entire chassis. The high voltage cage is at the left rear. The tuner unit is at the right front corner. You can see a pair of selenium rectifiers behind the tuner. These provide low voltage d-c for the set. (General Electric photo)

Removing the Chassis. A typical television chassis is shown in Fig. 3. The cathode-ray tube is mounted right on the chassis so that the entire assembly is handled as a single unit. The ordinary table model or television-only console set employs only this main chassis and a speaker, the latter usually being separately mounted and connected to the main chassis by means of a pair of leads and a plug.

Combination sets which may include a-m, f-m, and phonograph normally employ the manufacturer's basic television chassis plus the other units. They are interconnected by means of cables. The television chassis offers the only new problem to radio servicemen; the phonograph and radio units require no special techniques in their removal.

Study the Set First. Before attempting to remove the television chassis, look it over carefully if you are not familiar with it. Locate all leads which connect the chassis to the other units or which are fastened to the cabinet. Disconnect the plugs and free the leads so that they will not interfere with removal.

See if there is any form of mounting device which holds the cathode-ray tube to the cabinet. Some manufacturers use devices to hold the tube rigidly in place during shipment. One type of mounting employs a steel-cable harness which fits around the bell of the cathode-ray tube and is bolted to the front panel of the cabinet at each side of the tube. Release whatever mountings you find except those which hold the cathode-ray tube onto the chassis itself.

Speaker Removal. If the speaker is in such a position that it may interfere with the removal of the chassis, take it out. Make sure that when you get around to pulling the chassis out, there will be no bottlenecks, because the chassis with its tube is a fairly heavy and cumbersome thing to handle.

Knobs. Remove the knobs. They are similar to radio knobs in that most of them are push-on types. Make certain that the knobs of concealed controls (if such are provided) are also removed, unless you know for certain that they will not interfere with removal.

Chassis Bolts. Turn the cabinet around so that you will have enough room to withdraw the full chassis and its control shafts without bumping into things. Finally, remove the chassis bolts. Before you pull the chassis out, make a last quick check to make certain that the set is free to come back. Pull it back carefully an inch or two to see if anything is binding.

How to Lift the Chassis. When you are sure it is free, stand behind the chassis and grasp either side firmly and fairly well forward, because much of the weight is usually near the front where the heavy structure of the cathode-ray tube is located. Have your dropcloth ready on the floor, and pull the chassis out, using one knee to support part of the weight as shown in Fig. 4. Then set it down on the dropcloth from which point you can tip it as you need to and figure out exactly how you will carry it out to your car, if that is necessary.

If it is a simple matter to connect the set so that it will work on the floor, you may want to do that. You can check its operation in that position and look for possible causes for its improper performance which were not as easily checked in the cabinet. You can also inspect the inside of the chassis for obvious defects which may permit you to fix it right on the spot.

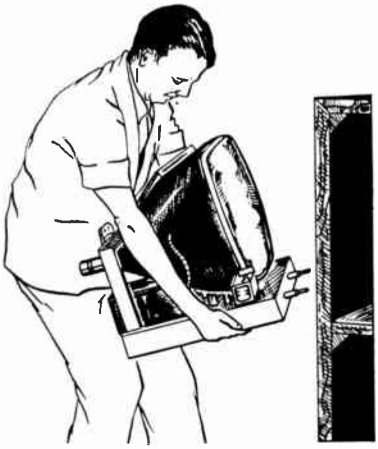


Fig. 4. Handling a chassis as it is withdrawn from a cabinet. The hands are well forward to support the heavy front end and much of the weight rests on the thigh. The tube neck is kept clear of the body to avoid damage

Cleaning the Glass. If you are lucky enough to find some obvious defect and to get the set in working condition, do not put it back in the cabinet until you have thoroughly cleaned the face of the cathode-ray tube and the *inside* of the safety glass. This alone will usually make a big difference in performance because cathode-ray tubes collect dust on their faces to an alarming extent and reduce brightness considerably.

Explain to the owner that all sets gather this dust because they are powerful dust magnets. The high voltages used in the set make it act as a dust precipitator and it attracts dust at an astonishing rate.

Use a little mild face soap and a soft cloth to clean the tube and the glass, and wipe them dry. Then you can put the set back.

Taking the Chassis to Your Shop. If the defect is not obvious when you look the chassis over, tell the customer that you will have to take the chassis to your shop. Some selling may be required to get his O.K. but you will want to do that on your first jobs and until you have more experience; you will be able to do a much better job on your own workbench, at least for the first few months of television service work.

If the set is a combination unit or one which employs more than one chassis, do not try to set it up in working condition on the floor. You can look for obvious defects, but you will probably not want to go further. Assembling the units is often an awkward operation which you can perform much more comfortably in your shop.

If you do decide to take the set to your shop, take all units except the phonograph. Usually the cable system is so interconnected between units that you will not be able to operate one unit without the others. In addition, the amplifier and speaker will probably be shared between radio and television so that there would be appreciable difficulty in trying to operate the television unit without the other chassis.

Handling the Chassis. Before you carry the set out, tag it with the owner's name, address, and telephone number and mark down the date of promises which you made about contacting him. Tie the tag securely to the chassis.

Make room in your vehicle for the chassis and leave the doors open so that you can carry the chassis directly to it and set it in place. It may grow heavier as you carry it out!

When you pick up the chassis, be especially careful not to tip the cathode-ray tube forward. With some sets the cathode-ray tube can slip out and fall.

Be careful of the control shafts. They are not only longer than most radio control shafts, but they are sometimes more fragile, particularly dual-control shafts. Because they are longer, they are more easily bumped and broken. The problem is all the more difficult because of the larger size and greater weight of the television chassis. Don't use the control shafts as carrying handles!

When you carry the chassis so that the adjusters at the rear are against your body, you may upset their settings materially. This is not as important on the way to your shop as it is on the way back after repair, because you will then have to spend the time to set them up again. If they are fairly short, as they usually are, a strip of masking tape placed across the back of the chassis and over the shafts will keep them in position.

Car-upholstery Hazards. If you must carry the chassis on the seat of a passenger car, be particularly careful to avoid damage to the under-chassis components. The weight of the chassis may cause the upholstery to bulge up into the under-chassis space and to hammer at the components as you ride over bumps. This can make an extremely interesting service job out of a simple one. The solution is to use a solid panel of wood or heavy corrugated board as a platform on the cushion.

It is a good idea to take the control knobs with you because this will make it easier to turn the special concentric shafts. Keep them in a hardware bag tied to the chassis so that you won't lose them and won't leave them behind when you return the set.

Fig. 5. The proper way to carry a picture tube. It should not be carried by the neck

Handling Cathode-ray Tubes. Cathode-ray tubes are breakable, expensive, and dangerous, and must be handled with great care. There are three ways in which they can be damaged through handling. The viewing screen can be scratched, the tube base broken, or the glass envelope broken.

Breakage. The most common manner in which cathode-ray tubes are broken is at the neck. The very nature of the tube is such that this neck is vulnerable to accidental blows. The tube should be carried by the bell rather than by the neck, as shown in Fig. 5, making certain that as you carry it the neck is kept from hitting anything.

You should be careful when you carry television chassis with the tube in place, to make certain that the focus magnet is securely in place. If it is permitted to bump around loosely it can easily break the tube. You should also place the chassis so that the tube base is in the clear and not up against a solid object in the car.

When transporting the tube itself, employ a padded container such as was suggested earlier.

A defective tube should not be discarded in a public facility without destroying it; otherwise it may represent a serious hazard to children or to persons who are not aware of its implosive possibilities. When a cathode-ray tube breaks it is capable of violently scattering glass fragments which can cause severe injury.

Fig. 6. Using a screwdriver to pry a stubborn socket off the picture tube base. This method is especially recommended if the tube base is loose

Many tubes can be traded in to your tube supplier for salvage of the glass. He may also accept the worthless ones to scrap in a safe manner.

Scratches. The face of the cathode-ray tube is made of fairly soft glass and is easily scratched. The weight of the tube, when it is placed face down on a dirty surface, may grind abrasive dust particles into the glass and scratch it. This is not only dangerous in that it may set up a weak spot in the tube, but it is also destructive in itself. One or two prominent scratches in the center of the screen (where the scratches will occur) can spoil the picture.

Avoid placing the tube face down on *any* hard or dusty surface. Place a soft cloth or some facial tissues under it when you rest it anywhere.

When you remove the tube from a cabinet or chassis in a customer's home, you may be tempted to rest it either on the rug or an upholstered chair. The rug should be avoided because it probably contains abrasive particles, if for no other reason. Most upholstered furniture may offer good protection but the tube will invariably come out with a healthy coating of black dirt which will soil the furniture. Your best bet is to place a few tissues or a clean soft cloth on a rug in a safe spot before you remove the tube and then to place the tube face down on that pad. Be careful not to dislodge any dirt from the tube where it can soil anything.

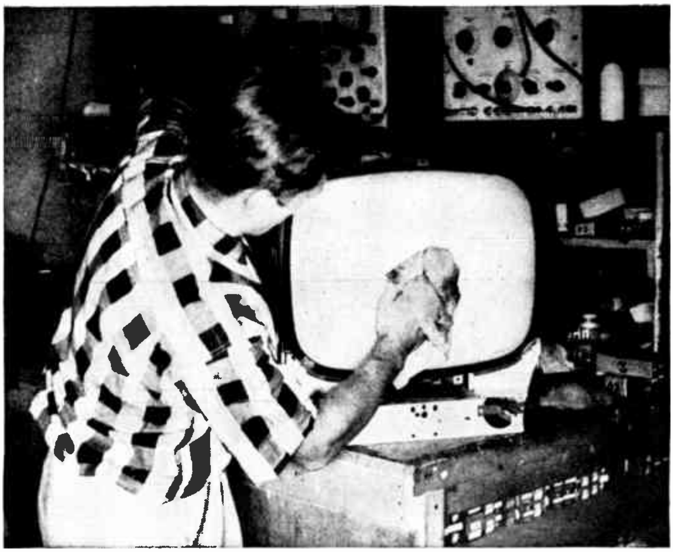


Fig. 7. Cleaning the screen of a picture tube. All tubes collect a heavy coating of dirt which must be washed away. It is wise to do this in your shop when you have the set there so that you need only wipe it clean of fingerprints when you return the chassis

Removing Cathode-ray Tube Socket. A cathode-ray tube is easily damaged if the base is loose. Never trust it—be on the safe side. When you remove the socket from the tube, pry it off carefully, as illustrated in Fig. 6—don't try to rock it off while pulling unless the socket slips off very easily. Be especially careful if you find that the base is actually loose.

Returning the Set. After you have told the customer what the repairs will cost and he has agreed to them, complete the repair and arrange an appointment to return the set. It is a good idea to do this formally so that the customer will know you are coming and will have the money ready.

The chassis should have been thoroughly cleaned and adjusted as well as possible without the cabinet so that you will spend as little time as possible in getting it in order. Replace the units in the cabinet in the reverse order in which you took them out. Clean the inside of the safety glass before you put the television chassis in.

Putting the Chassis Back. When you replace the television chassis, make certain that it is pushed well forward so that the cathode-ray tube fits snugly against the mask. Also make certain that the tube is properly centered in the mask before you tighten the bolts. The same is true of the station-selector shaft; it should be centered within the channel markings, if these are on the cabinet, to make certain that the index will read properly.

After you are finished, try the set out and make whatever centering, focus, ion-trap, and other adjustments are needed to provide proper results. Then let the customer try it to see how it works before he pays you. Hand him your itemized bill as soon as you have gotten your tools together and are ready to leave. If the set is working properly, you should have no difficulty in collecting your fee.

Final Cleanup. Little extra services help to make a satisfied customer. If you have gotten fingerprints on the cabinet, wipe them off. If your customer approves, you may go over the cabinet with furniture polish.

When you leave, let the customer know that you were pleased to have been called and that you tried to do the kind of work which would lead to other recommendations. This simple suggestion may be all he needs to take the initiative and recommend you to his friends.

QUESTIONS

1. State ten rules which you think a serviceman should adopt in making home calls.
2. What standard parts items should be carried on service jobs?
3. What precaution should be observed in removing the back of a television set?
4. Why do cathode-ray tubes collect an unusually high amount of dust?
5. Why is it important to take *all* units of a multichassis set to the service shop?
6. What general precautions apply to the carrying of a television chassis?
7. State the three ways in which a cathode-ray tube can be damaged through careless handling. How can damage be avoided?

7

Testing and Replacing Tubes

Life Expectancy. You may be surprised to learn that the life expectancy of a tube is poorest when it is brand-new. This may be true because so many tubes fail for reasons other than simply wearing out. A lead may open, elements may become loose or short together, gas may be given off from one of the heated metal parts, or air may seep in through one of the metal-to-glass seals such as at lead wires. Most of these defects, if not all, are born with the tube. A few may not show up until later; most of them, however, will show up rather early in the life of the tube.

Once a tube has been operated for awhile without trouble it is a good bet to keep going for a long time. This is especially true of those tubes which are operated at plate currents well below their ratings, as many tubes are. Tubes used as sweep output, damping, power amplifiers, and power rectifiers are normally operated near full ratings, consequently have a limited life; they actually wear out or lose some of their emission after two or more years of steady use, depending upon exactly how much they are used.

Picture tubes also begin to lose brightness after extended use and may become fairly dim as they reach the last mile. It is difficult to give hours-of-use because so much depends upon how brightly the tube is normally set, the type of tube, hours of use, and other variables. Experience seems to bear out that about 3 or 4 years of normal use can be expected.

New-tube Failures. A brand-new tube taken right out of a carton is the poorest insurance risk so far as expected life is concerned. This is not to say that the quality of new tubes is poor; it is, as a matter of fact, surprisingly good when modern tolerances and tube complexities are taken into account. There is a percentage of inherent weakness, however, that cannot economically be forced into evidence in the manufacturing and inspection process, but which shows up after relatively short use.

The warranty offered by tube manufacturers protects the purchaser in that it offers a new tube for one which fails within a reasonable time, but the failure can usually be discovered only by a serviceman.

Do not be surprised, therefore, if a new tube fails soon after it is put into service. Don't assume that a tube is good because it is new. If you replace *all* tubes in a set at once there is a fair chance that one of them may fail rather quickly, or may fail to operate properly from the outset.

In order to keep the odds in your favor, replace tubes only when they are bad; don't replace them simply because they are old, when they test well and perform properly. When you test a tube by substitution, and find that it is O.K., put the original back in the socket.

How Tubes Fail. There are three distinct classes of tube failures in television sets, and each requires a different method of checking. The classes are: *outright failures*, *imperfect tubes*, and *tolerance failures*. The *outright failure* is the dead tube, with an open filament, broken glass, broken internal lead, or permanently shorted elements. The *imperfect tube* is one which may check well in a tester but which is noisy, microphonic, or intermittent in operation. A tube classified as a *tolerance failure* is one which may test properly in virtually every respect but which fails to work satisfactorily in a circuit which is critical.

Outright Failures. These tubes are easiest to locate because they are dead. Sometimes you can spot them simply by looking at them, sometimes by feeling them (they may be cold), and they will almost invariably show up as bad on a tube tester. The circuit information given in a later chapter will help you narrow down the list of suspects out of the total tube compliment by observing and interpreting the *symptoms* of faulty operation. Dead tubes are easy to find.

One of the valuable things which you will learn is that a dead tube doesn't always mean a dead set. If the tube is a sync amplifier tube, for example, the set may work perfectly well except that it is difficult or impossible to keep properly synchronized. There are other relatively minor conditions which may be the result of a completely dead tube.

Finding Open Filaments. If a tube has an open filament, it will not light nor will it heat up after the other tubes have become warm. When you turn the set on, see if all the tubes are lit—you may spot a dead one immediately. If it is hard to see the tubes, let the set run several minutes, then turn the set off and feel each one. If you feel a cold one, try a new one in its place.

The heater of the picture tube is sometimes hard to see, but the warmth can be felt at the glass near the tube base after several minutes of running, if the heater is good.

High-voltage Tube. An exception to the no-heat method of attack is the high-voltage rectifier tube, most often located in a shielded high-voltage compartment. This tube employs a low-power, directly-heated filament which gives off little heat, and which is almost always hidden from view by the plate structure within the tube.

When this tube is bad, however, the screen of the picture tube will not light up. Thus, there is no need to check it unless the picture tube is dark, in which case the check can be most easily made by simple substitution.

Checking Filaments with Ohmmeter. If you *think* the filament of this tube is open (or of any other tube, for that matter) and you do not have a similar substitute to try out, remove the tube and check the filament or heater with your continuity checker. Most manufacturers show all pin numbers on their schematic diagrams so that you don't have to remember the filament pin numbers nor will you have to have a tube data book handy.

If you don't have any pin number data, simply put one test lead on pin 1 and test for continuity to every remaining pin, one at a time; then start with pin 2, and so on, until you have gone completely around. In the process you will have checked every possible heater connection at least twice and if none of them shows continuity, the filament is certainly open.

Two-filament Tubes. You must be careful not to consider a tube *good* so far as the heater is concerned if you get a continuity reading, because some tubes have *two* heaters, both of which must be good for the tube to work. They are among the 12-volt tubes, starting with the number 12 in their type designations (like the 12AT7), and having miniature 9-pin bases. Many of these tubes have three terminals (4, 5, and 9) which should show continuity to each other. In general, 6-volt tubes (starting with the number 6 in their designation), picture tubes, and high-voltage rectifier tubes have only a single filament.

Of course, if you do not get *any* indication of continuity, the tube is definitely open and you should replace it.

It is probably easier to carry with your tube kit one of the handy pocket guides for radio and television tubes because it will show you exactly what kind of filament arrangement is used with each tube type and to which pins it is connected.

Series-string Tubes. The practice of checking heaters for continuity is particularly helpful when you have an open heater in a television set of the transformerless type. In this type of set, the tubes are connected in series as in an a-c/d-c radio set. When one heater opens up, the rest of the tubes in the string also fail to light.

A typical transformerless filament wiring circuit is shown in Fig. 1.

Generally, at least two separate strings are used so that roughly half the tubes of the set fail to light when one of the tube heaters opens up. If you notice this condition (several tubes unlit), check each unlit tube separately for heater continuity or by substituting them one at a time until you find the bad one.

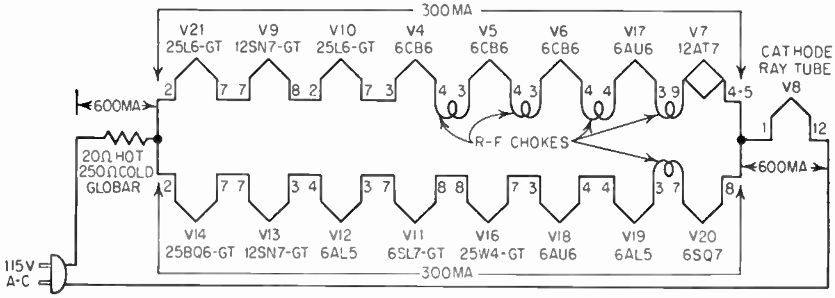


Fig. 1. Schematic diagram of a typical series filament circuit

Picture-tube Filament. The cathode-ray tube is usually in series with *both* strings of tubes, because it requires *twice* the heater current needed for the smaller tubes. Thus, all tubes fail to light when the heater of the cathode-ray tube opens. If you see that none of the tubes light in a transformerless set, check the cathode-ray tube heater. Remove the socket and check the tube for continuity between pins 1 and 12 (the heater pins for standard cathode-ray tubes).

Shorted or Gassy Tubes. The heater of any tube may light up or the tube may get warm, and yet it may be in the dead classification. It may have an internal short, it may be gassy, or it may actually contain air due to a small crack in the glass.

There is no way to *see* an internal short in a tube. You will have to learn that the tube is dead either by checking it in a tube tester or by substitution.

Gassy tubes are usually easy to spot. They often glow with a violet haze which looks like an illuminated fog within the tube, being most brightly illuminated *within the elements* of the tube. Such tubes may work badly or not at all.

Do not confuse a gas condition with the common violet fluorescent glow which seems to be on the *surface* of the *glass* of certain tubes when they are in use. This is normal and is in no way an indication of gas.

Picture tubes sometimes fall victim to gas; the glow can be seen in the neck of the tube, near the base.

Cracked Tubes. Tubes containing air will, of course, be dead; they will not light up visibly (the air prevents the heater from getting red-hot) but they can get warm. If you see such a condition, i.e., tube is warm but does not appear to be lit, check the tube in a tester or by substitution. There may be a crack in the glass where you can't see it. Often such cracks occur in miniature tubes on the bottom of the envelope, between tube pins.

Imperfect Tubes. Tubes with partial failures are sometimes hard to locate in a set, particularly if they are intermittent in operation. It may be necessary to substitute new tubes one at a time and to run the set for awhile with each new tube, until the culprit is found—if it is indeed a tube. Intermittent tube failure is rare, fortunately, and need not be given more than a mention here to point out that tubes *can* fail in this manner.

Intermittent Filaments. There is one type of intermittent tube condition which does show up on occasion. This is an intermittent *heater* condition. The heater of the tube lights up for a short time, then goes out, after which it lights up again and so on. Usually the effect repeats itself in 5-second to 1-minute intervals.

The condition can often be spotted without even turning the set around, because its effect is usually a gradual fade-out and fade-in of whatever symptoms it causes. The sound may gradually die out, or the picture may slowly fade away, or something else may happen slowly, after which things fade back to normal. The defective tubes can ordinarily be spotted by watching all of the tubes to see which one is acting up. You can also do the job by substituting tubes, one at a time if you prefer.

In series-heater circuits, a whole group of tubes may light up and then go out, in which case you will have to locate the one of the group which is the cause. In this case, substitution is probably the simplest way to locate it.

Intermittent heaters do not always produce a fading-out effect in the operation of the set. If the bad tube is in an oscillator circuit, for example, the oscillator will suddenly stop at some point as the heater cools and, just as suddenly, will start up again after the heater starts working.

Noisy and Microphonic Tubes. These cause trouble as the result of mechanical vibration. Either the elements are caused to short together when the tube is vibrated, or the circuit in which the tube is used is so critical that the very movement of the elements causes trouble, even when they don't short.

The vibration which makes the tubes act up may be caused by the speaker, by someone walking near the set, or by some other, less obvious disturbance.

The simplest case of noise or microphonics to recognize is the one which causes trouble in the sound, because you can hear the result. The microphonic tube may cause the set to howl, while the noisy tube may cause it to give forth with a loud crackling, sputtering, or clicking noise. In either case, bumping the cabinet with the heel of the hand will usually cause the tube to act up. The noise or howl may be started, stopped, or otherwise changed as the cabinet (or the chassis) is bumped.

Tapping Tubes. The best way to locate the offending tube is to tap each one carefully while the set is running, in the meantime listening for a reaction to that tapping. In the case of microphonics, tapping the offending tube will cause a decided bong in the speaker, just as though you were hitting a drum. A noisy tube will usually produce loud clicks, buzzes, or crackling in the speaker as you tap the tube.

The tubes should be tapped firmly but not so hard that you will damage them. You can tap them with the eraser-end of a full-length lead pencil, or with the wooden handle of an average size screwdriver, but never with a metal instrument. If you use a screwdriver handle, be careful not to strike the tube too hard or you may damage it. A good idea of how much force to put into tapping is to use your knuckles as a guide; try tapping your extended knuckles with the instrument you intend to use. When it just begins to hurt, you are tapping about as hard as you should. This should be hard enough to reveal a noisy or microphonic tube.

Flashing Pictures. Noisy or microphonic tubes in circuits other than the sound are almost as easy to locate except that you must watch the picture while you tap the tubes so as to see the effect. These tubes cause many kinds of effects but they all have one thing in common: the effect is responsive to the tapping.

A noisy tube, for example, may annoy your customer if it causes the picture to flash violently when the sound volume is above a certain point, or when someone walks across the floor. You may spot the condition as indicative of a possible noisy tube if, at very low volume, the picture is good but starts to flash when the volume is turned up, or if it flashes whenever you bump the cabinet with your hand.

Fig. 2. Noise bars caused by thumping a microphonic video tube. (General Electric photo)

Instead of flashing, the synchronism may momentarily fail or the picture may develop horizontal bands like those shown in Fig. 2, or its edges may weave sideways as shown in Fig. 3, causing the scene to hula-hula. Any of these effects can be the result of a so-called noisy or microphonic tube so long as the effect appears as the result of mechanical vibration.

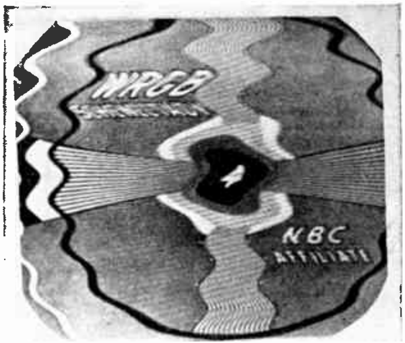


Fig. 3. Weaving caused by thumping a microphonic sync amplifier or horizontal sweep circuit tube. (General Electric photo)

To check the tubes, tap them one at a time as described above and watch the picture. If the effect occurs each time you tap the tube, it is almost a certainty that the tube is bad.

Entire Set Seems Microphonic. In some cases, a set may act as though it has a noisy or microphonic tube, and one tube may even appear to be bad because the effect appears whenever you tap it, yet the trouble may be something else. You may discover that after you put in a new tube, it also appears to be noisy. This may happen when the tube socket is bad or when something very close to the socket is loose or shorting. Fortunately, this does not happen too often, but when it does, it may display all the symptoms of a noisy tube, except that a new tube will not cure the condition.

Frequently, a set with a noisy tube is so sensitive to vibration that it acts up when you tap almost any tube or jar any part of the chassis. When this is the situation, turn the volume down and tap each tube extremely lightly, in the meantime making certain that you remain almost motionless, except for the tapping. Try to find the tube which acts up with the *lightest tap*. If the noise is in the sound, you will, of course, need to have the volume high enough to hear the set, but keep it as low as you can. If the speaker causes difficulty even at low volume, either remove the speaker from the cabinet, or connect the set to another speaker outside the cabinet, so that its vibration will not be transmitted to the chassis.

Locating Gassy Tubes. A tube will not always be dead as the result of gas. As an example, a video i-f amplifier tube with gas may work well when the set is first turned on but may begin to cause trouble after 5, 10, or 15 minutes (or even more) of operation. The picture may increase in contrast very gradually until, at last, it is so high that it cannot be corrected by the controls of the set.

A video amplifier tube with gas may cause the picture to appear "washed out" or may even cause it to become negative (whites become black and vice versa).

Frequently, cases such as this are the result of small amounts of gas in a tube, so small that the gas cannot be seen as a glow. The best way to search for the tube is by substitution, giving the new tube time to heat up (if the original effect is one which takes several minutes to appear).

Tolerance Failures. Tolerance failures are the most difficult to locate because there is nothing fundamentally wrong with the tube. A tube checker usually will show it to be good and if you try substituting, the new tube may also fail to operate properly in the same socket.

The reason for this is that all tubes have manufacturing tolerances in almost every characteristic, while some of the characteristics are not standardized at all. When a circuit is fussy or relies upon one characteristic very heavily, it is possible that a suitable tube may be found only by *selec-*

tion. You may have to try out several before you find one that suits the circuit properly.

Fortunately, all television tubes and circuits are not this temperamental. There are only certain ones that are. Some of these are listed in Table 1 and are explained in more detail in the following paragraphs.

Table 1. Circuits Which Frequently Require Selected Tubes

Circuit	*Explanation*
R-f amplifier	In low-signal areas different tubes may make a big difference in gain—particularly in high channels (7–13).
Local oscillator	Some tubes refuse to oscillate in high channels. Some tubes are microphonic, particularly in high channels.
Vertical sweep amplifier	Some tubes will not provide good size or linearity. Some cause a white fold-over line in the picture.
Horizontal sweep amplifier	Some tubes will not provide good size or linearity. Some produce a black river in the picture.
Horizontal damping tubes	Some tubes will not provide good horizontal linearity.
Horizontal sweep oscillator	Some tubes are cranky oscillators and do not start easily.

Vacuum-tube "Prima Donnas." Table 1 lists the circuits which are most frequently temperamental so far as tube selection is concerned. One of these circuits may be so critical in a particular television set that as many as half a dozen tubes may have to be tried before a satisfactory one is found.

The list is intended to cover most of the critical circuits in all types of receivers. The problem is more likely to be observed in older television sets. The circuits are not critical in all sets; if a certain model turns out to have a critical circuit, that circuit may be critical in only some of the sets.

Critical circuits such as this are often due to what engineers call the pile-up of tolerances. Every component used in manufacture is subject to variation. Resistors and condensers, for example, are not expected to be of exact value. Instead, a range of variation is permissible. Resistors are specified with 5 or 10 per cent tolerances; condensers may have even wider tolerances. Vacuum tubes also have a tolerance figure for most of the characteristics such as capacity, mutual conductance, etc.

Ordinarily, this causes little difficulty because the variations tend to average out. In some cases, however, the tolerances pile up by coincidence.

Most of the components turn out to be in error in the same direction, so to speak. The result may be a critical circuit.

In other instances, critical circuits may be the result of receiver design; a circuit may depend very heavily on a certain characteristic of the tube which it uses, whereas many tubes of the same type do not meet the circuit needs in that particular respect.

Some circuits and tubes are critical by their very nature and there is little that the manufacturer or serviceman can do except to select tubes when this is necessary. This is not unusual in high-frequency oscillator circuits.

R-F Amplifier. The r-f amplifier is often critical so far as the tube is concerned. Usually this is not important where the television signals are moderately strong. It becomes noticeable when the signals are very weak, as in some fringe areas.

Under these conditions, you can try a handful of tubes in the r-f amplifier and find that some of them will be quite poor whereas others will be hot. By this simple process you can do much to bring up the signals in a set which is used for long-range reception, and especially when the higher channels are involved.

The extent to which this will work depends upon the design of the receiver and the type of tube used in the r-f amplifier. Some sets are greatly influenced by changing the tube while others appear to be almost immune to the changes. In any event, when you're up against very weak or snowy signals it is worth trying. If you don't get a pronounced improvement, *put the original tube back.*

Oscillator. Local-oscillator tubes are sometimes selective for one of two reasons. The first is failure to oscillate and the other is microphonics. When the oscillator fails to function, the set is dead. When the tube is microphonic, the set may howl. This type of microphonic condition, incidentally, is limited to split-carrier sets; it does not occur in intercarrier sets.

If you come across a set in which the local oscillator is dead, don't look for a circuit defect before you consider the possibility of tube selection. This is particularly true if the set works well on some channels and cuts out on others. Most frequently, the low channels will be good and oscillation will stop at channel 7 or higher. Try substituting a new tube for the oscillator.

Try several tubes, not just one, if the first substitute fails to work. If you are really skeptical of the set and believe that there may be something basically wrong, try ten or more tubes if you have them. If the set works with only one or two of the tubes, there is probably something wrong. If it works with, say, three out of four, the set may be assumed to be normally selective in this respect.

It is good service practice to reach this conclusion after such a test and to consider the repair completed. To protect your reputation you should advise your customer of what you have done and point out that the set will probably continue to operate satisfactorily. Point out the possibility that something *may* be wrong in the set which will again cause the same failure. If this happens, you will have to remove the chassis and test carefully. Your customer may insist that you make this double check immediately or he may prefer to take the fairly certain chance that the trouble is cured. The latter is usually his preference because it will cost him less if the new tube continues to operate satisfactorily.

Microphonic oscillator tubes are common to split-carrier sets. They cause a howl in the audio system when the volume control is turned up. This is an out-and-out case of tube selection. You may have to try several before you find one which does not howl. Some manufacturers provide a heavy lead jacket for the oscillator as a repair part to stop microphonics. If you cannot find a tube that does not howl try an antimicrophonic jacket.

Vertical Sweep Amplifier. Vertical sweep amplifier tubes are sometimes selective because normal variations in characteristics can affect the vertical sweep very noticeably.

When you have a set which has poor linearity or poor picture height, don't look for a component defect until you have tried at least one or two new tubes. Each tube will produce different linearity, at least to a small extent. Try adjusting both height and linearity with each tube change. If none of the tubes produces acceptable results you can then feel fairly certain that the trouble lies elsewhere.

Sometimes, the vertical sweep amplifier tube produces another effect which can be cured only by tube replacement. That effect is called a step in the sweep; it appears as a brighter horizontal line across some part of the picture. If you see such a line, you can identify it as a tube problem in two ways. First, the line appears whether you are tuned to a station or not, just so long as you see a raster. Second, the line remains in about the same position on the screen even when you change vertical speed to make the picture roll. Either of these observations is evidence that the line is caused by the vertical sweep amplifier tube.

Horizontal Sweep Amplifier. The horizontal sweep amplifier tube, like the vertical, may be selective so far as size and linearity are concerned. Before looking for defects in a set which has insufficient horizontal size or poor horizontal linearity, try one or two new tubes. Try the adjusters with each new tube and particularly the horizontal drive adjuster.

The condition illustrated in Fig. 4 is caused by Barkhausen oscillation in the horizontal sweep amplifier and is most often cured by selecting sweep amplifier tubes, although adjustment of the horizontal circuits may clear it up. Some sweep output tubes will develop strong oscillation, others may not do it at all.

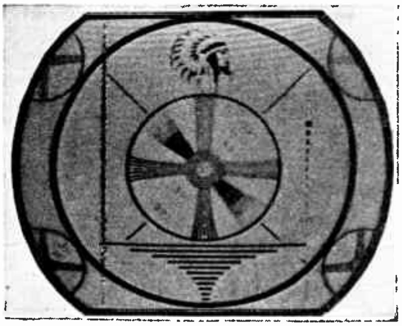


Fig. 4. Picture with Barkhausen oscillation interference. The interference shows up as the vertical black line toward the left of the screen. (General Electric photo)

Identifying Barkhausen Oscillation. The condition is easily recognized and identified. It is a parasitic oscillation condition and occurs at r-f frequencies. The interference is radiated from the sweep amplifier stage and is picked up somewhere in the r-f stages of the tuner unit or in the antenna itself. It usually looks different in different channels and may appear only in some channels, whether or not a signal is received in that channel. It may appear wider or very narrow and it may occur at different distances from the left-hand edge of the screen, but it will always be a vertical line and it will always be closer to the left-hand edge. The appearance may also change with tuning, that is, as the tuning control is turned, the line may grow stronger or weaker. Any of these effects are enough to identify the interference as of the Barkhausen type, and its elimination may be accomplished by selecting horizontal sweep amplifier tubes.

The defective tube will probably work perfectly well in another television set because the problem is not entirely due to the tube. Many sweep amplifier tubes act this way when the set in which they are used employs fairly low plate voltage. At higher plate voltages fewer tubes develop this type of parasitic oscillation. The exact circuit, lead dress, and adjustment also serve to encourage or discourage the condition. In view of these facts, you should save a brand-new tube which acts this way in a certain set because the chances are that it will work perfectly well in others.

Damping Tube. Damping tubes, like horizontal sweep amplifiers, can also be somewhat selective so far as sweep size and linearity are concerned. Try one or two new damping tubes if the horizontal linearity or size is not quite right. This is particularly true of older television sets employing a type 6AS7G triode damper. These tubes were a good deal fussier than the more modern and simpler diode.

Horizontal Sweep Oscillator. Some models of television sets employed critical oscillator circuits in the horizontal sweep generator. Often they would fail to start when the set was first turned on, so the set appeared dead so far as the picture tube was concerned. There was no horizontal sweep, consequently no high voltage, and the picture tube remained dark. The oscillator may suddenly start after several minutes or it may not start unless the set is turned off and on a few times. The voltage surge caused by this switching may be enough to get the tube started. The set acts most cranky when line voltage is low.

The cure usually is to select an especially "hot" tube for the horizontal oscillator, by trying several until you find one which always starts oscillating properly from a cold start.

Cathode-ray Tubes. Cathode-ray tubes can fail to operate for many reasons. The job of identifying a dead tube, however, is more difficult because it is not easy to try a new tube by simple substitution, especially in a customer's home. Instead you must be reasonably sure that the tube is bad before you even think about trying another tube. This is sometimes an absolute necessity because you may not have a new tube to try out and one must be purchased before it can be tried.

The simplest type of cathode-ray tube failure is, of course, an open heater, and it is also fairly easy to identify. The method was explained earlier; the final clincher is checking the heater for continuity with an ohmmeter.

Ion-trap Problems. A tube may appear to be dead if the ion-trap magnet is improperly located or adjusted. When the ion-trap magnet is way out of adjustment, the tube will not light up at all. Do not try readjustment, just yet, but look for telltale signs of recent tampering and ask your customer whether anyone has touched the adjusters. If you have good reason to believe that tampering was done, and everything else looks right, try readjustment; otherwise leave it alone because you will only make things harder for yourself. You may upset what is really the *correct* position only to find later that something else is wrong. You will find that the tube still fails to light up after you have corrected the condition because the ion-trap magnet is now also out of adjustment.

Customers sometimes do tamper with adjustments, especially the do-it-yourself, general handyman type. If one does mess up the set he may be reluctant to admit to tampering, so don't always accept his first flat answer if you have reason to suspect that such is the case. As tactfully as possible, ask whether someone may have accidentally touched the set internally, whether the back was removed, or whether other persons in the home could have touched the set without his knowledge. Point to the ion-trap magnet and ask whether that was disturbed; most laymen do not know that it is really an adjustment and they may move it about without thinking, while cleaning the dust out of a set, for example.

Checking Cathode-ray Tubes. If the heater of the cathode-ray tube lights, and there is no evidence of tampering with the ion trap, check the high-voltage cable which attaches to the side terminal on the bell of the tube; it may have fallen off. If that appears to be right, you must make more careful checks.

The first of these should be checks of the horizontal sweep circuit. If the horizontal sweep circuit is dead there will be no high voltage. To eliminate the possibility of the defect's being in the horizontal sweep circuit, you can either measure the high voltage with a high-voltage tester or you can check it by the brute-force method of sparking it to ground as described below. In either case you must be careful to avoid a shock.

High-voltage Measurement. Testing the high voltage with a tester made for this purpose should be done as recommended by the manufacturer of the tester itself. If the tester provides a voltage reading, check the reading against the television set manufacturer's service data. In general, these voltages are employed:

10- to 12-inch tubes . . .	7,500 to 10,000 volts
14- to 16-inch tubes . . .	10,000 to 13,000 volts
16-inch and larger	12,000 to 16,000 volts

Low readings to the extent of 25 to 50 per cent, although denoting something wrong, will not prevent the tube from showing *some* light.

Not until the voltage drops perhaps below 4,000 or 5,000 volts will the tube fail to light. In other words, if the cathode-ray tube appears to be dead, you should check the high voltage only for *abnormally* low voltage rather than to see whether the voltage is *correct*.

If you possibly can, the voltage should be checked while the high-voltage lead is connected to the cathode-ray tube. The object in doing this is to help you identify a short circuit in the cathode-ray tube if one exists. In most cases you can do this by making your meter connection to the other end of the high-voltage lead (while the set is off, of course). If the voltage is very low or near zero with the connector in place at the cathode-ray tube, yet is normal when the connector is *off*, the chances are that the tube is internally shorted and should be replaced.

If the high voltage is low or zero in both cases, the trouble is in something other than the cathode-ray tube.

Sparking Test. If you have no high-voltage tester, the high voltage can be checked roughly by sparking, although some set manufacturers frown on this practice. Rarely does this method damage anything if it is done carefully and quickly, and most servicemen use it. The chances of damaging anything (the high-voltage rectifier is the most likely victim) is remote if you avoid a *direct* short circuit from the high-voltage lead to ground.

The best way to do it is to turn the set off, disconnect the high-voltage lead from the cathode-ray tube, and place it so that it is clear of the chassis. Then clip one end of a test lead firmly to the chassis. Turn the set on and after you have allowed warmup time, slowly bring the other end of the grounded test lead toward the high-voltage terminal. If the voltage is normal, a bright spark will jump to the grounded lead at a distance of from ¼ to ½ inch.

Cathode-ray Tube Checker. If these tests show conditions to be normal and you have a cathode-ray tube checker, you can check the cathode-ray tube with it. If you do not have a cathode-ray tube checker, you will have to measure all voltages supplied to the tube by referring to the manufacturer's service data. If all voltages are proper and the tube fails to light up at any setting of the ion trap, you may conclude that the cathode-ray tube is defective.

Dim Picture. Sometimes the cathode-ray tube may produce some light on its screen but it may be very dim, perhaps visible only in a darkened room, and the question may arise as to whether it is the tube or the set that is bad. This can be checked fairly easily, as follows:

First adjust the ion-trap magnet to make certain that you do have the most light that the tube can produce. Then check the action of the brightness control while watching the picture, preferably in subdued light. At some adjustment of picture brightness, the picture will appear perfectly normal except that it is very dim, if the set is O.K. and the tube is bad. Then, as you advance the brightness, the picture will begin to wash out and lose the blacks, but it will not get materially brighter in the white areas. These effects point immediately to a cathode-ray tube that has low emission and which should be replaced.

The most important observation in the above check is that the picture appears to be *normal* at very dim levels; that is, the size and linearity are approximately correct. If the tube is dim because of some defect in the *set* such as loss of high voltage, the picture will also become severely stretched or compressed in either or both directions.

Replacing Cathode-ray Tubes. Cathode-ray tubes should be removed and replaced with care to avoid breakage. The tube is moderately heavy and easily conveys an impression of ruggedness, but the neck of the tube is rather fragile in relation to the weight and size of the tube as a whole.

Before removing a defective tube, remove the tube socket and the ion-trap magnet and disconnect the high-voltage terminal. Then release the mechanism which holds the bell of the tube in place. Note carefully the position of the tube if there is any possibility of changing it when you put the new tube in. Ordinarily, this is no problem because the tube fits snugly into the yoke which is firmly mounted so that the longitudinal position of the tube is fixed. The bell mounting is generally so made that it will automatically position the tube properly at the front of the chassis.

Discharging the Second Anode. Just before you pull the tube out, discharge the voltage which may be stored in the second anode. Discharge the voltage by jumping a wire from the outside coating to the high-voltage terminal. Do this several times, until no further spark is obtained. The tube acts as a good condenser, the inside coating of the tube (the second anode) acting as one plate and the outside coating acting as the other. It can hold a high-voltage charge for quite awhile. If you happen to touch the high-voltage terminal while removing the tube, you may get a shock which, although not harmful, may cause you to jump or drop the tube.

Pulling out the Tube. Make certain that there are no obstructions which will prevent you from pulling the tube *straight* forward until the neck is free. Then grasp the bell firmly and pull the tube out. Hold it in the manner illustrated in Fig. 5. Do not force the tube, and make certain that you do not put too much strain on the neck. If it won't come all the way out, push it back in and find out why; don't leave the tube part way out without supporting its weight with your hands.

Frozen Picture Tube. In some cases the yoke may have frozen to the tube so that you cannot budge it. In this case, you will have to disconnect the yoke leads and remove the yoke with the tube so that you can later free it while the tube is resting on its face. You will find that much easier to do because both hands will be free and there will be no strain on the neck of the tube. You can then clean out the yoke so that it slides freely and replace it on the chassis where it belongs. The binding may be due to an accumulation of dirt and wax, if the latter is used in the yoke.

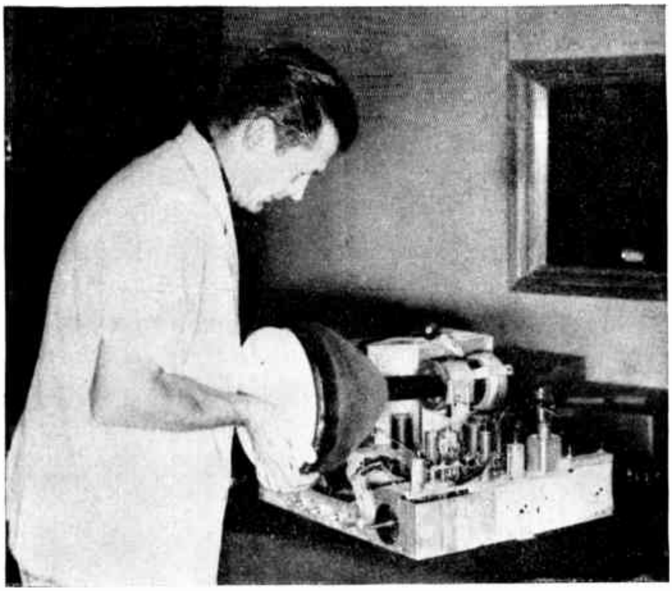


Fig. 5. Removing a picture tube. The tube is carefully guided out of the yoke assembly to avoid breakage due to binding or tilting

Inserting New Picture Tube. The new tube should be inserted as carefully as the old one was removed. Make certain that the high-voltage terminal is in the correct position so that the high-voltage lead can reach it. After you have finished installing the tube, adjust the ion-trap magnet. After this, focus and centering will probably need adjustment but need not be done carefully until after the chassis is reinstalled in the cabinet.

As a matter of fact, careful adjustment is sometimes a waste of time because the tube may have to be repositioned after installation in the cabinet. Tubes vary somewhat in dimensions so that the new tube may extend forward more than the old one. When this is the case, the tube may press firmly against the mask before the control shafts project far enough through the panel of the cabinet, and the knobs may not fit well. If the tube is shorter, it may fail to reach the mask and may leave an objectionable space around the picture. This not only looks poor but allows dust to reach the face of the tube.

Yoke Adjustments. The forward-and-back position of the cathode-ray tube is governed by the position of the yoke against which the flare of the tube rests. If the position of the tube must be changed, the yoke mounting must be loosened and the yoke moved to a new position. Perhaps the easiest way to do this is to loosen the yoke and to leave the tube-mounting assembly loose enough to permit the tube to be moved forward and backward. Then mount the chassis properly in the cabinet, after which you can push the cathode-ray tube forward snugly against the mask. Tighten the tube-mounting assembly; then, while pressing the yoke forward firmly against the tube, tighten the yoke-mounting screws.

QUESTIONS

1. Which tubes (name by function) would you expect to exhibit a decline in performance through steady use?
2. How would you go about looking for a dead tube, other than by substitution?
3. How would you go about locating a noisy or microphonic tube?
4. Identify two circuits which sometimes require careful selection of tubes and explain why selection is required.
5. How would you identify Barkhausen oscillation and what would you do to correct it?
6. Why is it unwise to attempt adjustment of an ion trap before you know why the screen is unlit?
7. How can the high voltage be roughly checked without using a meter?
8. What precautions should be observed relative to voltage stored by a cathode-ray tube and how is it discharged?
9. How should a cathode-ray tube be removed if it is frozen to the yoke?

8

Replacing Parts in Television Sets

Circuits Calling for Special Care. Lead dress and layout of parts are much more important in television sets than they are in ordinary radio sets. This is true not only because of the more complicated and critical circuits involved but also because of the higher frequencies that are employed.

The serviceman should understand and appreciate this so that in his repair work he will try to duplicate the original physical characteristics as much as possible and thus will avoid creating new problems. The paragraphs which follow are intended to explain the more important physical requirements of television circuits so that you will have a better idea of what to do when you replace parts.

Tuner Unit. Layout and lead dress are more critical in the tuner than they are in any other part of the television set. The reason, of course, is the high frequency range of the tuner. Every lead, coil, condenser, and resistor is carefully placed and should not be changed.

The r-f coils in particular should not be disturbed unless this is unavoidable, or is done by accident. In almost every case, a change in the coils will require that the tuner be realigned in order to restore original performance; in some cases, realignment may be absolutely necessary.

Virtually every lead and component plays a part in the response of the tuner, and thus must be replaced in the original position as closely as possible when repair work is done. In addition, the components used to replace defective ones should be physically and electrically identical with the originals.

The most common parts which are replaced in tuners are resistors and condensers; coils rarely need replacement. Occasionally, a tube socket may have to be replaced.

Resistors and condensers are relatively easy to replace when you have the right tools. Because of the usually cramped quarters in tuners, special tools such as soldering aids, tweezers, dentist's mirrors, and miniature soldering irons are not only helpful but often indispensable. After doing this kind of work, you must check carefully to see that no leads or components are shorting together. This is especially important because most parts in tuners are so close to each other that shorting between parts is always a possibility.

Resistor-replacement Procedure. In doing this work, don't try to do it fast. Take your time and do it as neatly and deliberately as you can. If, for example, you are replacing a burnt-out resistor, do it in this general manner:

Remove the bad resistor and its leads very carefully. Then remove the excess solder from the terminals to which the new resistor is to be connected. Try to open a small hole in one of the eyes of each terminal with the pointed end of the soldering aid or with the point of a sharp awl while the solder is kept fluid with a soldering iron.

Cut the leads of the new resistor to roughly the same lengths as the original, then check the lengths by trying the resistor for size. Do this by placing the resistor in position with its leads inserted into the eyes (which you opened in the terminals) and noting whether it occupies the same position as the original. You may have to trim the leads further or bend them to make the location come out right.

When the leads are correct, tin them neatly with the soldering iron and then put the resistor in place. You may have to hold it with tweezers while you solder the first end. Before you solder the second lead, bend the resistor leads into the final position.

Use Minimum Heat. When removing old leads, removing excess solder, or opening terminal eyes, avoid heating the terminal too much at one time. The excess heat may damage the component (socket or switch) of which the terminal is a part. Also avoid too much physical force because most tuner parts are fairly delicate. These requirements make it necessary for you to examine the terminal carefully, perhaps with a dental mirror if it is hard to see, before you do *anything*. Make up your mind exactly how you will remove the lead or clean out the solder, or whatever else you are about to do, *before* you pick up your tools. Then, go about it directly without fumbling so that you can do the job with the least amount of strain and heat. As you can readily understand, good lighting will help immensely. Tuner work should never be attempted under poor lighting conditions.

In short, you should attack the work of replacing parts in a tuner in much the same way as a dentist approaches the problem of preparing a tooth for filling. He examines the tooth at all possible angles, with good light and with the aid of a mirror before he starts. When he picks up his tools, he already knows exactly what he is going to do, and he does the actual work as directly and quickly as possible.

Tuner Sockets. Replacing a defective socket is a difficult and time-consuming job because each terminal must be treated with the same individual care and attention just described. Usually it is better to try to repair a socket by replacing a broken *terminal* instead of by replacing the whole socket. New socket parts may be obtained by taking a replacement socket apart. When the socket construction allows you to take it apart, you should do so, although sometimes you may find that complete replacement is the only answer.

Although the best way to make up your mind on how you will go about replacing the socket is by studying the layout carefully, there is a general rule which may be helpful: Whenever you can, leave the components on the socket and disconnect them at *their far ends*. Thus, most of the wiring will remain on the socket until after it is removed. It is then comparatively easy to transfer components and leads, one at a time, from the old socket to the new one where you have plenty of room and can see what you are doing.

Always make certain that you clean out any drops of solder which may have fallen into the tuner. They are often causes for future troubles because of the close spacing between terminals and parts.

You may find that certain repair jobs on tuner units are more easily done when the tuner itself is removed from the chassis. Socket replacement, for example, will generally be much easier if the tuner is removed and may take less time in the long run. Most tuner assemblies are so built that they can be removed with little trouble.

I-F Circuits. Although less critical than tuner units, i-f circuits are also quite critical with respect to component replacement and lead dress. The wiring, however, is usually wide open so that replacing parts is easily done.

Hot leads, resistors, and condensers are usually dressed away from the chassis and should be replaced in the same manner. If they are not dressed properly when a replacement is made, i-f alignment may be affected.

Long, free leads should be kept clear of unshielded i-f coils and transformers because that can easily cause oscillation, or at least severe distortion of the i-f response.

When i-f transformers are replaced, i-f alignment is necessary since few are supplied pretuned. These transformers, however, rarely become defective by themselves but may be accidentally damaged.

It is common practice to use flat ceramic or mica condensers across tube-socket terminals in such a way as to act as a shield between input and output circuits. When this is done, the condenser is mounted on edge across the socket and should be replaced in the same manner.

When replacing parts, be most careful not to drop hot solder onto the windings of i-f transformers, because that can severely alter the alignment. If that should happen, pick the solder off carefully so as not to disturb the turns of the coil.

Video Circuits. Although less critical than i-f circuits, video amplifiers call for careful lead dress and component placement. The components are often contained in a small space and the nature of the circuit is such that replacement of parts is required more often than in most other circuits. The typical video amplifier may include four or more chokes, half a dozen or more resistors, and several tubular condensers, all in a fairly small area.

If any are replaced, the new part should be as nearly identical with the old one as possible; the chokes should be the original manufacturer's replacement part.

Sweep-oscillator Circuits. These circuits, in general, are not particularly critical as far as lead dress is concerned but it is safer to duplicate the original layout as much as possible when replacing parts. The practice should be employed because there may be certain spots in the circuit which are critical as to dress, but which do not appear to be critical.

As an example, the placement of resistors directly on the socket of a sweep-oscillator tube is sometimes subject to certain limitations. When very short leads are used, the heat from the tube may be conducted to the resistor to such an extent that its value changes materially and drift in frequency results. This may show up as the need to readjust horizontal or vertical speed after the set heats up for 10 or 15 minutes. Some manufacturers use fairly long resistor leads when drift is otherwise a problem, so that the resistors stand some distance away from the tube socket. Although this may not look as neat as it might, the arrangement should be duplicated if one of the resistors is to be replaced.

High-voltage Circuits. The physical placement of parts and leads in these circuits is especially important because of the high voltages employed. The principal consideration is to avoid breakdown, corona, or simple coupling of the high-intensity signal to other wiring in the set.

In the high-voltage circuit, the most important single consideration is corona. When it occurs, it may actually be seen or heard, or it may cause interference in the picture.

Corona can often be seen in the dark; it may appear as a violet glow or as very faint violet sparks shootings into the air out of a high-voltage wire or terminal. It can usually be cleared up by correct placement of the lead, by insulating it properly with high-voltage tape or plastic insulation, or by cleaning up the terminal involved as described below in the description of high-voltage soldering techniques.

Corona can sometimes be heard; it sounds like a faint frying or crackling sound coming from the chassis, near the high-voltage circuit. Sometimes it sputters only occasionally. Usually it is accompanied by a characteristic smell of ozone. This form of corona is no different from the kind you can see except that it may be weaker or it may occur where it is hidden; consequently, the exact location may be harder to find.

Corona Interference. Corona can sometimes be observed initially as interference on the picture. When this is true it usually represents a fairly heavy corona discharge and must be cured, not only because of its effect on the picture but because it may eventually lead to a serious breakdown. (Weak corona may not result in breakdown but it can reduce high voltage and thus spoil picture brightness and quality.) The corona interference may appear as strong all-over snow or as streaks and blotches on the picture, and it may be intermittent. You may suspect a corona condition if you get a strong but noisy picture, when you would ordinarily expect a strong noise-free picture. Careful analysis, however, is not needed to identify a corona condition because the cause of interference is almost always accompanied by visible corona or by corona which you can smell or hear.

Replacing High-voltage Parts. The above comments are made not so much to demonstrate troubleshooting techniques, but rather to indicate the kind of care and attention which must be given to replacing parts in the horizontal sweep and high-voltage circuits. These parts include the horizontal sweep transformer, the yoke, the high-voltage rectifier socket, and general wiring and components associated with these circuits.

Care should be exercised to duplicate the wiring dress and the manner in which soldered connections are made. All sharp points must be avoided, particularly in wiring connected to the high-voltage rectifier. Solder must be applied in a round, smooth shape, and sharp points must be filed off or otherwise removed. If a component, such as a series resistor in the high-voltage lead, is originally wrapped with high-voltage tape, it must be similarly wrapped when it is replaced.

Printed Circuits. Many modern television sets use printed or etched circuits which call for special care in the replacement of parts. Figure 1 shows a typical printed circuit subassembly and illustrates the proper method of going about the removal of a component part. The part happens to be a tube socket but the general principle applies to most other parts as well.

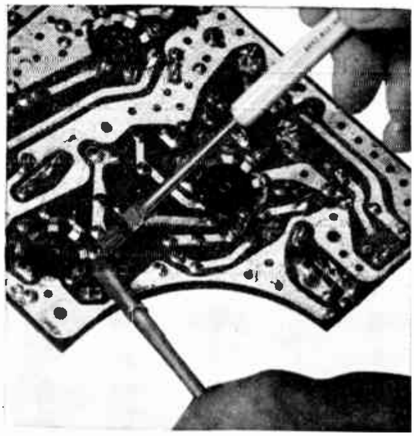


Fig. 1. Preparing to remove a socket from a printed circuit. The solder is melted with a small iron and cleaned off quickly with a small stiff brush. (General Electric Photo)

Each terminal is cleared of solder completely before the removal is attempted. This is done by the method illustrated; the solder is heated with an iron and the solder brushed away with a small stiff brush until the terminal is free.

Care must be taken to avoid the use of excess heat (do the work quickly) and to make certain that the brushed-off solder does not stick to the printed circuit board and cause shorts. Solder which has splashed onto the board will not fuse to it and can be pried off with the tip of a sharp knife, being careful not to injure the printed circuit.

When all terminals are free they should be bent into positions which will permit removal. The old part can then be removed. The new part will have to be physically identical with the old one. It should fit into place easily, if the solder points have already been brushed free of excess solder.

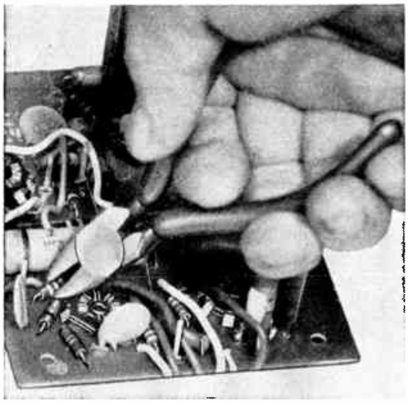


Fig. 2. First step in replacing a resistor on a printed circuit. In this step, the resistor is cut in two. (General Electric Photo)

Small Components on Printed Circuit Boards. The usual practice with small components in printed circuit assemblies is to mount them by their own leads and to place them on the opposite side of the board from the printed wiring. This is true of tubular condensers, mica condensers, ceramic condensers, and resistors. This can be seen clearly in Fig. 2.

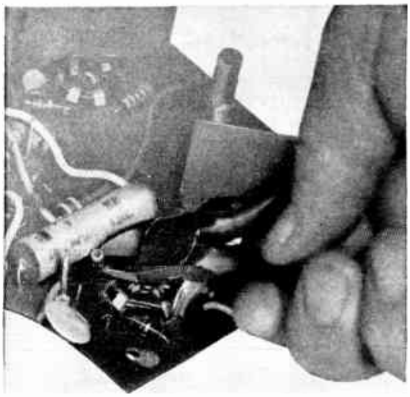


Fig. 3. The second step in replacing the resistor. The two parts are snipped off leaving the original leads in place. (General Electric Photo)

The series of illustrations in Figs. 2 through 4 show the most practical method for the replacement of a small part. In this case it is a resistor.

The resistor is broken in half with diagonal cutters, as shown in Fig. 2.

The two ends are then turned up as in Fig. 3 and snipped off so that most of the original lead remains on the board. The new part is then connected to the original leads by means of a tight wrap made with long-nose pliers. Finally, it is soldered in place as shown in Fig. 4.

Tubular condensers are not easily cut in half, but the leads are more accessible and may be snipped off right against the condenser. This will accomplish the same result.

The method described is recommended in preference to *unsoldering* the old part because the latter calls for more work than is really needed and because of the desirability of applying no more heat or strain on the printed wiring than is necessary.

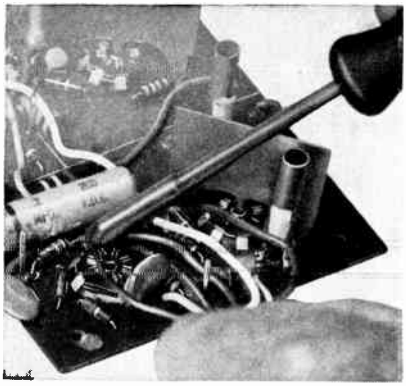


Fig. 4. The final step. The new resistor is hooked to the original leads and soldered in place. A minimum of heat is used by keeping the iron tip clean and well tinned so that the solder flows almost instantly upon contact. (General Electric Photo)

Modules. The module type of construction is another new technique in the assembly of television receivers. It involves the use of a stack of wafers each of which is a miniature printed circuit. A representative module is made up of several ceramic wafers held in position with 12 wires called risers. These wires serve as electrical connections between wafers and as a mechanical support for them. If the module includes a tube in the circuit, a tube socket is mounted on top of the first wafer. Such an assembly is shown in Fig. 5.

The module is mounted on the chassis by inserting it into a matching square hole, after which the extensions of the risers are bent over and soldered to terminals on the chassis. The terminals on the chassis deck are ordinarily part of a printed or etched circuit. The soldered connections serve to support the assembly. A television set using modules is shown in Fig. 6.

A module is a component subassembly and is replaced as an entire unit. The riser wires are clipped at the chassis terminals, the old module is removed, the chassis terminals are cleaned, the new module is pushed into place and the riser leads are bent over and soldered.

Figure 7 shows a portion of a conventional vertical output circuit. Figure 8 shows the same circuit as it is adapted for modular construction. The area within the dashed lines contains the wiring and components contained in the module. Figure 9 shows the layout of the individual wafers making up that module. Note that each riser is given a number and that these numbers are shown on the circuit diagram. This is done to simplify circuit tracing.

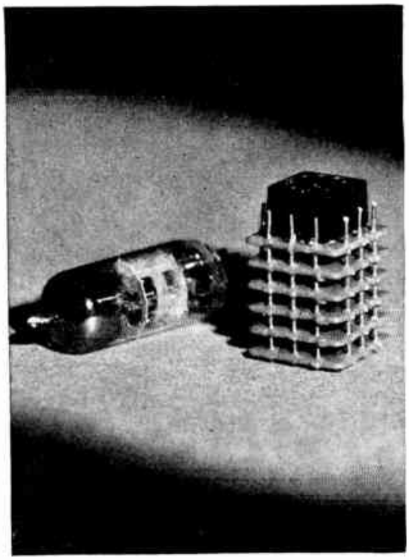


Fig. 5. A module cssembly attached to a tube socket. The wire extensions are used to make connection to the chassis circuitry and to support the assembly. (ACF Electronics photo)

Types of Replacement Parts. When you need a new part for a television set, you must decide whether to use an *original* part made by the manufacturer of the set, a *recommended substitute* made by the parts manufacturer, or a *universal replacement* part such as can be purchased in advance and used in almost any kind of radio or television set. So far as cost and convenience in buying are concerned, the universal type of part is best, but it will not always do the job. By the same token, the recommended substitute has advantages but also may not be satisfactory. Sometimes, only the original part should be used.

In order to help you decide what kind of parts to get for television repairs, the following paragraphs explain some things you should know about the different kinds and where they apply best.

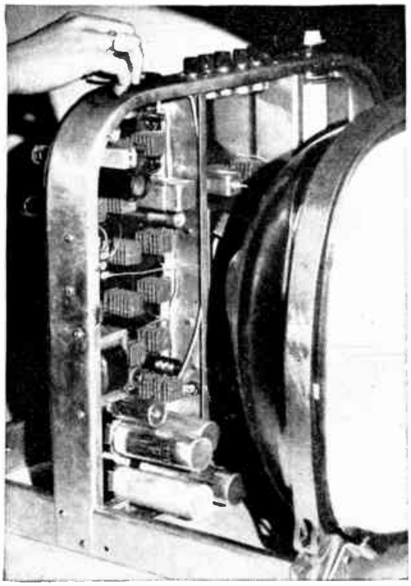


Fig. 6. A close-up of a television set using modules. (ACF Electronics photo)

Original Manufacturer's Parts. The television manufacturer makes available original repair parts exactly like those which are built into his sets. He lists them in his parts lists and packages them separately under the same catalog number shown in his parts lists in service manuals. Because of this special handling, the price of these parts is often somewhat higher than similar parts made for general use by specialty parts manu-

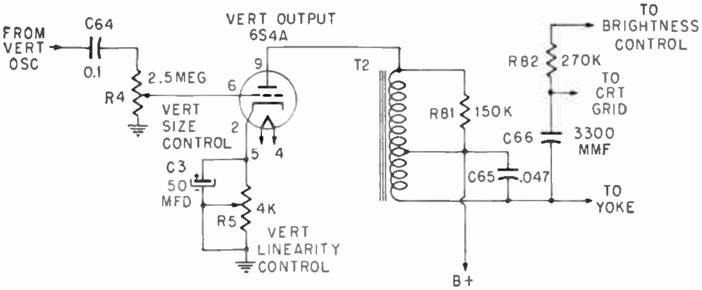


Fig. 7. A conventional circuit of a vertical sweep amplifier stage

facturers. There are, however, several important advantages to using the original parts: they are of known quality, are often preferred by the owner of the set, are easier to install as a rule, and frequently cannot be substituted.

Television manufacturers rarely handle all parts used in their sets because so many of the parts are standard and are more easily obtained in the open market; but they all handle those special parts which cannot be obtained elsewhere. They also handle those parts which they feel are not readily obtainable in *exactly* the same form as used in their sets, or for which owners or servicemen may prefer the manufacturer's original part.

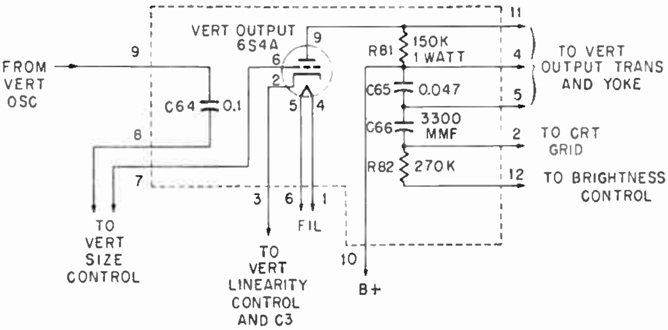


Fig. 8. The circuit of Fig. 7 as it is adapted for the use of modules. The dashed line shows what is included in the modules, while the numbers near the outline represent the numbered risers of the assembly

Recommended Substitutes. These parts are made by specialty parts manufacturers, under their own brand names, for replacement purposes in radio and television sets. Sometimes the part is *identical* with an original part in a given television set, in which case it may be identified as an *exact duplicate* for that particular part. More commonly, the part is a general replacement for many *nearly identical* parts in sets and is readily adaptable for that purpose; it may not be identical mechanically nor electrically, but it is close enough to serve as a good substitute. Usually the parts manufacturer provides a chart with the part to show in which television sets it can be used. Some of these parts are quite inexpensive, but may be of questionable quality, while others are of high quality and provide excellent results.

Often, substitutes are selected for use by the serviceman himself, based upon his experience and knowledge of the specifications of the part needed in the set and of those pertaining to the substitute. This, however, requires appreciable know-how and should not be done unless you are sure that you are completely familiar with the component in question.

Replacing Power Transformers. Power-transformer substitutions, for example, are quite common because of the relative ease with which an experienced serviceman can translate the original transformer into a standard set of specifications. He may be able to determine exactly what voltages and currents are required by the television set, as well as the physical space available for the transformer. He may then find a standard transformer on the market which can fit into the space and which provides identical voltages and currents. The transformer may be a cheap unit to keep cost down, or it may be equal to or better than the original (and may still cost less); or it simply may be used because the original cannot

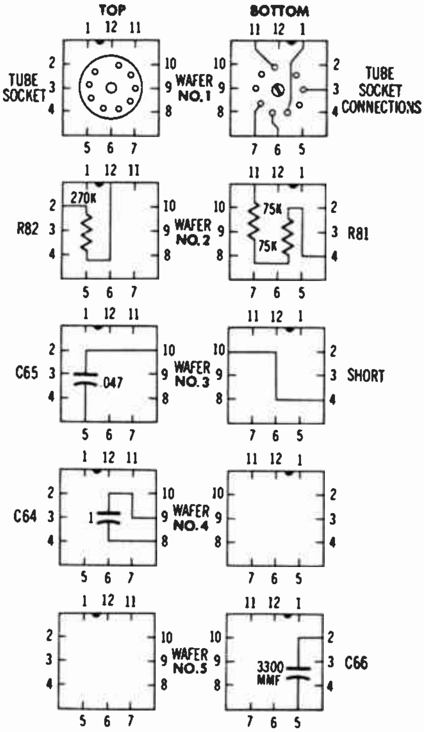


Fig. 9. The layout of the modules for Fig. 8. The numbers are riser numbers and all like numbers connect together through the vertical risers which cross the edge of each wafer where they are soldered

be obtained or because the original is known by reputation to be troublesome.

Universal Replacements. These parts are standard radio items such as resistors and condensers, sold under the brand names of the parts manufacturer. They are identified entirely by specification, rather than by specific use. A circuit may employ, for example, a half-watt carbon resistor of 5,000 ohms at a tolerance of 10 per cent and it may be completely identified in this manner in the television manufacturer's parts list for the set. When it is, an identical part can be obtained from standard suppliers in any one of many popular brands. As a rule these components are of equal quality to those originally used in television sets and many of the brands are, in fact, the very ones used by the set manufacturers.

Selecting Replacement Parts. No hard or fast rule can be given which will apply to all parts used in television sets and which will tell you whether the original, a substitute, or a universal part would be best. In many cases, it is purely a matter of choice. In other cases, the factors of convenience, cost, quality, and customer preference must be weighed before a decision can be made. There are some general rules about specific parts, however, which can serve as a guide for you until such time as you learn enough about certain parts to exercise your own judgment with confidence. These rules are given in the paragraphs which follow, starting with parts normally requiring original replacements.

Ordering New Tuner Unit. The tuner unit is usually obtainable only as an original part from the set manufacturer. This is true even when the tuner may *appear* to be similar to a standard unit on the market. The reason is that even when manufacturers purchase a standard unit in preference to making their own tuner, they specify certain features which apply exclusively to their own sets. These may include special mounting brackets, special shaft lengths and shapes to take a particular design of control knobs and to fit a given cabinet, special i-f frequencies, or special forms of circuit connections.

To be on the safe side, it is better to avoid buying a substitute unless you have a compelling reason to do so, in which case you may have to do some work on the tuner to make it fit and work properly. It is usually safe to buy a substitute if the *television manufacturer* states in his service manual that the tuner is a *specific model and brand* of tuning unit and thereby provides the information you need to buy that particular tuner. If he fails to make this kind of identification, the chances are that there is something special about the tuner and that the only exact replacement is the part obtained under the brand name and model of the television set.

Ordering Special Parts for Tuners. About the only tuner parts which you can safely substitute are the carbon resistors and tubes. Mechanical parts and items such as coils, switch sections, trimmers, and antenna transformers are obviously special and should be replaced with original parts. To be on the safe side, the ceramic condensers in tuners should also be replaced with original parts because they so often are dependent upon specifications and characteristics which are not, or cannot be, fully described in parts lists. A given condenser may have a special temperature coefficient, for example, which may not be fully described in the parts list for the set; or the circuit in which it is used may depend upon specific physical dimensions which cannot easily be expressed in the parts list.

Tube sockets in tuners, although they may conform to standard sizes, are often made of special high-frequency insulation or may be specially treated with wax or other material. This is particularly true of oscillator tube sockets. It is therefore wise to check the service manual to see if these sockets are specially listed in the parts list. If they are, it is usually safer to get the original part when you need a new socket.

Failure to observe these general precautions relative to tube sockets or ceramic condensers may result in excessive oscillator drift or may actually prevent the oscillator from working after you have replaced the part, and you may have to do the job over again.

Ordering I-F Transformers and Coils. These items should always be replaced with original parts because mechanically and electrically identical parts are either unavailable or hard to locate. As a rule, most television manufacturers make their own i-f coils and transformers or have them specially made, and similar items are rarely available as standard parts.

Ordering Video Chokes. The characteristics of video chokes are more exacting than is conveyed by the parts list description given in television service manuals; consequently, satisfactory replacements cannot be guaranteed by using only that description. As a rule, only the inductance of the choke is given, whereas the distributed capacity and physical size are also important. In view of these facts, such chokes should be replaced with original parts to make sure that you get the correct ones.

Ordering Sweep Oscillator Transformers and Coils. This category is intended to include both horizontal and vertical *oscillator* transformers, linearity-adjusting coils, and sweep-width-adjusting coils. These components are ordinarily special parts in terms of electrical and physical properties and should be replaced with original parts.

Many standard components in this category are available but these are intended to be used by experienced servicemen who know more than the average about television circuits. They are frequently used as replacements in off-brand sets assembled from kits, for which exact replacement parts may not be readily available. They can also be used to replace parts in many brand-name television sets, but the burden of adapting the part to the circuit is carried by the serviceman.

Ordering Horizontal Sweep Output Transformers. This part is sometimes called the flyback transformer or simply the horizontal output transformer. Many television sets require that the original part be used as a replacement although standard transformers are available as substitutes for certain originals. It is recommended that the serviceman with little experience use the original because this is most easily done without mistakes, and mistakes may be difficult to clear up in this circuit. The original manufacturer's part usually provides leads of correct length and has terminals in exactly the same location as the part which it replaces so that it is necessary only to duplicate the connections without having to do any circuit tracing. Some general-purpose substitutes are quite different from the original and require modification of wiring and drilling of holes to make them fit.

There are a number of *exact-duplicate replacements* on the market which are offered by transformer manufacturers and which serve as excellent substitutes. If they include *exact* information as to substitution in the particular set which you are repairing or if they are claimed to be *exactly* the same as the original, they can be used as well as the original replacement; a good-quality replacement transformer should perform well.

Until you have more experience you should avoid universal replacements which include very broad instructions as to substitution in sets.

Ordering Deflection Yokes. The deflection yoke is a specialized part, carefully designed or purchased by the set manufacturer. As such, your best bet is to use the original part for replacement work. There are many universal replacements on the market, identified by deflection angle (the flare angle of the cathode-ray tube with which they are to be used) and by inductance, but these two factors alone do not express all of the features of the product. Furthermore, many different kinds of physical mountings are employed, and universal replacements often lead to difficulties.

Poor-quality deflection yokes can produce blurry pictures or can cause physical distortion of the picture which may be obvious and objectionable to your customer. If he is critical, the safest choice is the original replacement part, especially if he has an expensive, high-quality television set.

There are, of course, very good substitutes on the market under known brand names. More information about these is given under a later subhead.

Ordering High-voltage Tube Sockets. These sockets are often special parts because they are supported by special insulators and often include some form of anticorona shield. Examine the socket carefully if you have to replace it, to make certain that you get the right kind of replacement. It is poor practice to use one which is physically different from the original.

It is possible that the socket may be a standard unit and that only the mounting is special, but you can determine this by comparing the socket with standard units on the market. High-voltage rectifier sockets employ ordinary insulation because even the best socket, by itself, is not adequate for the voltages involved; suitable insulation from the chassis is provided almost entirely by the supporting insulation on which the socket is mounted.

Ordering Controls and Adjusters. Controls and adjusters come in a wide variety of sizes, shapes, combinations of sections (dual units), and shaft dimensions. Many of them are special and can be obtained only from the set manufacturer. Others are available as standard replacements and are commonly supplied in kit form; they can be adapted to almost all standard circuits in television sets.

Special controls offer little or no chance for substitution, whereas, with most of the standard controls, the decision to use universal replacements or original parts is a matter of choice by the serviceman. If universal controls are not ordinarily carried in your stock, you are probably better off to get the original part because it will be completely assembled, will be known to be electrically correct, and will have the correct shaft dimensions.

Ordering Special Resistors. Although most resistors in television sets are of the universal type, some special resistors may be used. These are usually listed as special resistors in the service manual. They may be considered to be special because of odd physical sizes and shapes, odd wattage values, or odd resistance values. In the long run they may be more easily obtained from the set manufacturer than by trying to improvise substitutes. Substitutions, however, are not difficult to make and are usually fully satisfactory if the ordinary principles of substitution (to be explained later) are employed.

There are certain resistors, however, which are better replaced with original parts. These are the ones which involve some form of regulating characteristic. The resistor may be identified in the parts list as a Globar type (one of the current-regulating types) or simply as a current- or voltage-regulating resistor. It is often employed as a current regulator in sets using series filament circuits. To be safe, it is better to buy the original resistor specified in the parts list of the service manual.

Recommended Substitutes. There are many parts manufacturers who make replacement parts for servicemen to use as replacements in television sets. Some make high-quality products which may be as good or better than the original parts used in sets. Others sacrifice quality for price. No attempt will be made to recommend between these, because each has its purpose. Often, a serviceman has little choice but to use the least expensive part he can get because his customer may request him to do so.

In any event, it is good business practice to let your customer know that there are different quality levels and prices for television parts, and also to ask him whether he wants only the original manufacturer's parts to be used. Many customers will insist on original parts even if they may be more expensive (you may have to charge more because they may cost more or because you may have to make a special trip to buy them). It is morally wrong to let your customer believe that original parts are used when, in fact, a substitute brand may have been used. It is much better to use quality of parts as a selling tool, because you can earn more profit when you sell more expensive, high-quality parts.

These comments are not intended to imply that the set manufacturer's parts are always the highest in quality; good-brand substitutes are better in some cases. Your customer, however, may not want to consider anything but the original part, or on the other hand, he may welcome a higher quality part of another manufacturer if you explain clearly your reasons for this recommendation.

The following paragraphs cover the most common types of parts which are available as substitutes for original parts.

Substitute Power Transformers. A number of transformer manufacturers make power transformers which are adaptable to certain standard television receivers. The general requirements which the transformer must meet are that it fit into the *physical space* and that it have suitable *windings*.

The job of determining whether a given substitute transformer is satisfactory is simplified by many transformer manufacturers. They have tables available which list the more popular models of television sets together with a cross reference of transformers which can be used as replacements in those sets. If you intend to use substitutes, get whatever lists you can from your parts supplier in advance, because they can save you time and unnecessary work.

Note particularly that replacements may be classified as *exact duplicates*, as exact *electrical* duplicates, as *recommended* types, or by some similar, qualifying terminology relative to the specific transformer which you want to replace.

You should expect an *exact* duplicate to fit perfectly both as to mounting and electrical connections.

An exact *electrical* duplicate may be somewhat different in physical size or mounting. Until you have examined the transformer you should reserve judgment as to whether you can mount it satisfactorily. It may require some chassis drilling or cutting, or may look poor on the chassis. You will have to decide whether it is worth the trouble.

A transformer identified as a *recommended* replacement, or by some other phrase weaker than those given above, may be perfectly satisfactory but may require more adaptation on your part. It may have extra windings which you will not need or it may require extra work to mount, or it may differ in some other respect. Here again, you will have to compare the replacement to the original to determine whether you want to use it.

Substitute Horizontal Sweep Output Transformers. This transformer is sometimes called the flyback transformer or simply the horizontal output transformer.

There are only a few basic designs for sweep transformers, and many good substitutes are available for replacing originals. There are differences between these transformers in important details, however, and these differences are not readily expressed in terms of generally recognizable specifications. In view of this, substitutes should be selected on the basis of the transformer manufacturer's specific recommendations for each model of television set in which he claims they can be used.

As in the case of power transformers, most manufacturers supply good cross-reference data showing which of their transformers can be used with which specific sets, and exactly how they must be connected for such usage.

If you cannot get an exact duplicate or a substitute with specific information as to its installation in the particular set in which you are interested, your best bet is the original transformer. If it is not available for one reason or another, the parts supplier may have a technician on his staff who can advise you as to a suitable substitute if you take the service notes and schematic of the set to him. Many parts suppliers provide this kind of service as an aid to their regular parts customers.

All horizontal sweep transformers have plate windings which are similar in terms of electrical characteristics; the principal electrical difference is in the yoke winding which, like the voice-coil winding of an audio output transformer, must match the load impedance. In the case of the horizontal output transformer, the load is the horizontal winding of the deflection yoke. Its impedance is expressed in inductance, in units of the millihenry. Although considerable mismatch is tolerable in audio transformers, fairly accurate match is needed in horizontal sweep transformers, otherwise the high voltage may suffer and both size and linearity may be poor.

Substitute Vertical Sweep Output Transformers. The vertical sweep output transformer can more easily be substituted than the horizontal, since it is not nearly as critical. As a matter of fact, the transformer is so easily connected into the circuit that there is little trouble in connecting up a substitute to see if it is O.K. before you make up your mind to use it.

As in the former cases, your most reliable guide for substitution is the parts manufacturer's published recommendation.

The vertical output transformer is similar to an audio output transformer in many respects. It is designed to match a given output tube to a given yoke impedance. In order to select a substitute when no specific recommendation is available, it is usually enough to know what kind of vertical sweep output tube is used, and the impedance of the vertical winding of the yoke. The impedance is often expressed in ohms on schematic drawings of sets. When you do not know the yoke impedance you may have to take a chance on the most popular available replacement. If an incorrect transformer is used, it will usually show up as insufficient picture height.

Substitute Yokes. Deflection yokes are available in the form of recommended substitutes for many different television sets. Unless you have a good deal of experience in substituting yokes, it is better to stick to those which are described as *exact* duplicates.

When you cannot get an original or when an exact-duplicate recommendation is not available, you must keep in mind the five main variables which define any particular yoke. They are: (1) inductance of horizontal deflection coil; (2) inductance of vertical deflection coil; (3) deflection angle of cathode-ray tube; (4) quality of yoke; and (5) physical mounting.

Yoke Inductance. The inductances of the two coils are independent considerations. Yokes are sometimes made with one winding of low inductance (heavy wire, few turns) and the other of high inductance (fine wire, many turns); or they may be both low, or both high. In any event, they must match the vertical and horizontal sweep output transformers used in the set. This represents the first problem usually encountered in trying to select a substitute, because some manufacturers fail to indicate yoke inductance values in their parts lists or on their schematic drawings. Perhaps they follow this practice because of their conviction that the only proper replacement is the one made specifically for the set, thus they consider individual electrical specifications to be of little value. A fairly common combination, however, is a 15-millihenry horizontal coil and a 30-millihenry vertical coil.

Yoke Angle. The deflection angle is easily found; it is defined by the particular type of cathode-ray tube with which it is used. The angle is given in cathode-ray tube data sheets or tables. Older cathode-ray tubes such as the 10- and 12-inch sizes employed from 50- to 60-degree deflection angles. Later tubes employed 70 degrees and then 90 degrees. Now there are extra-short 110-degree and 120-degree tubes. The surest way to find the correct angle is to look up the data for the particular cathode-ray tube.

The deflection yoke should have the approximately correct angle because that angle determines the shape of the physical flare on the yoke itself and it will fit better against the bell of the tube if it is correct. The yoke will generally be made to cover a range such as from 66 to 70 degrees or from 80 to 90 degrees.

Yoke Quality. The quality of the yoke is difficult to express in simple terms. As a rule you must depend upon the reputation and quality specifications of the manufacturer. A good yoke employs a carefully controlled winding pattern in the coils, has carefully located coils, and employs proper damping resistors and balancing condensers. It also employs good insulation to handle the extremely high peak voltages which are developed in the horizontal coils (1,000 or more volts), and to provide good life. The design features are important to maintain small spot size (to get good all-over focus); to maintain good picture shape (square corners and parallel sides); and to eliminate striations (vertical ripples in picture brightness starting at the left side of the picture and gradually diminishing toward the right). A poor yoke may exhibit some or all of these undesirable effects.

Yoke Construction. The physical construction of the yoke is obviously important because a replacement yoke must fit into the mechanical supporting structure of the set. It must fit well because the yoke serves as one of the major supports for the cathode-ray tube. A sloppy assembly may make it difficult to adjust the geometry of the picture and to keep it right.

Universal Replacements. There are many kinds of universal parts available as replacements for parts in television sets. These parts are almost always sold on the basis of their brand reputation and their individual specifications. The serviceman, in other words, is expected to buy these parts as such, and to use them where and how he sees fit without benefit of recommendation as to specific application by the parts manufacturer or supplier.

The items listed below represent most of the common parts which *can* be purchased as universal parts. The decision as to whether to do so or not still rests with the serviceman and will usually be resolved in price negotiation with his customer. A universal speaker, for example, may not be acceptable to a customer; a cheap substitute may be inferior to the original. On the other hand, there are speakers on the market which are of better quality than the average speaker originally provided with a television set.

In the case of carbon resistors and tubular condensers, there is little reason to use anything but universal parts.

Carbon Resistors. Carbon resistors are identified in parts lists for television sets simply as resistors without any further qualification, or specifically as carbon resistors. The common physical sizes, or more properly, the wattages, are ½, 1, and 2 watts.

The characteristics of carbon resistors are completely identified by wattage, resistance, and tolerance, and all three should be duplicated when making a replacement. All three of these characteristics are usually shown in the parts list for the set. In addition, the resistor itself is identified in terms of resistance and tolerance by the familiar color code system used in both radio and television.

In reading color codes, the fact should be remembered that the lack of a tolerance ring in the color code signifies a tolerance of 20 per cent. A silver color band denotes 10 per cent, while a gold color band denotes 5 per cent.

Importance of Resistance Tolerances. In making substitutions for 5- or 10-per cent resistors make sure that a resistor of the same tolerance is used. Don't substitute a 10 for a 5 because it appears to work well; it may have some secondary effect which will prove annoying to the set owner. It may, for example, shift the center speed of a hold control which may then fail to bring about synchronization under all conditions of operation. It is perfectly O.K. to substitute resistors of *smaller* tolerance than the original and this practice is considered good.

If you have only a wider-tolerance resistor to substitute for a closer one, you cannot depend upon ohmmeter measurement to determine whether it is really close enough to the correct value to be used. Multipurpose meters have a tolerance of their own and they can be particularly poor, in terms of accuracy, when measuring resistance. They can easily be in error by more than 20 per cent. It is much safer to get the right resistor in the first place.

When buying resistors, try to get known brands and avoid bargain packages unless you know what you are getting. The bargain may consist of rejected resistors which are either unstable or improperly coded, especially so far as tolerance is concerned. You can check such resistors, however, with your ohmmeter, using a 5 per cent resistor as a *comparison* standard. When making such comparisons, keep in mind that a difference in reading between the two of up to 5 per cent, guarantees an accuracy of only 10 per cent (the 5 per cent resistor may be 5 per cent off value in the first place). By the same token, a difference of up to 15 per cent guarantees an accuracy of only 20 per cent.

Wire-wound and High-wattage Resistors. The circuits in which wire-wound and other types of higher-wattage resistors are used generally permit free substitution to be made. These circuits are usually power circuits and are not particularly critical in either tolerance or physical characteristics of the resistor. When narrow tolerances are required, this is specified almost without exception in the parts list for the set and should be observed. Wire-wound resistors are generally within a 10 per cent tolerance.

It is important to substitute a resistor of the same or higher wattage, otherwise it may overheat. Odd wattages, such as 7 watts, should be replaced with the next higher standard wattage available.

When a resistor is identified with some form of special characteristic such as "regulating," or when it is described in an unorthodox manner such as "*hot* resistance—20 ohms"—the chances are that it is not a conventional resistor and should not be replaced with a standard unit. The original replacement part is a better bet for these.

Potentiometers, Controls, and Rheostats. Many controls and adjusters of the variable resistance type in television sets can be built up from potentiometer kits. These kits include many standard resistance units, power switches, and shafts so that they can fill a wide range of needs by assembling the right combination for each individual repair job.

Complete information and instructions for these kits are provided by their manufacturers and are available from most radio parts supply houses. They can also recommend a suitable inventory to fit your needs and your pocketbook and will no doubt be willing to do this when you are considering the purchase.

Keep in mind that potentiometers are characterized not only by their resistance but also by their *taper*. A volume control, for example, calls for one kind of taper, identified as audio taper, while a focus control calls for a linear taper. A potentiometer with an audio taper or one of the other forms of nonlinear tapers changes in resistance with rotation more rapidly in one part of the range than in another while a linear taper is evenly distributed throughout the range of the control.

In radio service work, most controls requiring replacement are volume or tone controls and the audio taper is almost the only one the serviceman deals with. In television, most of the adjusters have linear tapers (speed, focus, linearity, size, etc.) so that you should make it a point always to check the performance of a control after you have replaced it to make sure that it feels right. This is to say that its range of control should be smooth and easy to use.

The replacement control manufacturer's data will have information about tapers and will tell you what kind of taper to use for different basic television control circuits.

Mica and Ceramic Condensers. To be safe, mica and ceramic condensers should be replaced kind for kind. The parts list for the television set will identify the basic type, will specify the capacity, the voltage, and the tolerance, if the latter is important. Standard condensers can be obtained to replace almost any found in a television set.

The exception to the above rule is the case cited earlier with reference to ceramic condensers used in tuners, or other special ceramic condensers having critical temperature characteristics. These are more safely obtained as original replacement parts unless the parts list expresses the specifications completely enough to permit a similar unit to be purchased elsewhere.

Paper Condensers. Paper condensers in television sets fall into one or two general classes, the ordinary tubular wax-dipped kind, and the plastic-molded kind. The former is identified simply as a paper condenser in parts lists while the latter is identified as a *molded* paper condenser.

The ordinary paper condenser is a general-purpose unit and can be replaced freely with similar standard units. In general, it should be replaced with one of equal or higher voltage rating.

The molded paper condenser is a higher quality unit in that it is sealed against the entry of moisture. It is used in those circuits where low leakage is necessary. Molded condensers should be replaced with molded condensers, never with ordinary paper condensers.

In extremely humid climates, molded paper condensers are recommended as replacements for all tubular condensers.

Electrolytic Condensers. Single-section electrolytic condensers are available to replace almost any similar unit used in television sets. Standard units come in a wide range of both voltage and capacity. As a rule, replacement should have an equal or higher voltage rating and an equal or slightly higher capacity if the exact value is not on hand.

Multiple-section condensers are not as easy to match in standard units although even here it is possible to find suitable substitutes in most cases. Usually, only one of a multiple-section condenser fails and a satisfactory repair can be made with a single-section condenser of equal value to replace only that one section. Single units are available in the form of cardboard-covered units which take little space and which are supported by their own leads.

High-voltage Filter Condensers. This condenser is used to filter the voltage delivered by the high-voltage rectifier so as to provide pure direct current for the cathode-ray tube. One is used in most sets employing a single high-voltage rectifier. Several are generally used in sets having a high-voltage multiplier circuit using two or more rectifier tubes. The typical high-voltage condenser has a rating of 500 mmfd at 15,000 or 20,000 volts.

The one-rectifier, one-condenser circuits are not critical in terms of replacements. Almost any standard condenser offered on the market will serve in this circuit so long as it is mechanically suitable and is rated at least as high as the original. There is no harm and some advantage in using a replacement with a voltage rating higher than the original.

In voltage-multiplying circuits it is safer to duplicate the *capacity* of the original condenser when a replacement is made. This will ensure original performance which may not be obtainable when a condenser of different capacity is used. This point appears to be purely academic, however, since the value of 500 mmfd is a virtual standard for this type of condenser, and one of widely different rating may not be available.

Crystal Diodes. Crystal diodes in television sets can be replaced with standard units which are made by any one of several prominent manufacturers and which are available at radio parts supply houses. The diodes are made in a number of distinctly different types; a defective unit must be replaced with one having similar specifications.

Each manufacturer uses his own system of type designations, consequently, it is necessary to use a cross-reference list if you intend to purchase a new crystal diode whose brand is different from the original. Crystal diode manufacturers have cross-reference tables available to enable you to do this. Your parts supplier should be able to provide one for you.

Speakers. Unless a speaker is quite an expensive one, it does not pay to replace a damaged or defective cone. The cost of a new cone (should it be available) plus the labor to replace it often exceed the cost of a brand-new speaker of the same type.

There are many brands of standard replacement speakers on the market from which to choose a substitute. The primary specifications which should be satisfied are voice-coil impedance and cone diameter. The matter of physical compatibility is seldom a problem because standard mounting dimensions are used by manufacturers for given speaker sizes.

The replacement speaker should be capable of handling the audio power of the television set. The typical set using a single-ended output amplifier delivers about two or three watts of audio power which represents no problem in selecting a substitute. Most speakers will easily handle at least this much power if they employ a cone diameter of 6 inches or more.

If the audio power amplifier is larger than this, or if there is doubt in your mind about the power output, the manufacturer's service manual will specify the power level, especially if the amplifier delivers more than a minimum amount of power. For audio power levels approaching 5 watts and higher, make certain that the rating of the replacement speaker is high enough for the set.

As a general rule, customers are apt to be relatively indifferent to speaker quality or brand when a table model television set is involved. They become more critical and often are extremely critical about the speaker when they own console sets and especially those sets with high-quality audio systems. It is usually better to think in terms of an original replacement in such cases, or at least to offer this choice to your customer.

Expensive speakers are often more economically repaired than replaced. The manufacturer may have a cone-replacement kit available with full instructions as to its use, or he may render the repair service for a fixed fee. The principal disadvantage to the latter is that it generally takes a few weeks to get the speaker back if repairs are not done in a local shop and your customer may simply have to wait for its return. The problem can be solved nicely if you have a speaker of your own which you can lend him in the meantime.

Audio Output Transformers. The replacement of audio output transformers is no different in television than it is in radio. Radio parts suppliers have a wide selection of standard replacement output transformers to replace almost any audio output transformer in a television set.

The requirements are that the transformer suit the circuit (single-ended or push-pull), that its impedance be correct, and that it be capable of handling the audio power.

High-quality output transformers should be used for receivers employing high-quality audio systems. It is wise, in such cases, to consider seriously the use of the original replacement.

Tube Sockets. Most tube sockets used in television sets are standard stock items having a given pin arrangement and one of several standardized mounting configurations. The possible exceptions, as noted earlier, are the sockets used in the tuner unit and the high-voltage rectifier socket.

When selecting a replacement for a defective socket, make certain that the new socket meets these two criteria: the dimension between mounting holes and their relationship to the pin numbers should be the same. To illustrate the latter point, one of the mounting holes of an octal socket may be between pins 1 and 8; the new socket should be the same, otherwise you will either have to drill new holes in the chassis or change the wiring, which is poor practice, at best.

Most octal sockets are made with one mounting hole oriented between pins 1 and 8 (and the other between pins 4 and 5) but it is nevertheless wise to double-check, just to make sure. Similar orientation standards are used for miniature tube sockets but likewise should be checked before you start replacing the socket.

Some of the newer television sets which are manufactured with automatic soldering machinery use special sockets to permit the use of this production technique. These may be available only through the set manufacturer although it is possible that your parts supplier may have some types in standard brands. The same is true of sets using printed circuits, which also call for special sockets.

Selenium Rectifiers. Selenium rectifiers are used in many television sets in place of vacuum-tube rectifiers for providing d-c plate voltage. These rectifiers are standard units and may be freely replaced with units offered out of the general stocks of parts suppliers. The ratings, however, should be observed and duplicated.

The ratings involve two factors, the a-c voltage with which they are intended to be used, and the rectified current which they are required to carry. The voltage rating should be duplicated, while the current rating may be equalled or exceeded.

The voltage rating should be equalled but not exceeded materially because this factor has a great influence on the series resistance represented by a rectifier. A 117-volt a-c unit, for example, would be a poor substitute for a low-voltage rectifier such as might be used to provide vacuum-tube heaters with d-c, even though its current rating be high enough. The probability is that it would provide too little voltage for the circuit.

The current rating, in a practical sense, is determined by the plate area, although the manner of cooling has an influence on that rating. Rather than measuring plate area it is much better to use the set manufacturer's specifications for the part as shown in his parts list.

Ion-trap Magnets. Although ion-trap magnets do not fail of their own accord, they can easily be broken or lost and thus must be replaced. The characteristics of the ion-trap magnet are fixed by the type of cathode-ray tube employed. Standard units are available through parts supply houses.

The proper reference for identifying a suitable replacement is either the specification sheet of the ion-trap magnet manufacturer or the specification sheet of the cathode-ray tube. Each tube calls for a certain kind of magnet, and conversely, each magnet is made to cover specific cathode-ray tube types.

Because this part is only infrequently replaced, there is no need to obtain specification data in advance. Most parts suppliers will provide the correct part if you simply inform them of the type number of the cathode-ray tube with which it is to be used.

QUESTIONS

1. What special precautions should be observed when parts are replaced in a tuner unit?
2. Why is wiring critical in high-voltage circuits?
3. How is corona recognized?
4. How should soldering connections be made in high-voltage circuits?
5. How should soldering be done on printed-circuit boards?
6. What are the advantages of using the original manufacturer's part to replace a defective part?
7. Name five types of parts which are generally replaced by universal replacements.
8. Name five types of parts which are generally replaced with the manufacturer's original part.
9. What rules apply to the ratings of a replacement selenium rectifier?
10. How can you determine what kind of ion-trap magnet a set calls for, or whether none is used, without referring to the service manual?

9

Installing Television Antennas

General Requirements. The principal requisites for good antenna installation are that the installer be handy with tools and be neat in his work, not only in the manner in which he goes about it but also in the appearance of the finished job. Many outdoor installations involve a certain amount of personal risk, but the chance of accident is greatly reduced by proceeding as neatly and deliberately as you can. When you consider the danger, you simply cannot afford to hurry with this work. The chances are that you will work more quickly if you don't concentrate on speed, anyway. So take your time (without wasting it) and do each step of the job in a neat and orderly manner.

Equipment Needed. The requirements for tools and equipment vary to a great degree with the kind of neighborhood in which you work. The equipment required in a neighborhood which is predominantly an apartment-house area, for example, is quite different from that required in a neighborhood which is composed of individual dwellings. There is also a big difference in equipment requirements between areas having strong television signals and areas where fringe reception is required. In the latter case, installation may call for elaborate antennas and masts, whereas the former may be satisfied with the most simple types of installation.

In view of the possible variations in required tools and equipment, it is a good idea for you to find out what the television installers carry in your neighborhood. If you know one well enough, he may advise you as to which tools he considers a waste of money and which ones are most valuable, and perhaps which tools he would like to have instead of those he does have.

Two-way Telephone. It was once common practice for installers to carry a two-way telephone system to permit one man on the roof to talk to another at the television set. Experience has proven in some communities that this equipment is rarely used. This is especially true in rather strong signal areas where good clean reception is the rule, and one-man installation the prevailing practice. In these areas it is usually sufficient simply to direct the antenna in the same general way as the others in the neighborhood without making further tests or changes.

In other areas, especially those calling for elaborate systems because of poor reception, it is common to use teams of two or more men to put up antennas, and a two-way telephone may prove to be a valuable tool.

Some modern television installers prefer to replace the roof man with a temporary antenna rotator. Orientation can then be done carefully, right at the set, after which the rotator is removed and the antenna firmly secured in the final position of adjustment. Once you try this method you may accept none other and you may then include a rotator as part of your installation equipment.

It is with these points in mind that Table 1 is provided. The table is primarily a check list against which you can determine your own particular requirements.

The table is broken into three categories, namely, *Need, May Need,* and *Consider These.* The *Need* items are the ones which you will want in almost any case. The *May Need* items are those which you may or may not need, depending upon the kind of installations which you do. The *Consider These* items are those which you may overlook. They are not essential but are sometimes worth their weight in gold in the extra convenience they offer, in helping to make a better impression, or in making extra profits.

Locating the Set. Before you start actual work, make certain that the television set is located in its final position. Most customers will know where they want the set, especially those to whom television is not new. New owners, however, are often not sure where they want the set and request help in choosing a location.

Make it a point to find out how your customer stands on this matter. Point out that the installation must be done for a specific location; that a last-minute change may require that a new lead-in wire be installed or that further work be done.

To a great extent, the location of the set is a matter of compromising personal taste with common sense. The experience you get simply by ob-

Table 1

Need	*May Need*	*Consider These*
	Hand Tools	
Set of screwdrivers Pliers—gas and long-nose Wire cutters Pocketknife Wrenches—(adjustable or fixed to fit your regular antenna hardware) Tack hammer Flashlight Hacksaw Hand drill and bits Wood drill bits Work gloves (especially for winter)	Electric drill Masonry drills Carpenter's saw and hammer Trowel (for applying roofing cement) Soldering iron of your choice Pipe wrench (for turning antenna masts)	Explosive driver (for driving studs and fasteners into steel or masonry) Taps and tap wrench Dies and stock Vise (probably mounted in vehicle)
	Equipment	
Vehicle (panel truck, station wagon, or private car) Carriers (for ladders, pipe, antennas, masts) Step ladder (for indoor work) Soft shoes (for work on roof) Extension ladder (24 feet or more) Ladder section (12 feet or more)	Special ladders Telephone set with cable Compass (to help in orienting antennas) Extension power cable (for drill, soldering iron, portable light) Mechanic's work light	Mechanic's hand soap and towel Ridge hooks (to suspend ladder on peaked roof) Electrician's snake Rope (for hoisting material and for safety harness when needed) Portable television set (for test purposes, so you don't depend on customer's set) First aid kit (to take care of minor cuts and bruises) Antenna rotator (for test purposes)
	Supplies	
Cabinet touch-up kit (to take care of minor scratches) Transmission line Antennas Antenna mounts Chimney strap Standoff insulators Assorted hardware Tacks (for indoor runs of line) Roofing cement Weatherproofing plastic spray Caulking compound No. 33 Scotch electrical tape	Solder Guy wire Putty (to fill holes you have drilled) Lightning arresters Ground wire (to ground antenna masts) Guy hooks Extension masts Lag bolts Masonry anchors Grounding rods	Boosters (for test purposes; to sell) Wave traps Furniture polish (to use; to sell) Fuses (to use; to sell) Household extension cords (to sell) Antenna rotators (to sell)

serving how other customers locate their sets will equip you to give help to a new owner.

You may, of course, try to influence the location for the simplest and neatest installation. This will usually provide better reception, especially in weak-signal areas. As a matter of fact, the simplicity of location, in terms of short and direct lead-in wires, is usually the number-one consideration where signals are weak. In any case, try to avoid locations which call for very long runs of lead-in.

Room Lighting for Television. The points which you should keep in mind (beyond simplicity of installation) when you are asked for recommendations are *room lighting* and *seating location*. The customer is usually aware of seating requirements although new television owners frequently underestimate the distance from which they can view the picture comfortably.

Room lighting, especially natural daytime lighting, is an important factor in the location of the set. A location which places the set directly in front of windows should be avoided if possible; it places a bright background behind the set and makes the picture difficult to see during daylight hours. A location which permits daylight, and particularly sunlight, to fall directly on or around the set should be avoided. Artificial room lighting is less important, first, because it is less intense than daylight, and second, because it can be altered easily while viewing television.

Room-heating Factors. Do not permit your customer to locate the set directly in front of a heating radiator without warning him of the possibilities. This not only interferes with room heating, but may lead to overheating, and thus to damage of the television set.

Finally, avoid locating the set under or near a heating-system thermostat. This mistake has often been made with the unpleasant result that the heating system fails to operate properly while the television set is running. The reason for this is that the heat rising from the set may cause the thermostat to click off even though the room may require heat.

Selecting Type of Antenna System. The type of antenna system which is in common use in the community should be used as a guide; first, because it indicates in a rough way what the local needs are, and second, because it may represent what your customer expects. To illustrate the point, if simple outdoor antennas are in common use, or if motor-rotated antennas are in common use, you should be prepared to discuss the advantages and disadvantages with your customer since he will undoubtedly look to you for recommendations.

Built-in Antennas. Most television sets are equipped with some form of built-in antenna. The typical built-in antenna is a simple nonadjustable system of wires fastened to the inside of the cabinet. In some areas, this is all that is needed to give good results. In this case, installation consists of little more than plugging the set into a power outlet and turning it on.

Even when a better antenna is contemplated, the built-in antenna is often useful because it may serve as a perfectly satisfactory temporary antenna until such time as it is decided to install a permanent antenna system.

In many cases where outdoor antennas are precluded and the built-in antenna fails to provide satisfactory results, improvement is possible with either a commercial indoor antenna or an attic antenna. This is true because the typical built-in antenna is necessarily a compromise in terms of space, orientation, and geometry and it is rarely adjustable. Good indoor reception is often possible simply by changing from the built-in antenna in the set to a good indoor antenna placed on top of or near the set.

Indoor Antennas. Indoor antennas fall into two general classes; the first is the commercially built type in any of its various forms, while the second is the kind made of ordinary wire tacked to a window frame, molding, or other convenient support.

Either class of antenna can and generally does work better than a built-in antenna because it can be located in a more advantageous position for reception than can be the built-in antenna. In addition, the indoor antenna can be adjusted to the best length for reception, a feature not provided with the typical built-in antenna.

Unless the area offers good, strong, clean signals, the indoor antenna is a compromise and will not perform as well as an outdoor antenna or an attic antenna. In areas having only moderately good signals, the indoor antenna may provide ghosts or snowy signals which might be easily cured with an outdoor installation.

Attic Locations. Although located indoors, an attic antenna is frequently satisfactory. In some cases, customers object to the appearance of outdoor antennas, or the type of building construction makes outside installation extremely difficult. If the signal area is moderately good (say, within 20 miles of the station without intervening hills) attic installations work out extremely well. The signal, however, should be rather strong, otherwise reception may deteriorate seriously when the roof is wet with rain or covered with snow. These possibilities should be pointed out if your customer is not quite sure whether to have an attic antenna or an outdoor antenna installed.

Attic antennas are not necessarily easier to install than outdoor antennas. Frequently they call for *more* work because of the difficulty of running the lead-in line through walls, or because the line must be led outdoors for the vertical drop and then back indoors to the set.

Attic installations should be avoided if the roof is made of metal or is slate-covered or if metal-foil insulation lies between the proposed antenna location and the outdoors.

Rotators. Motor rotators are valuable in locations having several television stations of the fringe-reception variety and particularly so when they are located in different directions. The rotator may also be valuable even though the stations be located in somewhat the same direction, because most television antennas look in different directions in different channels. This is to say that maximum pickup is not always directly from the broadside direction. To illustrate, a given antenna may pick up best on channel 2 when it is broadside to the station, whereas, the best pickup on channel 9 may be obtained when it is turned away, say about 30 degrees.

Fortunately, a rotator is easily added to most outdoor antennas to serve as your roof-top assistant or for customer demonstration on a temporary basis. Most are made to slip onto the existing antenna mast and provide means for using a short section of rotatable mast onto which the antenna can be mounted. The control wires can be dropped temporarily into the house.

It is wise to select a rotator (to offer for sale) with some form of direction indicator rather than one having a simple forward-reverse switch. It is hard to imagine how confusing the latter can be, even to an experienced technician. Chances are that only the most devoted gadgeteers would find it satisfactory. When the rotator has a direction indicator, it is a relatively simple matter to find, initially, the best direction for each station and then to return to that setting when the station is again tuned in.

Surveying Your Neighborhood. When it comes right down to selecting exactly which antenna to use you will get the most help from three sources in combination. These are your own observations, the recommendations of other, friendly local television servicemen, and the recommendations of your local parts supplier.

Your own observations should consist of inspecting the neighborhood and observing visually the types of antennas in common use. This will give you a pretty clear picture of the kinds of antennas which are in practical use, and which you can assume are performing satisfactorily.

The chances are that a friendly local serviceman will be able to do no better than you can do with simple observation, but he may be able to provide some practical tips including the names of the parts suppliers through whom you can get the best buys.

The recommendations of parts suppliers are usually good, partly because they know what types of antennas are most popular and partly because they are anxious to keep doing business with you and cannot afford to give poor advice. You will have to use your judgment, however, to decide whether or not your supplier is really capable of giving advice and is interested in your installation problems.

Installing Antenna Systems. Once the decisions as to the location of the set and the type of antenna system have been made, you can go ahead with the work of erecting the antenna, running the line, and connecting it to the set. Information about this work is given later in this chapter.

In the course of the work you must not only observe some common-sense rules with regard to personal safety, but also those relating to the care of your customer's property. Often the latter are overlooked, or appear to be overlooked, by servicemen, with the result that the customer is annoyed and is reluctant to do business with the same man again.

Ladders. Ladders leaned against shingle siding, and especially one of asbestos shingles, can break or crack shingles if handled carelessly. It is better to rest the ladder against a horizontal structural member if one is handy.

A much better plan is to fasten a flat-surfaced plate to the top of the ladder so that the pressure is distributed over a wide area rather than being concentrated at the ends of the ladder rails. The plate should be covered with a soft, clean pad to prevent scratching, marring, or staining the walls. An alternative is to mount two separate flat, padded pressure plates at the ends of the ladder rails, or simply to pad thickly the ends of the rails themselves.

Commercially produced ladder-resting plates are available in some hardware stores.

Care of Roof. Do not wear hard street shoes when working on a peaked roof. Not only is this dangerous, but you stand the chance of marring or even damaging the roof shingles. Rubber-soled shoes or, better yet, soft sneakers should be used. It might even be wise to let your customer know (if you can do this gracefully) that you will wear special shoes while working on his roof. Often you won't have to look for an opportunity; your customer may insist in advance that you be careful of the roof.

Care of Garden. If you do not happen to be a gardener yourself, it is easy to take a lawn and garden for granted. Not so with a gardener; he knows how much toil, care, and outright expense often go into the landscaping of private homes. To some home owners, every blade of grass, every plant, is precious.

It is most important, therefore, to take extreme care in your customer's garden. Do not set up ladders in flower beds if you can possibly avoid it. If you cannot, call this to your customer's attention and ask his advice as to where best to place it.

Be especially careful to avoid dragging wire through or dropping tools and equipment into flower beds.

If you stand a ladder on the lawn, try not to tear it. It may not be possible to avoid making depressions but it should be possible to avoid dragging the ladder through the grass. By the same token, be careful if you must assemble the antenna equipment on the lawn. If you can, do this on a sidewalk or driveway.

General Cleanliness. During the course of antenna installation and especially if you have worked on a sooty chimney, your hands may get very dirty. It is then particularly important to be careful of what you touch. Try not to lean against light-colored walls, inside or outside the home, and keep your hands off doors. If you slip up and leave an ugly handprint somewhere, clean it up.

It may be necessary to walk in and out of the house several times during installation work. Make it a rule to wipe off your feet, even if you have to supply your own rag, if there is any chance of dragging dirt into the house.

Clean up carefully when you're through. Don't leave paper, packing cartons, bits of wire, or other refuse either on the roof or on the grounds. If you can't find a refuse container, put the refuse in your vehicle and dispose of it later.

Demonstrate the Set. When you are finished with the antenna work, try out the set, first to make certain that you are satisfied, then for the benefit of your customer.

If the customer is a new television owner, you will no doubt be called upon to explain the operation of the set. Unless you are familiar with the set, your best bet is to read through the owner's instruction leaflet along with him, interpreting and demonstrating as you go along. Frequently, new television owners fail to grasp the first explanation fully and are not really ready to absorb instructions until they have tried to use the set for a few days. If you can work it out, offer to return in a few days to explain the set again, perhaps when other members of the family will be home.

Collect Your Bill. When you are ready to leave, collect your money. It is good practice to make out a bill on a printed form on which you list what you have done and provided, with the itemized charges for each. This makes bill collecting easier, smoother, and more businesslike.

If you have done the job on a flat-rate basis, there is no need to itemize the work. If it is on a time-and-material basis, list these items in reasonable detail. List, as separate items, the antenna, the antenna mount, the hardware, and the transmission line. As a rule, the latter is listed as so-many-feet at so-much-per-foot. List your labor as a single item. List separately any extra items which you may have sold to the customer (fuses, extension cords, etc.).

The above are suggestions and reminders rather than ironbound rules; you may have good reason to make out your bills differently. If you have, go to it, but make certain that your customer is satisfied with the information which you provide. The typical customer is hardly impressed favorably with a bill which states simply "Antenna installation – X dollars" unless it is a flat-rate proposition. In this case a statement such as "Antenna installed per flat-rate price – X dollars" would probably serve better.

Encourage Additional Business. Before you leave, let the customer know about the other service work you do and how he can contact you again. You should at least leave a card with him and perhaps attach one to the back of his set. Point it out to him so that he will know where to find it.

If you have done your work neatly and efficiently and have left a favorable personal impression, you stand a good bet to hear from him again or from one of his acquaintances.

Outdoor VHF Antennas. There are perhaps hundreds of kinds of vhf antennas available, enough to prove quite confusing to a beginner. The wide variety, however, is due primarily to the large number of manufacturers rather than to the needs of installers. To illustrate the point, two basic antennas such as shown in Fig. 1*A* and 1*B* can serve almost every need you will face, in an area having several vhf channels.

The examples were selected because they include a relatively simple antenna (Fig. 1*A*) for moderate-to-strong signal areas and a two-bay unit consisting of two such antennas stacked into a single unit (Fig. 1*B*) for weak-to-moderate signal areas.

The first antenna can be used in the strongest signal areas while the second can be used in the fringe areas. In the latter case, it becomes more important to get good antenna height and accurate orientation than to try more elaborate antennas. In intermediate signal areas (say 30 to 40 miles over average terrain and with moderate station power) either antenna may be used, the simpler one with greater height to compensate for its lower sensitivity.

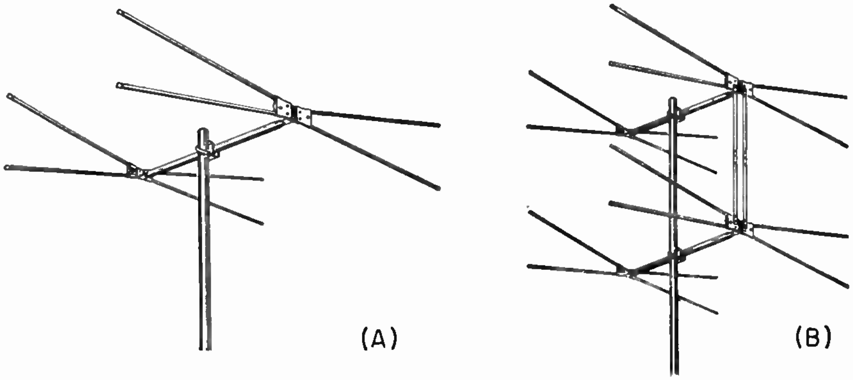


Fig. 1. Two basic antennas for vhf work. A shows a single-bay unit for moderate to strong signals. *B* shows a stacked two-bay unit for weak to moderate signals

These principles apply in general, no matter what particular make of modern vhf antenna you select for use. This is to say that you can meet all normal requirements with two basic antennas, one a single-bay unit and the other a two-bay version of the same antenna.

Stacked Arrays. The two-bay antenna may be spaced at either ¼ wave as shown in Fig. 1*B* or ½ wave. The ¼-wave unit is wider than it is high, being spaced by roughly *half the length of the span* of the antenna elements. The ½-wave unit appears to be roughly a cube in shape, being spaced by the *full length* of the antenna elements. As might be expected, the ½-wave unit provides more pickup than the ¼-wave unit so that you really have *three* basic types at your disposal if your supplier offers a choice of ¼- or ½-wave spacing.

It may be convenient to think of the basic antenna as having a sensitivity of 1, of the ¼-wave stacked array as having a sensitivity of 1½, and of the ½-wave stacked array as having a sensitivity of 2. Thus, you can think of the first as a strong-signal antenna, the second as an intermediate-signal antenna, and the last as a weak-signal antenna.

In between, you have considerable leeway because of the additional effect of height. The simple antenna on a 15-foot mast, for example, may perform better than the ¼-wave stacked unit on a 5-foot mast under certain conditions.

Single-channel Yagi Antennas. The preceding comments apply to *multichannel* reception and the antennas illustrated are typical of multichannel units. Prevailing practice differs somewhat in areas having only a single television channel in service. In these areas, advantage can be taken of the fact that the antenna need not provide reception at all vhf frequencies by using single-channel antennas designed for a specific channel. The common form of this antenna is the Yagi shown in Fig. 2. It provides much greater gain for one channel at the sacrifice of the others, and thus permits better reception where weak signals are a problem. The antenna is also much more directional and requires a corresponding increase in accuracy of orientation.

Fig. 2. A typical single-bay Yagi antenna having five elements

Single-channel Yagi antennas for use in weaker-signal areas are available as single-bay units with more elements, or as stacked units.

In some multichannel fringe areas where signals are especially weak, separate single-channel Yagis are frequently used for each channel. Obviously this is most practical when no more than two or three channels are involved.

Local Practice is Best Guide. There are really no hard and fast rules which can be expressed, as nice as it would be to have a chart showing distance, antenna height, station power, and *type* of antenna. Television sets themselves are widely different in terms of sensitivity and noise level. Transmitting-antenna elevation, nature of intervening country, and location of objects in the immediate vicinity of the receiver all have a major influence on results to a degree which would make a chart useless. That is why you should use prevailing local practice as your most important guide to what kind of antennas you use.

In any case, you will be able to limit your stock to the basic antenna and its stacked variations such as were described. If you work in a fairly compact area of almost uniform characteristics (a single town, for example) you will probably find that one antenna will do, using different mast heights to take care of individual problems.

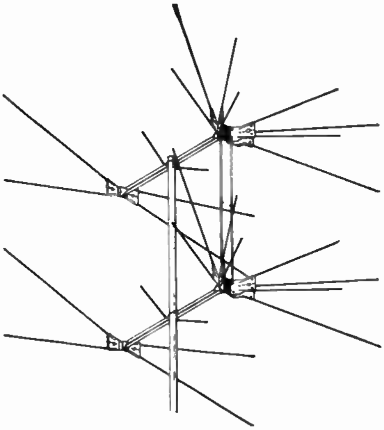


Fig. 3. A stacked two-bay antenna designed for uhf and vhf reception

To illustrate the possibilities, you may install an antenna initially on a 6-foot mast and note the quality of reception. If it is too weak to be satisfactory, the problem may be solved simply by using a 15-foot mast.

Antenna Price. The real area of difference in standard antennas is in the quality of workmanship and materials and in the ease of assembly. It is on these points that you will have to make your buying decisions.

An inexpensive antenna will probably work just as well as an expensive unit, especially when the two are similar in geometry. The cheaper unit, however, may not withstand wind strains so well and may corrode seriously in a short time.

The matter of assembly is entirely one of personal preference. Some antennas take appreciably more time to assemble than their snap-into-shape competitors but may provide a more rugged job, or may permit more flexibility in making up stacked combinations.

It is probably wisest to stick to recognized brand names when you start, unless you have some reliable advice or proof of satisfaction with unknown products. This is where an experienced, friendly serviceman can be most helpful. He can tell you what his experiences are with locally available products.

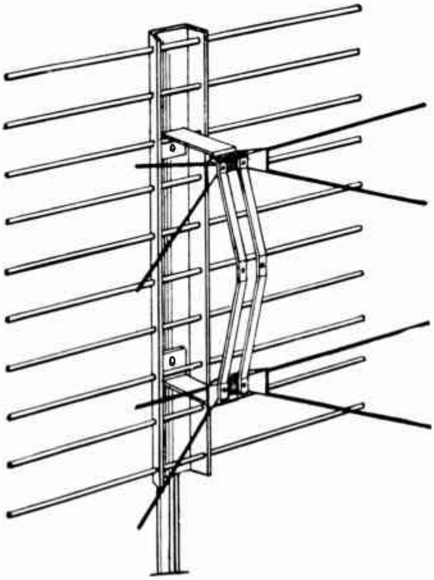


Fig. 4. A two-bay uhf antenna using a sheet reflector

Outdoor UHF Antennas. Standard vhf antennas are virtually useless for uhf reception. When both types of reception are desired, two separate antenna systems are frequently employed, although combined vhf-uhf antennas such as that illustrated in Fig. 3 are available.

The most striking difference between uhf and vhf antennas is in the physical size. Because of the much higher frequencies employed in uhf, the antennas are much smaller.

The small physical size of the antennas permits greater flexibility in design; there are many variations available on the market. One of the principal features in many uhf antennas is the use of some form of sheet reflector, such as that shown in Fig. 4, rather than a parasitic element (as vhf reflectors are called), a feature not employed in vhf because of the outlandish size of an appropriate sheet. In addition, uhf antenna elements are sometimes made of sheet material rather than rods, and fashioned into unusual geometric patterns. An example is the bow-tie antenna illustrated in Fig. 5.

Most uhf antennas are available in single-bay and multiple-bay arrays to take care of different field requirements. The simpler antennas are used where stronger signals are available while the more complex arrays are used for weaker-signal areas.

Blanket recommendations for the use of combined uhf-vhf antennas or for the use of specific uhf antennas under different field conditions cannot be made easily in practical terms. Any serious attempt is apt to be more confusing than helpful. Uhf signals are so different in terms of power and propagation characteristics and uhf receivers differ so widely in performance that general rules cannot be laid down.

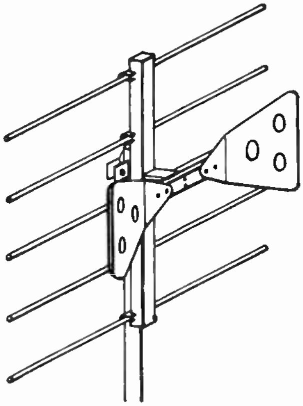


Fig. 5. A bow-tie uhf antenna with sheet reflector

This means that you may have to experiment with available antennas or lean heavily on your observations of prevailing practice in your neighborhood. The recommendations of local servicemen with uhf experience or of antenna suppliers should also be solicited.

Height Is Critical for UHF. Whatever form of uhf antenna you choose to use, it is recommended strongly that it be so made that its height is easily adjusted on the mast. The reason is that reception is usually quite sensitive to changes in height. The greatest height (within limits) does not necessarily provide the strongest signal. By sliding the antenna up and down, a hot spot can often be found and it should be deliberately sought in each installation.

Several commercial types of uhf antennas are shown in Figs. 4 through 6. Any of these would be satisfactory for use in strong uhf signal areas. The two-bay antennas may perform well in fringe areas if greater care is taken in the installation. More elaborate, high-gain uhf antennas are made especially for weak-signal reception.

Indoor Antennas. When thinking in terms of all-around *performance* there is little basis for selecting one type of indoor antenna over another. In other words, their general performance is roughly the same. Selection is ordinarily based on appearance, special features, price, or availability.

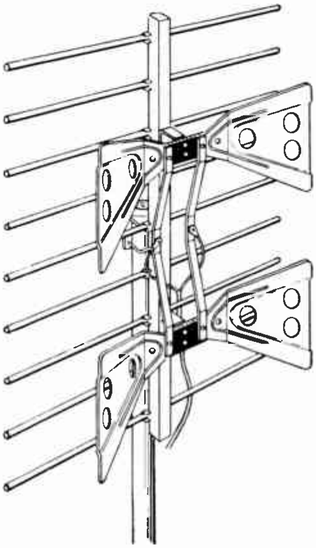


Fig. 6. A stacked bow-tie uhf antenna with sheet reflector

Because indoor antennas are limited to use in strong-signal areas, antenna sensitivity is not particularly important. The trick is to find the best position for the antenna which provides the strongest and most ghost-free reception. Often this calls for a great deal of experimenting.

Lines for Indoor Antennas. Most indoor antennas come equipped with a length of transmission line, usually about 6 or 8 feet. Installation should be made with this line, without adding any more if at all possible. The reason is that indoor antennas are used in strong television signal areas and, under these conditions, the line itself may pick up a fair amount of signal. When the line is short, this is not much of a problem; when the line is lengthened it may pick up more signal than the antenna itself.

Thus, it is almost useless to try moving the antenna about to find a good spot because most of the signal is picked up by the line.

Line pickup is especially severe if the line runs horizontally for any appreciable distance. There is much less pickup on vertical runs. As a matter of fact, the line can usually be extended considerably if the run is almost entirely vertical. This might be done in the case where the antenna is located in a room directly above the television set, and the line is run almost straight up to that room. This situation, however, is seldom found in practice.

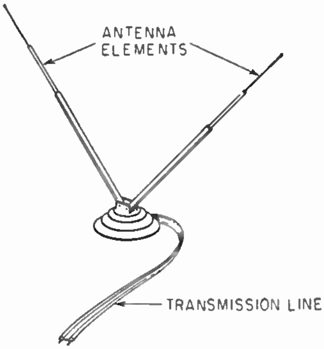


Fig. 7. A simple indoor antenna

Locating an Indoor Antenna. Most indoor antenna problems boil down to the search for an antenna location within about 6 feet of the set—a location which provides a good, clean signal and a suitable support for the antenna. A table, shelf, or the set itself can serve the purpose since most indoor antennas are designed to stand on a flat surface.

In each of the trial locations, the antenna is rotated and adjusted by whatever means the antenna provides. Rabbit-ear antennas like the one shown in Fig. 7 permit the length of the arms to be changed and their angle altered. Some antennas provide tuning condensers built into the base or have other variable elements.

In especially tough areas, it is a good idea to have two or more types of antennas because, often, one type will work better than another. The antennas should be basically different in the kinds of adjustments they provide so as to give you the advantage of as many combinations as possible. That increases your chances of finding one combination which produces good results.

Boiling these facts down, indoor installations are commonly cut-and-try propositions, not only in what kind of antenna you use but also in where you place it and how you adjust it. Even an experienced television engineer will find it difficult, if at all possible, to predict in advance what the best answer will be in any given case. He too will have to cut and try.

Antenna Appearance. One of the major considerations in your selection of indoor antennas is appearance. Since the antenna often occupies a prominent position in the room, there is an advantage in using the most attractive or the most inconspicuous design. Women particularly seem to object to bulky or awkward antennas.

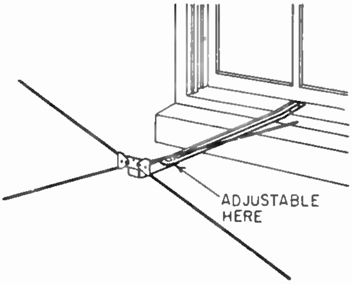


Fig. 8. A window antenna

Attic Installations. Although attic antennas can be classed as indoor installations, *outdoor* antennas are usually employed in attics. Standard outdoor antennas outperform most indoor antennas; attics generally have sufficient room for them and do not make any demands so far as appearance is concerned.

Window antennas like the one illustrated in Fig. 8 are superior to indoor antennas, especially in steel buildings.

Selecting Transmission Lines. The three basic types of transmission lines shown in Fig. 9 will satisfy almost all normal television requirements. The types are: 300-ohm ribbon line, 300-ohm tubular line, and 73-ohm coaxial line (type RG59U). Chances are that you will not need all three.

Each type of line is designed for a specific purpose or offers special advantages. These are described in the following paragraphs to permit you to determine the kinds of line you will need.

Ribbon Line. This is the general-purpose line used in the majority of television installations. It is a 300-ohm balanced line. All standard television receivers provide antenna connections which match the characteristics of this line.

To be more specific, the line is recommended for use in installations which meet *all* of these conditions:

1. General vhf reception.
2. Uhf reception of strong uhf stations.
3. Outdoor runs will be able to be mounted in the clear of other wires, walls, beams (especially metal), and pipes. Clearance of 4 or more inches is satisfactory.
4. Outdoor runs will be able to be held fairly taut by means of suitable standoff supports.
5. Indoor runs will be able to be located clear of other metal objects—will be run along wooden molding, for example.

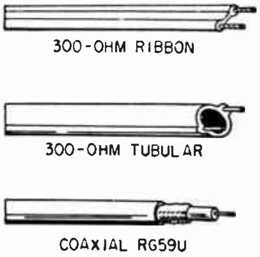


Fig. 9. Three basic types of transmission line

The line is *not* satisfactory if *any* of these conditions prevail:

1. Uhf reception of weak signals is desired.
2. Outdoor runs of line must be bunched with other wires (often the case in large apartment buildings).
3. Outdoor runs must be secured directly against walls, pipes, or other structures.
4. Long outdoor runs cannot be mounted securely and may sway against walls, pipes, or the like. (Long, swaying runs through relatively *free* space are O.K.).
5. Line must be run through metal ducts.
6. Indoor runs must run against metal molding.
7. The indoor run is extremely long in a commercial building within which interference-generating equipment is located (i.e., brush-type motors, elevators, extensive neon lighting or sparking devices).

From the above you can see that the 300-ohm ribbon line is well suited for most vhf installations in private homes and in moderate-size apartment dwellings. It may also serve quite well in many commercial installations (restaurants, professional offices, stores, etc.) in fairly small and uncongested buildings where the building owner places a minimum of restriction on how the line can be installed. The most important single requirement is that it be permissible to install the outside run *all by itself* and to support it a few inches away from the outside wall (supported by standoff insulators).

The line should be avoided on installations in tall buildings when the line must drop more than 10 floors or so or when several hundred feet of inside runs are needed. The principal reason for this is that such long runs become a problem in that they tend to pick up a great deal of interference and unwanted signals which often swamp out the otherwise clean signals picked up by the antenna.

Tubular 300-ohm Line. Low-loss characteristics are especially needed for uhf work because losses with any type of line are much greater in the uhf range than they are in vhf. It is the wet loss which is considered important in outside installation work. Ordinary 300-ohm ribbon has low losses when it is dry but these losses rise greatly when the line becomes wet.

The conditions under which the 300-ohm *tubular* line can be used are identical with those outlined above for 300-ohm ribbon line, but they must be more rigidly observed for uhf reception. The installer must be absolutely certain that he can keep the line clear of all outside surfaces and clear of all metal objects (again, 4 or more inches is generally satisfactory).

This line is often used for vhf reception in fringe areas because of its lower wet losses. This is good practice, especially when long outside runs are used. The losses of such runs, even at vhf frequencies, can increase to intolerable levels when the line gets wet, if the signals are quite weak to begin with.

Low-loss 300-ohm lines suitable for uhf use are manufactured in a variety of forms such as: tubular line, perforated ribbon line, and open-wire line. The last is essentially a line made with two parallel exposed wires, supported at intervals by means of low-loss spacers. It is probably the best in terms of electrical characteristics but may be the most difficult to handle. The tubular line is most popular.

Coaxial Line. This type of line is similar in general construction to ordinary shielded wire with these important differences: The insulation material around the inside conductor is a low-loss material such as polyethylene; and the outer metallic shield is covered with an external insulating jacket.

The most popular type of coaxial line is known by the designation RG59U. It is a little under ¼ inch in diameter and is thus easily concealed. The impedance of this line is 73 ohms. It is classed as an unbalanced line in that it has only one hot conductor rather than the pair of conductors used in the ribbon and tubular line.

Matching to Coax. Many television receivers provide connections for unbalanced or coaxial transmission line connections. Each set with this provision will include information in its installation instructions as to the manner of connecting 73-ohm coaxial line. Matching transformers which will match coaxial line to 300-ohm antenna terminals are available through radio parts suppliers. They can be used with any set.

When to Use Coax. The conditions under which coaxial line is recommended are almost the reverse of those listed above for the use of 300-ohm ribbon except that the coaxial line is also restricted in general use to vhf reception. It is quite poor for uhf work, unless the signal is strong and the transmission line is quite short.

To be more specific, coaxial line is recommended when these conditions prevail:

1. Vhf reception of moderate to strong signals is desired.
2. The length of transmission line is unusually long, say more than 200 feet, and it must be run against outside walls or must be bunched with other wires, or must run through metal ducts.
3. Indoor runs are against metal beams or molding.
4. Long outdoor runs are free to sway against walls, pipes, or the like.
5. Installation is in a large commercial building, in which there are noise-generating electrical devices.

The popular RG59U coaxial line is not well suited for weak signal areas because of its relatively high losses. Its losses are appreciably higher than those of 300-ohm ribbon, making it even less suitable for uhf reception.

Larger Coax. There are better coaxial cables than the type RG59U but they are larger and quite expensive. The type RG8U, for example, is about ½ inch in diameter and has losses about equal to 300-ohm ribbon in the vhf range. It may, nevertheless, be the best answer to a fringe reception problem in a building where there is no choice but to use coaxial cable.

The generalization can be made that coaxial cable is rarely used in private homes or small apartment buildings and that it is the usual choice in commercial buildings or large apartment houses.

Planning the Antenna Location. In the average private home, the best location for the antenna depends upon where the the television set is located and on how the line can be led from the outside to the inside. To illustrate the point, it is unwise to install the antenna on the chimney if it is at the opposite end of the house from the television set, unless the most practical lead-through point is also at that end of the house. The ideal situation is to locate the antenna at the highest practical point directly above the set and to run the line into the house at some point near the set.

Ideal conditions, of course, rarely prevail and compromises are usually needed. It is therefore essential that you plan the general route of the transmission line before you pick the location for the antenna. You should use, as your guide, the information given later relative to the running of the transmission line. Once you have done this you will be ready to look for a suitable antenna position.

Point of Entry for Line. The real key as to the best antenna location is the point you select for *entry* of the transmission line into the house; the ideal condition is to locate the antenna directly above that point. If the television set is near the center of a fairly small house, the most practical approach is to mount the antenna at either end, whichever offers a more convenient installation.

Use End Mounts if Possible. End mounts are easier to install than a mount designed to be fastened directly to the roof surface, although the latter should be used if it offers a distinct advantage in reception. An example of such an advantage might be found in a rather long house where the television set is near the center, and the signals are weak enough in the area to make it unwise to use any more transmission line than is absolutely necessary. In this case the best solution might be to install the antenna with a peak mount near the center of the house.

With most private home installations the question usually boils down to which *end* of the house shall be used for the location of the antenna. Many private homes, however, offer even more convenient possibilities. They may have one or more dormers on the roof, or a central chimney, or other structure which offers convenient antenna-mounting possibilities. You then have more chances to find a good location nearer to the point at which you have decided to run the line into the house.

Types of Mounts. Antenna-mounting assemblies are available for chimney mounting, vertical-wall mounting (just below roof level), standpipe mounting, and roof surface mounting (horizontal or sloped). Some of the more common assemblies are shown in Fig. 10.

Chimney mounts and vertical-wall mounts are usually adjustable in the spacing of the supporting brackets. If this spacing can be set at from 1 to 2 feet, adequate support should be possible for a simple television antenna on an unguyed mast of up to about 10 feet in height. The other forms of mounts should not be expected to support more than a 5- or 6-foot mast without guys unless they are extraordinarily rugged, are installed with great care, and are fastened to an especially secure support.

Most standpipes are not secure enough to warrant the practice of any self-supporting masts. The roofing of most small homes is likewise not rugged enough to support a taller unguyed mast by means of a base mount fastened to the roofing.

Use of Guy Wires. When selecting a location it is better to avoid a condition which would require guy wires unless you have no choice in the matter. Guy wires, at best, are unsightly and sometimes are a hazard. (People can trip over them.) If you restrict the antenna height to the approximate dimensions given above, you will not need guy wires.

In fringe areas, conditions may require taller masts (say 15 feet or more) in which case you should immediately plan on the use of guy wires. Then it is essential that you choose an antenna location which allows for the securing of guys in three equally spaced directions. This usually calls for placing the antenna nearer the center of the roof.

Apartment-house Problems. There is usually much less freedom of choice in locating an antenna on the roof of an apartment house or commercial building. Often the problem boils down simply to finding an available spot, whether or not it permits the most direct path for the transmission line. If you are lucky you may find an available location which also offers a good path for the line.

In the typical apartment house of brick construction, antenna location is normally restricted to the parapet along the edge of the roof. In commercial buildings there is little standardization of practice. In either case, it is advisable to make certain that your customer has permission to install the antenna and to get the owner's advice as to where you can install it if there might be any question as to the acceptability of your decision.

Installing Chimney Mounts. A typical chimney mount is shown in Fig. 10A. It is composed of two bracket assemblies with individual metal straps for securing them to the chimney. The brackets can be made to extend outward from any corner of the chimney.

Before you make the final decision to use a chimney mount, make certain that the chimney is in good condition. If the mortar is deteriorating so that some of the bricks are loose, it might be wise to avoid using the chimney. This condition, however, is found only in old buildings.

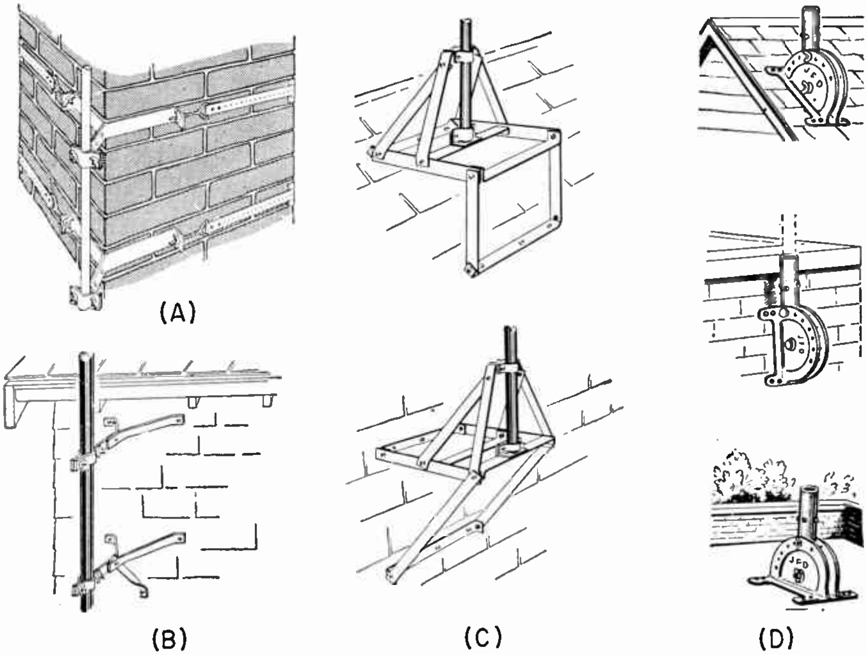


Fig. 10. Four types of antenna mounts. Types A and B are the most widely used

There is a real trick to installing many of the chimney mounts on the market. It involves those mounts which use flat metal straps to pass around the chimney (rather than flexible material). The trick is in bending the strap so that it fits snugly around the chimney, an essential to a long-lasting and solid installation.

Little more can be said but that the corners should be bent accurately to get a good fit; experience will show you the quickest way to do this. It is not a difficult problem when you can walk around the chimney, but this is not possible with outside chimneys. The job can be done by one man, and quite easily once you get the hang of it, but you will have to take your time at first to make sure that your bends are as accurate as possible.

Accurate bending is important because it will permit you to get the strap level all the way around the chimney. If you use metal corner guards (shown with the chimney mount in Fig. 10*A*) the strap will be able to slip through them as you tighten the take-up bolts. This will result in a good tight job. The strap should pass around the bricks rather than along the mortar.

The two bracket assembles should be spaced from 1 to 2 feet apart depending upon how high a mast you intend to use. One-foot spacing should serve well for a mast of about 5 or 6 feet. Two-foot spacing should be satisfactory for a 10-foot mast.

Make certain first that the brackets are in good vertical alignment with each other so that they will hold the antenna straight and true. Then loosen the mast clamps enough to permit the antenna mast to be slipped into place without interference.

Installing Wall Mounts. A typical wall mount is shown in Fig. 10*B*. This mount is in popular use on both private dwellings and on apartment and commercial buildings.

The most common application on private dwellings is to support an antenna mast from the outside wall of a peaked-roof house, just below the peak, so that the antenna extends upward and into the clear above the peak of the roof.

The most common application on apartment buildings is to support the antenna mast from the inside surface of the parapet running around the edge of the roof.

On commercial buildings, the wall mount is used on almost any vertical surface to which it can be attached and which permits the antenna to extend into the clear.

Mounting the wall bracket is a straightforward job of securing it to the wall either with sturdy wood screws or bolts. There are some practices, however, which should be observed and which will help make the job easier and more workmanlike.

When attaching the mount to a shingle-surfaced wall, and especially one covered with asbestos shingles, you must be especially careful to avoid cracking the shingles. This requires not only that you drill holes of good clearance through the shingles but that you try to pick a mounting spot which is solid. The best place is where the shingles overlap so that the screws pass through both shingles. If you use a spot between the overlaps, more or less in the center of the shingle, it is apt to crack as the mount is pulled up snugly to the wall.

Use nonrusting screws on private-dwelling installations. Unplated steel screws may cause ugly rust streaks down the side of the house in a short period of time.

After the mount is in place, seal the edges of the bracket and the screwhead with either a white caulking compound or black roofing cement, whichever is less conspicuous against the color of the wall. This will prevent leaks through the shingles and into the wall.

As in the case of the chimney bracket, use enough spacing between both bracket sections to provide good mechanical support for the mast.

The wall mount is secured to brick walls by means of lead anchors and lag screws. This requires that you drill holes in the brick with a star drill or power-driven masonry drill of proper size to match the lead anchors. Lead anchors with a ½-inch outside diameter are satisfactory for most installations.

After the mount is secured, cover the bolt and adjacent areas of the bracket with black roofing cement to prevent the entry of moisture and thus to reduce the chances of corrosion.

The method of securing the wall mount to other walls depends primarily on the material of which it is constructed. In any event, always use roofing cement to seal the job against leaks and corrosion.

Installing Roof Mounts. Typical roof mounts are shown in Fig. 10C and *D*. The more popular types (because of their universal design) are adjustable to match almost any slope between vertical and horizontal. This type of mount, when located near the ridge of the roof, serves the purposes of a ridge mount. Mounts designed especially for ridge installation are available but are not as popular as the slope-mount type because of their limited application.

It is absolutely essential to seal all screws, holes, and edges of the roof mount with roofing cement, otherwise leaks may develop.

Assembling the Antenna. The antenna may be assembled on the ground or on the roof, or part of the job may be done in each place, depending upon how complex the assembly is and how convenient it is to work on the roof. The antenna manufacturer's instructions for assembly should be followed.

The transmission line should be connected to the antenna as part of the assembly job, before the antenna is erected. The recommended techniques for making these connections are described later in this chapter.

All connections and assembly screws should be firmly tightened to ensure a long-lasting, quality job. If you wish, you may spray the connections and assembly screws with one of the commercial insulating sprays made especially for television work. This will normally add to the life of the installation, especially in ocean beach areas or where corrosive atmosphere is present. Because the fumes of heating systems are often corrosive, the use of the spray is a wise precaution on chimney installations.

As a final step of assembly, secure the uppermost transmission line standoff insulator to the mast and clamp the line firmly into it. This will save you the work and avoid any risk in installing the standoff after the antenna is erected. Then coil up the line or dress it properly so that it will not constitute a working hazard or interfere with the erection of the antenna.

Erecting the Antenna. Lift the antenna carefully and insert it into its mounting assembly and tighten the brackets enough to hold the antenna in place. Do not tighten the mount permanently until after the antenna is properly oriented.

If you are in an area with moderately strong signals, careful orientation may not be necessary. It may be enough simply to direct the antenna the same way as others in the neighborhood. If you have reason to believe that this has a good chance of working out, tighten the mount permanently after you have oriented the antenna as carefully as you can by eye. Later, when you check performance of the receiver you may find that the results are as good as you could reasonably expect. If this is the case, there is no need to make another trip to the roof.

In some areas, careful orientation is needed to get good results. This may be required, not only to get the strongest signals, but sometimes to get rid of ghosts. The job of final orientation is done after the installation is completed, preferably with the help of an observer at the set, or with a temporary antenna rotator, controlled at the set.

Looking Ahead. Before you proceed to the next step in the installation, take a few moments to ponder the possibilities of future antenna damage. High winds, ice-loading, or corrosion may, at some future date, cause failure of the mount. The antenna may be located so as to constitute a danger in such an event, particularly on commercial buildings, where the antenna might be located above a public sidewalk.

If a potential hazard exists, it is wise to connect some form of safety wire to hold the mast should the mount come loose. A length of ordinary guy wire will serve the purpose. One end should be firmly wrapped around a chimney, pipe, or other fixed object; the other end should be securely attached to the antenna mast. The wire should be slack so as to free it of strain. The slack part can be tacked or taped so as to keep it flush to the roof or other surfaces, to keep it from becoming a tripping hazard.

The chances are good that the safety wire, being free of strain, will remain in good condition for a long time, and will be able to hold the antenna and mast on the roof should the antenna mounting break or come loose. It should be able to hold it long enough for someone to take care of the hazard before serious harm is done.

Installing the Transmission Line. All transmission lines except the coaxial types must be so installed that the outdoor runs are in the clear. The line should be spaced away from walls and other physical objects, especially those made of metal. A clearance of 4 or more inches is desirable although 2 to 3 inches is commonly used in practice and works out well in most cases. In uhf work, however, it is advisable to stick to the 4-inch *minimum* although 6 inches is to be preferred. If two or more antennas are used, each with its own line, each of the lines should be run *separately*.

Antenna Hardware. A wide variety of insulating supports on standoffs are made to meet the above requirements. Some common types are shown in Fig. 11. The black inserts within the loops of the supports are made of pliable insulating material and are molded to fit standard transmission lines.

The supports come in various lengths from about 2 inches to 12 inches. This range satisfies almost all ordinary needs. The longer lengths are useful in guiding the line around gutters, eaves, and other obstacles; the shorter ones for straight runs over smooth surfaces.

There is also a wide range in fastening styles. The end may have woodscrew threads, machine-screw threads, or the support may be fashioned to resemble a square cut nail with integral head, for driving into mortar.

There are also variations of the support for clamping onto round masts. Some have strong spring clips which are simply snapped onto the mast; others have wrap-around clamps and still others use U clamps with a thumbscrew to secure the assembly to the mast or structural members of a building.

It is a good idea to stock most of the popular types so that you will be able to meet a variety of installation problems.

Fastening Hardware on Brick Walls. Insulating supports, by and large, are ordinary hardware and are handled with ordinary techniques and tools.

One of the situations, however, which often proves to be frustrating to installation men, is the mounting of insulating supports on brick-and-mortar walls. Nail-in supports frequently go in well, but not always. At times the mortar is so soft that it is impossible to get a rigid support; in other cases, the mortar is so hard that support after support is bent in the attempt to drive it in, without success.

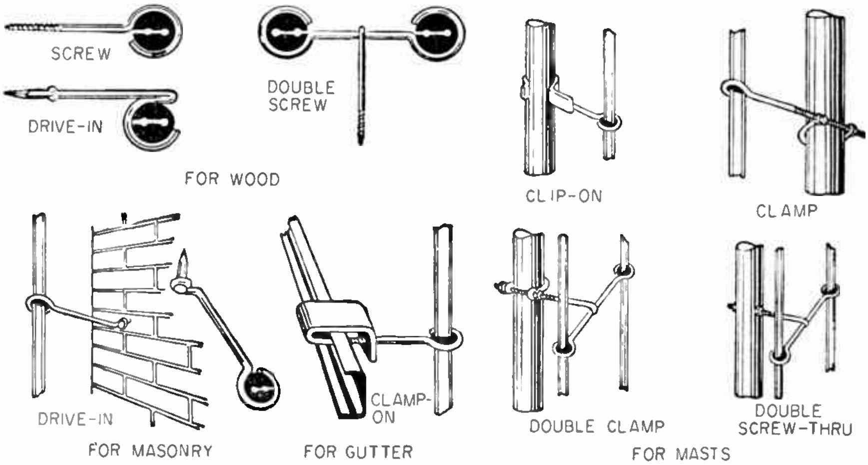


Fig. 11. Types of standoff insulators available. The double units are useful for installations using two antennas

Mortar installation, however, can be fairly easy to do and the final job can be something to point to with pride if you have the proper tools and know how to use them. This kind of a job can be done by drilling small holes in the mortar, inserting standard fiber sleeves, and using an insulator support having a wood-screw thread.

The holes are easier to drill than might be expected since they need be little more than ⅛ inch in diameter and about 1 inch deep. The holes may be drilled with a Rawl drill in a Rawl drill holder which is hammered much like a star drill. In most types of mortar, the hole can be drilled in much less than a minute, often in 10 or 20 seconds.

If you run into mortar which is so soft as to serve as a poor anchorage, the holes may be drilled directly into the brick. In all cases, and especially with brick, the drill should be rotated between hammer strokes to prevent binding, and to form a clean round hole.

Use of Rawl Plugs. A "Rawl plug" is inserted into the hole. The plug is a rolled fiber device with a tiny hole through its center. The woodscrew thread is turned into this hole, expanding the plug. The result is a rigid, workmanlike job which will last for a long time, especially if it is sealed with caulking compound or roofing cement.

The Rawl tools and plugs can be purchased in most electrical supply houses. They are used by telephone and power installation men. Each plug size calls for a corresponding drill size. Select a size that suits the threads of the hardware which you are using.

Running Outdoor Line. One of the most important parts of the job is the way in which you start the transmission-line run; that is, the way in which you install the very first loop of line from the antenna terminals to the first supporting insulator. This section of line should be a little slack so as to prevent strain on the antenna connections. The insulator must be clamped solidly around the line to prevent slippage which would end only when the line is hanging on the antenna connections.

The problem is a simple one with coaxial line because this type of line can be fastened right up against the metal boom which supports the antenna. It may be taped to the boom or clamped in place. *Never* fasten ribbon or tubular line to the boom; always use standoff insulators.

Sealing Ends of Tubular Line. Tubular line calls for a little special handling because it is hollow. Moisture must be kept out of it, otherwise the advantages of the line will be largely lost.

In all cases, the end of the line must be sealed shut as shown in Fig. 12. It is better and easier to do this before you even start putting up the antenna; you may find it lots easier to do it on the ground or indoors: Better yet, you will find it a decided help to seal all ends of tubular line back at your shop so that you always have sealed ends ready for use. Sealing the line is not really difficult under ordinary circumstances but it may be if you have to use matches as a source of heat on a windy roof top.

The general idea in sealing the end is to heat the insulation until it is soft and then to clamp the end tightly shut with a fair amount of pressure until it cools. The end of the cable should be prepared properly before this is done by stripping the insulation back to expose adequate leads and then cutting the insulation to form a neat square end. Heat may be provided by a soldering iron, matches, or cigarette lighter.

Gas pliers serve as an excellent clamp. The line may be held in the left hand (if you are right-handed) with the open end facing your right hand. As soon as the insulation is heated sufficiently so that it is soft, clamp it shut with the gas pliers. The nose of the pliers should rest between the leads so that only the insulation is squeezed. Hold the pliers tightly until you are sure that the insulation has cooled.

Because you can never really be certain that the seal is perfect, the end should be looped upward between the antenna terminals and the first supporting insulator. This is called a rain loop and will ensure that the rain will run off the line rather than into any opening at the end. Fig. 12 illustrates a rain loop.

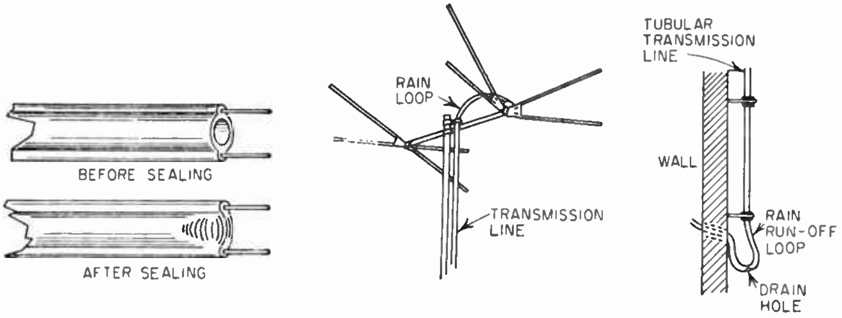


Fig. 12. Precautions to keep water out of tubular lines. The line is sealed as shown at the left; a rain loop is used at the antenna; a run-off loop is formed at the entry point and a drain hole is cut into the bottom of the loop

Installing Insulators. After you have passed the first support, the rest of the line offers no special problems. The insulators may all be installed before the line is run or this may be done progressively, whichever is easier on the particular job. The popular form of insulator comes equipped with a slot which does away with the difficult job of threading the line through each one. The line is simply slipped into the slot, centered within the insulator so that it is clear of the metal ring, and the ring is then clamped tight by means of gas pliers. This squeezes the insulator and line tightly enough to prevent slippage under ordinary tension. The ring should not be clamped too tightly as this provides no added advantage and may simply damage the line or the insulator.

The line should be looped clear of obstructions if pulling the line taut fails to provide enough clearance. These slack sections, however, should be no longer than necessary because the line should, in the main, be taut and free of sway.

Twisting Ribbon Line. Ribbon line should be twisted slightly between longer runs to reduce the effects of line pickup. The twist should have a pitch of one revolution per 2 or 3 feet of line.

Running Coax. Coaxial transmission line is often supported by means of insulated standoffs because of the ease of installing these supports. The line, however, need not be run in this manner but can be secured directly against walls, pipes, etc. Often this permits a much neater job to be done because this makes it less conspicuous and because the line can usually be routed to take advantage of existing camouflage. This should not be done if it requires a material increase in cable footage since this increases losses in signal. Sometimes you will have no choice because concealing the cable may be the number-one requirement in the installation.

The line can be fastened with ordinary telephone cable clamps or staples. In either case, you must be careful not to damage the cable. It is good practice to wrap several layers of tape around the cable where it is to be clamped. This not only protects the cable against damage, but also produces a good tight fastening job.

Ribbon and tubular line should be at least 4 inches away from walls and/or other objects. The best standards of practice call for 6 or more inches for uhf reception. In all cases, at least 6-inch clearance should be provided for the run along the antenna mast (or metal pipe).

Lightning Protection. It is not only good practice to provide lightning protection on television antenna systems but local ordinances often require it.

Good lightning protection adds several dollars to the cost of the installation but many customers will be willing to pay the extra amount for the security which it offers. You should therefore sell the idea, especially if arresters are not universally used in your local area. (It may surprise you to learn how many installations are made without them.) In this way, you can remain competitive with local installers who don't provide lightning protection, and earn a few extra dollars besides.

The ideal protection is afforded by grounding the antenna mast *and* by using a lightning arrester on the lead-in, although the latter alone will provide a high measure of protection.

Grounding the Mast. The mast should be grounded by means of a bare heavy wire, not smaller than No. 6. Number 4 is often specified by electrical equipment manufacturers. The wire must be securely connected to the mast or to its mount. The latter usually provides a better opportunity to make a solid connection by using one of the bolts as a terminal.

The ground wire should run as nearly vertical as possible so that it provides the most direct path to the ground, *regardless* of the path taken by the transmission line. The wire may be stapled or otherwise fastened directly to the wall of the building.

Unless you are lucky, there will not be a handy ground connection where you need it. In this case a ground rod should be used. The rod is provided with a terminal screw or clamp near the top and has a tapered end for easy driving into the earth.

About the only suitable made-to-order ground which may happen to be handy outdoors is the water pipe of an outside water hose connection.

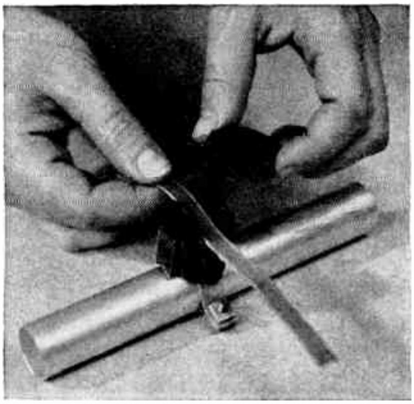


Fig. 13. A simple lightning arrester which clamps right on a water pipe. The cap secures the line and holds the wires against the arrester terminals. (RCA photo)

Installing Lightning Arresters. The lightning arrester should be located as near as practical to the point at which the transmission line goes indoors. The ground wire from the arrester to ground should also be heavy although it need not be as heavy as the mast ground wire. Number 8 or 10 should serve the purpose. The ground connection may be made to the same point as the mast ground if it happens to be close by. Otherwise, a separate ground should be provided.

Lightning arresters are also made for direct water-pipe installation, like the one shown in Fig. 13. The clamp serves as the ground connection, thus no ground wire is needed. This arrester is especially handy when an inside water pipe passes very close to the point at which the line enters the building.

Grounding for lightning protection is fairly simple when you use coaxial line. The shield itself serves as the ground conductor. Ground the shield solidly to the antenna mast at the roof, and also connect it directly to ground at the point where the cable enters the building. No lightning arrester will be needed.

Entering the Building. The transmission line can enter the building in many different ways depending upon the construction of the building.

In private dwellings which have a basement and in which the television set is located on the first floor, entry through the basement is usually the best arrangement. The line may be led directly through the wall if the construction permits this. A good guide as to this possibility is the telephone installation which is generally brought in in this manner. By examining both the inside and outside locations of the telephone wire you can get a good idea of what you can expect if you drill a hole through the wall on about the same horizontal level.

An alternative to drilling through the wall is to bring the line in through a basement window or through its frame. Often there is enough space between the window and frame to permit flat ribbon line to be squeezed through. Sometimes it may be necessary to cut a shallow slot to do this. A neater job results if you drill a hole through the frame and bring the line through in this way. Chances are that you will have to drill for either coaxial line or tubular line since neither can be squeezed through a narrow slot.

When the line must be brought directly into the living area, you have less choice as to where to bring it in. The most popular method is to drill a hole below the window sill where the line will be the least conspicuous. Here again, the flat ribbon line can often be brought in through the window itself, preferably over the sill. If weather stripping is employed, a slot may have to be cut in it to let the line through. This method of installation should be avoided, if possible, especially if the window assembly is made of metal.

Entering Apartments. In apartment houses, there is usually little choice but to run the line in through a window, partly because of the reluctance of the owners to permit drilling through walls and partly because of the heavier construction of the walls. When coax or tubular line is used, it is much better, even in this case, to drill through the window frame rather than to try to cut slots in the window to pass the cable.

Because most apartment houses are located in metropolitan areas where strong television signals are available you can take more chances in running the line over metal sills or through metal frames if you take care to keep these runs as short as possible. Generally, you can get away with squeezing ordinary ribbon line through the edge of a metal casement window, although this is not recommended with uhf signals.

In some cases there may be an advantage in bringing the line into the house through the attic. This can be done through an attic window, a ventilator, or through the wall.

Making a Rain Loop. No matter how you bring the line into the building there is one thing that *must* be done, and that is to provide a rain-runoff loop as shown in Fig. 12, otherwise rain will run down the line and enter the building. The best way to do this is to secure the line solidly by means of a clamp or insulator located near to and on a level with, or a little below, the entry hole. Then leave a little slack which hangs down at least 3 or 4 inches and loop the line back to the hole so that the final direction is *upward.* This arrangement will force rain to run off the cable.

Making a Drain Hole. One extra step must be taken with tubular line. A drain hole, roughly ¼ inch in diameter, should be cut through the *bottom* surface of the insulation at the very bottom of the loop (see Fig. 12). This will permit draining of moisture out of the inside of the cable. This must be done even if you are certain that no rain can enter the top, because moisture can collect inside through condensation.

Sealing Entrance Holes. If you wish to seal the hole which you have drilled through a wall, this can be done without too much difficulty, especially if you are using coaxial line. With this type of line, almost any kind of filler can be used, such as caulking compound, roofing cement, or putty.

With ribbon or tubular line you should choose the sealing material a little more carefully because it can increase the loss in the line. If the area is one with strong signals, you can get away with most of the materials named above. If signals are weak, or if you are dealing with uhf signals, use wax. The type of paraffin wax prepared for household purposes will serve quite well. You will probably have to use a soldering iron to soften it so that it can be pressed into the hole.

Even if you seal the hole, don't neglect to leave a rain-runoff loop. A great deal of rain can flow down an outside line and the danger of water entry exists even when there is only a tiny crack in the seal.

Running Coax Indoors. The easiest line to run indoors is coaxial cable because of its immunity to influence even by metal. Because of this, the line can be run by using ordinary methods, such as might be used when running telephone wire. It can be stapled or taped to supports, run through holes next to pipes, can be run through conduit or along metal molding. It can be painted without affecting its performance.

The only precaution of any special consequence is to avoid conditions which could lead to physical damage. The more obvious things to avoid are crushing the cable with the fastening staples or placing the line where it can be crushed by chair legs or in other ways. A less obvious precaution against damage is to keep the cable away from heat which can soften the inside insulation. The cable should be kept from making direct contact with heating pipes or other hot parts of the home heating system.

Running Ribbon Line Indoors. The fastening of ribbon line should be restricted to dry wood or plaster surfaces, although the latter is normally avoided because of the difficulty in doing a neat tacking job.

When practical (for example, in unfinished attics or basements), the line should be kept away from flat surfaces because even dry wood contains some moisture which can produce losses, especially if the run is long. This is a simple matter when the cable runs at right angles to wooden beams; the line can be tacked to the beams where it crosses them, leaving the line essentially in the clear. The tacks should have composition heads (paper or fiber) and should pierce the insulation halfway between the conductors.

When the line must *follow* beams or cross a flat surface, use standoff insulators to be on the safe side.

In the living quarters, neatness is the major requirement. The line is ordinarily tacked against the wooden molding where it will be least conspicuous. It can also be tucked between the floor molding (wooden, not metal) and carpet where wall-to-wall carpeting is employed.

If metal molding is used, try to run the line above it along the plaster or under a rug (a few inches from the wall).

All of these arrangements are compromises with performance because the line operates at lowest losses only when it is clear of all objects, a condition not easily realized in the living quarters. This points up the advantage of bringing the line into the room at a point nearest to the television set.

Neither ribbon nor tubular line should ever be painted. Tell your customer to avoid this when he does painting in the future.

Running Tubular Line Indoors. Tubular line should be kept clear of walls, especially when it is being used for uhf work. This recommendation is made to be consistent with the purpose of the cable, which is to maintain lowest losses—otherwise ribbon line would have been used. In attics and basements, the run should be handled like outside runs; that is, with standoff insulators which hold the line clear of surfaces.

The runs in the living quarters should be kept as short as possible because of the difficulty of getting a neat looking job. Special tack-on insulators are available to hold tubular line along wooden molding but even these are a compromise in appearance.

The line can be tucked between carpet and wooden molding if these runs are not too long but even these should be avoided, if possible, for uhf work.

Do not use tacks or staples to hold tubular line. If you must improvise, tack a short length of cotton tape to the wall with a conventional carpet tack, then use the tape to tie the line neatly to the tack head. Ordinary string could also be used in place of the tape. An alternative method is to wrap the cable with some plastic tape so that a tab sticks out at one side, then tack the tab to the wall.

Running Line Between Walls. If you are handy with the use of an electrician's snake you can do a lot of things in the way of installation that are otherwise impossible, especially in private dwellings. A good example in point is the case of an installation in a dwelling with no basement and where the television set is located against an inside wall. The best way of attacking this problem is to run the line into the attic and then to drop it through a hole into the proper wall behind the set, and then to bring it out of a hole in the molding, right where it is needed.

Coaxial cables can be snaked through walls without any special precautions; that is, they can follow pipes or electrical wiring if this is the easier way to do it. Ribbon or tubular line should be snaked through wall sections in such a way as to remain clear of wiring or pipes. The best assurance of this is to run it through sections of the wall which contain no wiring or plumbing.

Try to pull the line tight in the walls to keep it between the two outside surfaces if you think that metal lath is used in the plaster-wall construction. There is no need to take this precaution if the wall is constructed with plasterboard (dry-wall construction). Most homeowners know the type of wall construction in their homes and can tell you what it is. Modern home construction, especially in developments or subdivisions, is largely dry-wall construction.

Terminating Line at Set. When you have finished running the line, leave only enough slack to allow the set to be pulled away from the wall for cleaning or repair purposes without disconnecting the line. Do not leave excess line coiled up behind the set. This can do more to destroy reception, under some conditions, than a bad installation. In the case of uhf, a coiled-up line is almost surely ruinous.

If you can work out some way to do it, provide some form of strain relief on the line where it is connected to the antenna terminals of the set. This will permit the set to be moved frequently, for house-cleaning purposes, without breaking the antenna connections.

The most common form of strain relief is the taping of the line to the cabinet-back cover (unless it is metal) with plastic tape. A workmanlike job can be done with ribbon line if the two leads are torn out of the insulation for about 6 inches, equally on each side. This provides a length of insulating material which can be fastened under a screw or clamped between the back cover and the cabinet, or simply tacked to the cabinet. The two leads are cut down to normal length and attached to the antenna terminals.

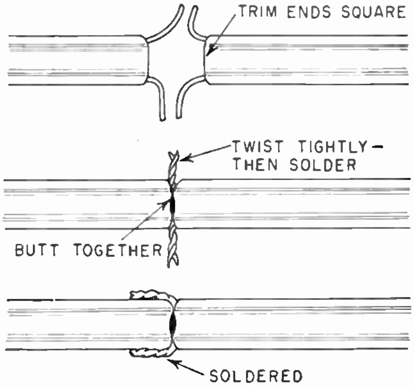


Fig. 14. How ribbon and tubular line is spliced

Splicing Transmission Line. It is best to avoid splices in transmission line although this is not always possible. You should, therefore, know how to splice lines in such a way as to preserve the line characteristics.

Splices in tubular and ribbon lines are very similar. The ends of tubular lines are sealed as described earlier so that they resemble the ends of ribbon line.

To splice the lines, the conductors are all bent straight out, away from the line (see Fig. 14). The two lines are then butted together and the conductors twisted tightly. They must be soldered because the connections will have to serve as the mechanical as well as the electrical bond. Do not use so much heat that the insulation gets soft and permits the wire to come loose. The excess leads are clipped off to about ¼ inch. They may be left sticking out at right angles to the cable or bent back against their respective conductors; never bend them across the line.

A good finished splice will have little or no gap between the insulation of both pieces; the insulation ends should butt right together and should line up just like an uncut cable. The splice may be sprayed with high-frequency insulating compound.

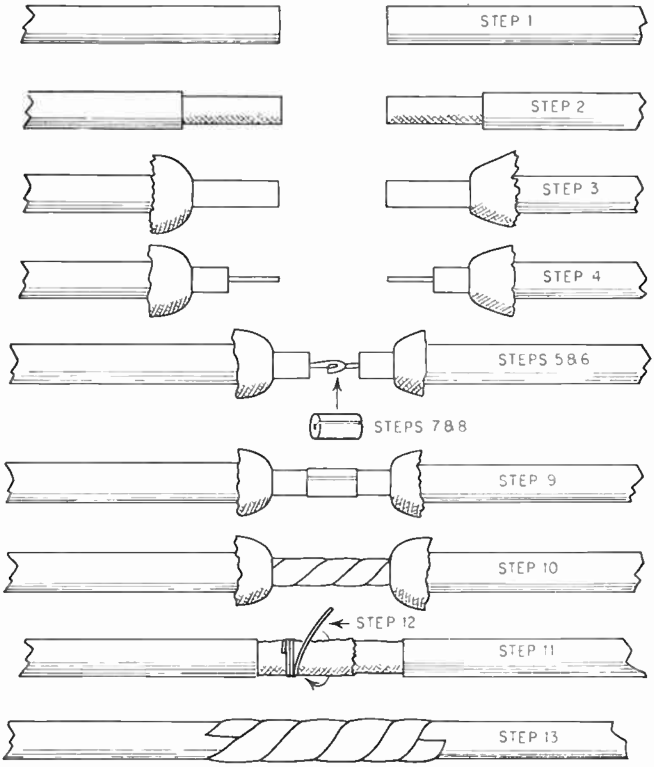


Fig. 15. A procedure for splicing coaxial line properly

Do *not* tape the connection because tape will usually serve to hold more moisture than it keeps out. This applies particularly to ordinary electrician's friction tape which should never be used on transmission line. This kind of tape is little better than a sponge after it has dried up; drying occurs in a very short time outdoors. Even when new, this tape is quite poor as a high-frequency insulating material.

Splicing of coaxial lines is much more difficult and must be done with care. The procedure is illustrated in Fig. 15. The desired result is to get a splice which in itself is coaxial; that is, the central spliced conductor must be enclosed by the outer shield.

Coaxial cable may be spliced as follows:

1. Cut the ends of the cable square to make certain that the shield, insulation, and central conductor are all equal in length.
2. Strip the outside plastic cover off the ends of the cable for an inch or more.
3. Push the shield back to give yourself working space.
4. Trim about ½ inch of the inside insulation off the central wire. This should be done squarely—that is, by cutting straight into the insulation toward the conductor with a sharp knife, being careful not to cut or nick the wire. This will leave ½-inch bare leads exposed.
5. Form small hooks at the ends of the central leads and hook them together. Crimp the hooks tightly with long-nose pliers, making sure that the points are bent back against the wire.
6. Solder the joint smoothly, without points, using only enough heat to do the job (otherwise the insulation will soften). File off any points which may remain.
7. Measure the space between the ends of the insulation material. Cut an equal length of coaxial cable from another piece.
8. Remove the cover, shield, and central wire from the piece of cable. Slit the insulator lengthwise, down to the slot for the conductor.
9. Slip this insulator over the splice so that it fills the gap between the two insulated cable ends.
10. Wrap the insulator tightly with a thin layer of plastic tape.
11. Slip both outside shield covers against each other so that they provide a continuous cover for the cable.
12. Wrap a thin bare wire around the shield starting on one side of the junction and progressing tightly until the junction is covered and passed. Do not solder the shield because the chances are that this will require enough heat to injure the insulation.
13. Tape the outside with plastic tape so that the exposed shield is fully covered.
14. If you have insulating spray material available, spray the splice to prevent the entry of moisture.

QUESTIONS

1. How should a television set be located in a room if the area is a fringe reception area?
2. Describe a method for using a rotator as a roof-top assistant in installation work.
3. What type of antenna is especially useful for weak-signal reception of only a single vhf channel?
4. How do uhf antennas differ from vhf antennas?
5. Name the basic forms of transmission line used for antenna installation work and state the principal advantages and disadvantages of each.
6. What procedure is used in mounting an antenna support against asbestos shingle siding?
7. What steps should be taken to keep water out of outdoor runs of tubular transmission line?
8. How is lightning protection provided on a television antenna system?
9. What is the proper way to splice: (*a*) 300-ohm ribbon; (*b*) 300-ohm tubular line?
10. What are the basic requirements of a splice for coaxial cable?

10

Basic Picture Signal Circuits

Tuner Unit. All television receivers manufactured to date are provided with a vhf tuner even when they are intended to be used for uhf reception. The uhf tuner is usually an added item or an added feature. Consequently, the basic vhf tuner will be discussed first.

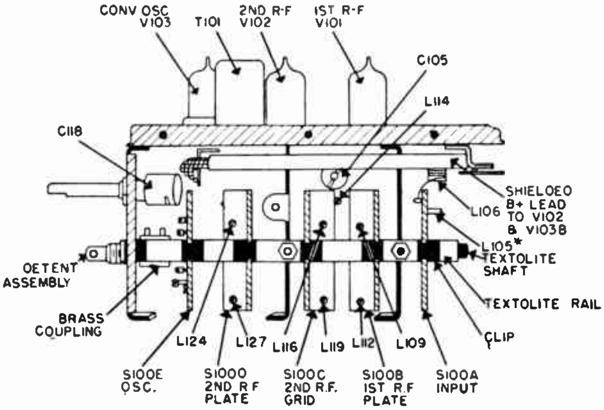


Fig. 1. Side view sketch of a tuner using a channel-selector switch. The schematic of this tuner is shown in Fig. 6

Vhf tuners are made in two basic forms. One is called the switching-type and the other the turret-type. In the former, a selector switch is used to pick out the right set of coils to be used in each channel, while in the latter, each set of coils is physically carried into position by means of the selector control. The coil-switching type of tuner is shown in Fig. 1, where the individual switch wafers are identified as S100A through S100E.

Turret Tuner. A tuner circuit is easiest to study when in the form of Fig. 2 because it shows only a single set of coils to serve only one channel. The tuner is the popular form of turret tuner shown in Fig. 3.

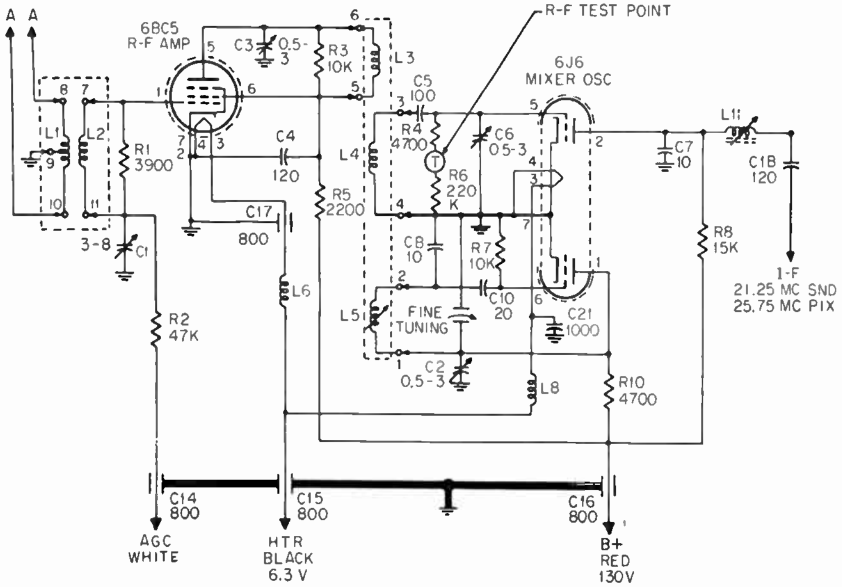


Fig. 2. Schematic diagram of a turret tuner using a pentode amplifier stage

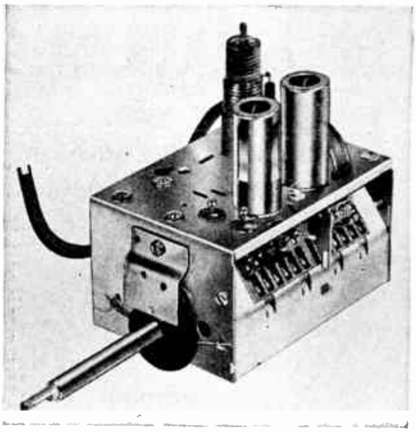


Fig. 3. Photograph of a complete turret tuner. (Standard Coil Products photo)

The turret is a drum-like assembly and is more clearly visible in the bottom view of the tuner shown in Fig. 4. It is a carrier assembly for the separate sets of coils, one set being used for each channel. The photograph shows one of the coil sets removed from the turret to give you an idea of how it fits into place. The coils are on the inside of the drum while the coil contacts project outside. As the turret is turned, one set of coils after another is moved into place against stationary contacts on the tuner chassis which bear against the coil contacts. The shaft includes a detent assembly to hold the drum in proper physical alignment for each channel position; the drum clicks into place in each channel.

When the tuner is in use, only one set of coils is employed while the others remain idle. This accounts for the simplicity of the schematic diagram of the tuner in Fig. 2. It shows only one set of coils (the coils contained within the dotted rectangles); the others are omitted from the drawing. The small numbers adjacent to the coil leads around the dotted boxes represent the stationary contacts for the turret assembly. Each of the coil sets is identical so far as its schematic diagram is concerned although each is tuned to a different frequency to correspond with the different television channels.

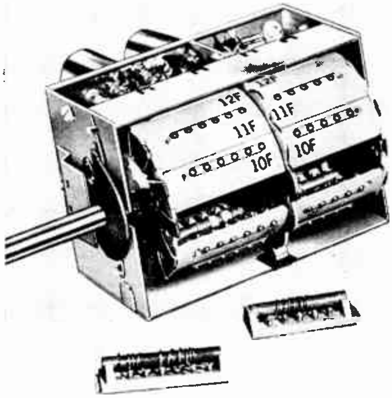


Fig. 4. Photograph of a turret tuner showing the set of channel 9 coils removed. (Standard Coil Products photo)

Turret-tuner Circuit. The type 6BC5 tube is a pentode r-f amplifier. The input circuit consists of input transformer L1-L2. The primary, L1, is center-tapped to balance the input to match a 300-ohm balanced line. The antenna transmission line connects to the terminals marked A. The secondary, L2, is tuned to the frequency of the television channel. The resistor, R1, is shunted across the coil to broaden it so that it will cover the full 6-mc band occupied by both the video and audio signals.

Input Adjuster. The variable condenser C1 is a general-coverage adjuster. Note that it always remains in the circuit, no matter what set of coils is in use. The purpose of the condenser is to permit a serviceman to alter the frequency of all antenna coils at once so as to compensate for any change which occurs in the associated fixed circuits of the tuner. If, for example, the wiring to the grid of the 6BC5 should be redressed so that the capacity of the circuit increases, all coils will be slightly off-frequency. If an adjuster such as C1 were not provided, all coils would have to be corrected individually and that would entail a great deal of work.

In practice, C1 is adjusted so that the highest channel, 13, is properly tuned because the highest frequency is most affected by changes in capacity. After that, the rest of the channels will normally come out correctly.

Turret-circuit Details. The resistor, R2, is a decoupling resistor which serves to isolate the grid circuit of the r-f amplifier from the external white lead, which is further filtered by means of a lead-through condenser, C14. Automatic-gain-control voltage is impressed on the grid of the r-f amplifier (from the agc circuit) so that the gain of the tube can be altered automatically to take care of widely different levels of signals.

The plate circuit of the r-f amplifier contains a tuned coil, L3, which is tuned to the television channel frequency. The condenser, C3, is the general-coverage tuning condenser serving the same purpose in the plate circuit that C1 serves in the grid circuit.

The plate circuit is loaded with a resistor, R3, to broaden the response of the coil so as to cover a bandwidth of 6 mc.

The upper triode of the 6J6 is the mixer tube. The r-f signal (both video and sound) is impressed on its grid by means of the grid coil L4 which is coupled to the r-f amplifier plate coil L3. The grid coil is tuned by C6, the general-coverage condenser for the mixer grid circuit.

The lower section of the 6J6 is the local oscillator. The oscillator coil, L5, is connected between plate and grid so that feedback is obtained and oscillation occurs. The coil is tapped, in effect, by the action of condenser C2 and the *fine tuning* condenser (along with the internal capacities of the tube).

Slug Tuning. Note that coil *L5* is adjustable in tuning (as indicated by the arrow through it). The tuning is done by means of a threaded slug in the coil which is accessible through a hole in the front of the tuner, visible in Fig. 3. Each oscillator coil has its own slug which can be reached through the hole in the tuner as each particular channel is switched into use. The purpose of these individual slugs is to permit each channel to be set up accurately to the correct frequency when the fine tuner is in the center of its range. The user of the set then has a comfortable margin of safety on each side of center to take care of drift or other incidental changes which may occur after the oscillator coils are initially adjusted.

Oscillator Operation. The oscillator signal is mixed with the incoming signal by means of the inductive coupling between L4 and L5. The output of the mixer is tuned to the 21- to 26-mc i-f range by means of C7 and L11. This is the i-f frequency range for which this particular tuner is designed. More specifically, each incoming television signal is converted to a sound i-f frequency of 21.25 mc and a video frequency of 25.75 mc when its particular set of coils (L1 through L5) is switched into place.

The output of the tuner is coupled through C18 to the first i-f amplifier stage of the set.

Note that both the mixer and oscillator tubes are provided with conventional grid-leak bias. In the latter, the condenser C10 and resistor R7 perform this function; in the former, C5, R4, and R6 do the same thing.

Turret-tuner Test Points. The grid resistor of the mixer is broken into two parts in order to provide a cold r-f test point, indicated by the letter T on the diagram. This test point is used as a signal output point to an oscilloscope during r-f alignment of coils L1 through L4. The alignment signal is obtained from a sweep generator connected into the antenna terminals. During alignment, the grid circuit of the mixer acts as a simple diode detector and develops an output signal across R6. Specific alignment instructions are provided in the service manuals of the television sets which employ this tuner.

Power for the tuner is provided through two leads, a black one for heater power and a red one for plate and screen power. The heater circuits are filtered by means of r-f chokes L6 and L8 and condensers C17 and C21. The filtering is used to increase stability by isolating the two tubes from each other as well as from other circuits in the main chassis of the receiver.

Tuner Tubes. The tuner unit just described employs a conventional pentode for the r-f amplifier. Although pentodes provide rather high gain, they are not especially good at high frequencies so far as signal-to-noise ratio is concerned. The pentode develops an appreciable amount of noise of its own which may appear on the picture as snow. Strong signals will override the snow, but with weaker signals, it can become prominent.

Triodes are superior to pentodes in this respect; they generate much less noise, thus add less snow to weak pictures. Triodes, however, provide less gain and two triodes are necessary to equal the gain of one pentode at the frequencies involved in vhf television. Even so, the noise is much lower, and better weak-signal reception is possible.

Triodes were somewhat slow coming into popular use as r-f amplifiers in television for two reasons. First, good triode tubes adaptable for this purpose were not available in the earlier years of television; and second, conventional triode amplifier circuits were not suitable because they required critical neutralizing circuits to prevent oscillation.

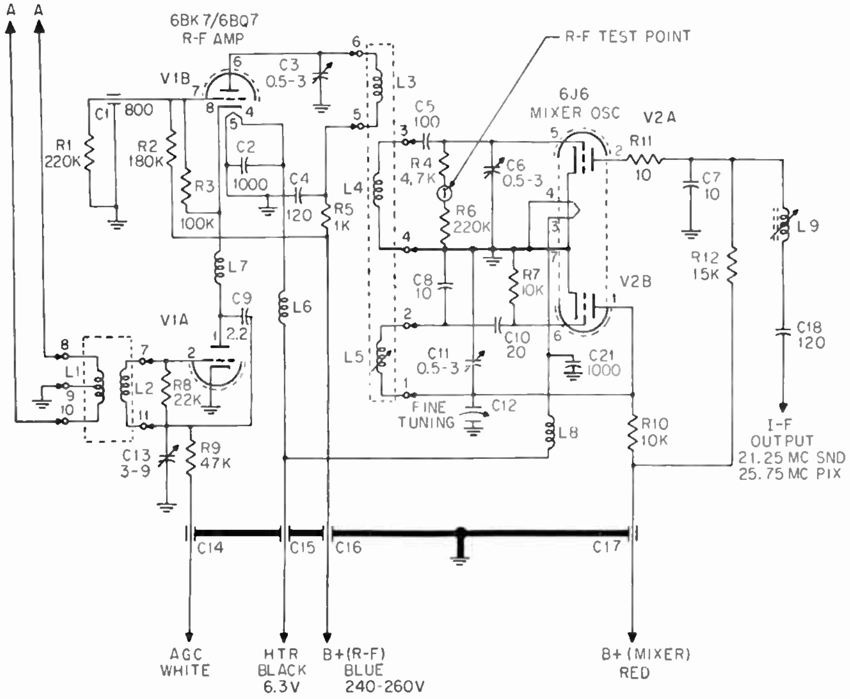


Fig. 5. Schematic diagram of a turret tuner using a cascode amplifier

Cascade Tuner. It was not until the development of the cascode type of amplifier circuit that triodes enjoyed the widest popularity as television r-f amplifiers. The cascode circuit employs two triodes in cascade (one following the other), the first being a neutralized amplifier and the second a grounded-grid amplifier.

The schematic diagram shown in Fig. 5 is a later development of the same turret tuner shown in Fig. 3, but adapted to a cascode r-f amplifier circuit.

The r-f amplifier is a dual triode, type 6BK7. The lower section in the diagram is the first stage. The input signal is applied to its grid from the antenna through the antenna transformer comprised of primary L1 and secondary L2, exactly as in the pentode circuit. The amplified signal appears in its plate circuit and is coupled through L7 to the second stage.

The first stage is neutralized by means of a combination of C9, C13, and L2. Through this network, a small part of the plate signal is fed back to the grid circuit in *opposite phase* to the input signal. This cancels the feedback which takes place *within* the tube due to the internal capacity between plate and grid. The internal feedback tends to make the stage unstable in that it encourages oscillation. Although it may not be great enough actually to result in oscillation, it does cause the tube noise to increase.

By feeding back an opposing signal, the effect is cancelled, the stage becomes more stable, and the signal-to-noise ratio is improved. The feedback has a cancelling effect because the action of the two capacitors C9 and C13 is to impress a small part of the output signal at the *bottom* of L2 which makes that end hot and in effect makes some point within coil L2 act as though it were grounded. Thus, the signal coming through C9 is reversed in the coil and cancellation of the internal feedback in the tube takes place.

Grounded-grid Amplifier in Tuner. The second stage is a grounded-grid amplifier. The grid is effectively grounded so far as r-f signal is concerned, by means of C1. The resistors R1, R2, and R3 serve only to provide an appropriate d-c grid bias for the grid. The signal is fed through L7 directly into the cathode of the tube.

Feeding a signal into the cathode of a tube whose grid is grounded is essentially the same thing as feeding the signal into the grid when the cathode is grounded. In either case, the signal excites the tube because it is the grid-to-cathode voltage which does the work, regardless of which element is hot and which is grounded. There is a difference in terms of input *impedance* to the tube between these two methods, although this consideration is primarily a design matter.

There is one other difference, and it is an important one. When the cathode is driven and the grid is grounded, the grid acts as a *shield* between the input (cathode) and the output (plate) circuits. Thus there is no need for neutralization since little feedback takes place, and the tube can be operated to provide high gain without instability or oscillation. High gain is realized by placing a fairly high-Q tuned circuit, L3-C3, in the plate of the second stage.

The balance of the circuits in the tuner are the same as those described earlier.

Drawback of Grounded-grid Input. Perhaps there may appear to be some inconsistencies in the cascode amplifier as it is described above. If the grounded-grid amplifier is so good for use in the second stage, why is it not also used in the first? Would it not eliminate the problem of neutralizing? It should be pointed out that some high-frequency receivers *do* employ two or even more grounded-grid amplifiers although this is not ordinarily done in television tuners.

As mentioned earlier, the input impedance of a grounded-grid amplifier is quite low. Were this circuit to be used in the *first* stage of an amplifier, the antenna would necessarily feed a signal into the *cathode*, and an efficient antenna transformer would not be obtained. In effect, a loss would be taken in the antenna input circuit and the purpose of the r-f amplifier would be partly defeated.

An appreciable amount of *gain* can be obtained in a good antenna transformer if that transformer can work into a *high-impedance* circuit. This requires that the signal be fed into a conventional *grounded-cathode* type of amplifier. Right off the bat, gain is obtained in the transformer, even if the tube fails to provide much additional gain. Antenna transformer gain is especially valuable because it is obtained without adding tube noise.

Tuner-gain Compromises. A conventional triode type of first stage cannot easily be operated at maximum circuit gain at television frequencies because of its tendency to oscillate, and thus cannot employ a high-efficiency plate circuit such as would be obtained were a high-$\underline{Q}$ tuned coil like L3 to be employed there. Full gain, however, is not sorely needed because of the gain already obtained in the antenna transformer.

The plate circuit of the first stage is heavily loaded since it feeds into the low-impedance cathode circuit of the second stage. Although this keeps the first amplifier stage efficiency fairly low, it does make it quite stable and easy to neutralize. The coil L7 is a low-$\underline{Q}$ (low-efficiency) tuned circuit since it is very heavily shunted by the low impedance of the second stage. The shunting effect is equal to a shunt resistor of only several hundred ohms. The same coil is used for all channels because it is so broad, due to the heavy loading, that it covers a very wide frequency range.

The two tubes used together in a cascode circuit provide an excellent set of compromises and advantages. The first amplifier stage is of moderately *low efficiency* but is more than compensated by the good gain obtained in the antenna transformer. The second stage loads the first stage heavily, keeping the first stage stable, and in the process obtains a heavy driving signal which contributes to good second stage performance.

Coil-switching Tuner. The schematic diagram of a coil-switching tuner is shown in Fig. 6. This tuner uses a gang switch to select the proper coil combination for each channel. It employs two r-f stages, the first, V101, being a grounded-grid triode amplifier and the second, V102, a pentode amplifier.

The grid of the first stage is grounded directly. Signals are fed into its cathode through an antenna transformer, T100. The transformer is of special design and covers the entire vhf range. The cathode current of the tube flows through L100, through the secondary of T100, and through a bias resistor, R100, which is bypassed by C101.

The cathode circuit is tuned by means of L100, and other coils and condensers which are switched into the circuit by means of the first wafer, S100A, of the channel-selector switch. In channels 2 through 6, the coil L101 is disconnected. In channel 2, the switch rotor (shown shaded) is all the way down to the bottom of the schematic drawing of the switch so that the right-hand portion of the rotor connects into the circuit the entire group of condensers and coils which appear to the right of and below the switch. Condensers C128, C129, and C130, and coil L102, are then connected, through C123, across the coil L100 and the secondary of T100. This tunes the cathode circuit to the channel 2 frequency.

I-F Wave Trap. The coil L106 and condenser C103 are an i-f wave trap, tunable by means of a slug in the coil, over a frequency range of from 40 to 50 mc. The purpose of the trap is to reduce or eliminate any strong, local, interfering signals which may happen to fall within the i-f frequency band of the receiver. The wave trap is connected to a contact on the switch in such a way that it is in the circuit only when channels 2 through 6 are in use. Above channel 6, the television channel frequencies jump to 174 mc and the normal r-f coils provide sufficient rejection to interfering i-f signals without the trap.

Channel Switching. In channels 3 and 4, the circuit is exactly as described above for channel 2, except that C130 is disconnected. The frequency response of the cathode circuit shifts to cover the range of channels 3 and 4.

In channels 5 and 6, C129 is dropped out so that only C128 and L102

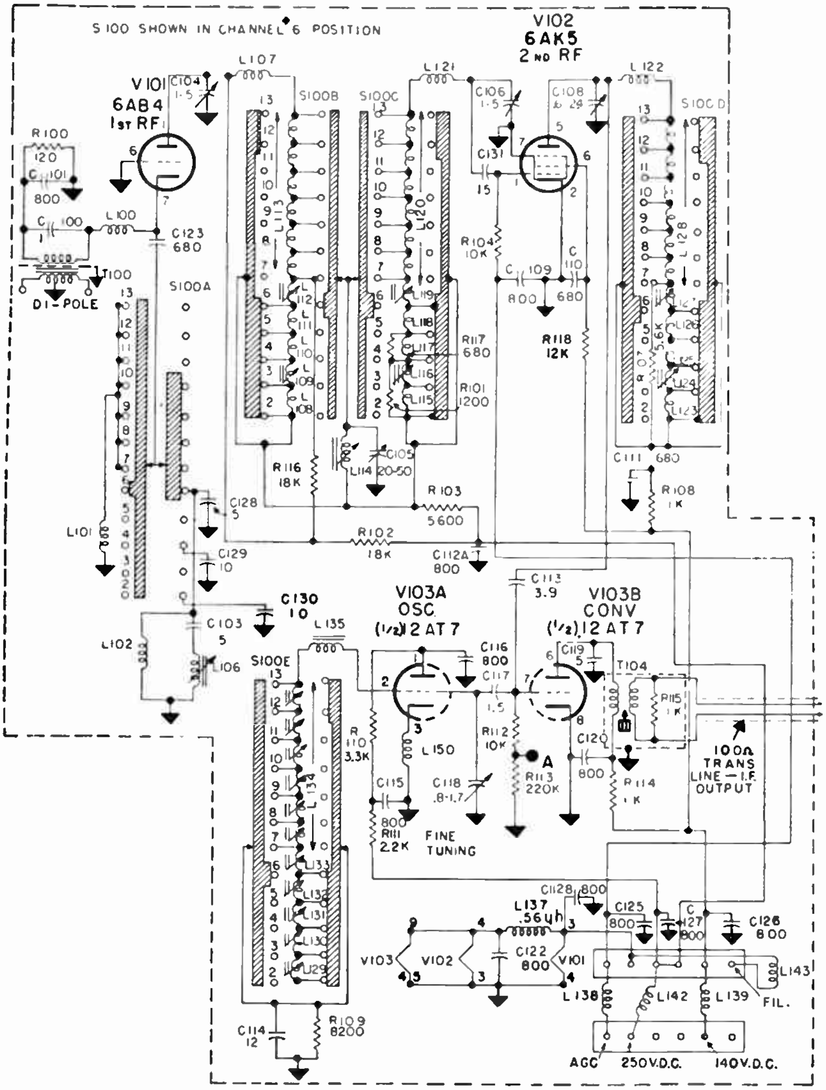


Fig. 6. Schematic drawing of a tuner which uses a selector switch. This tuner is used with the General Electric E chassis

(and the wave trap) remain. This produces a response covering channels 5 and 6.

In channels 7 through 13, all of the components to the right of the switch are dropped out and coil L101 is connected into the circuit in place of L102. This raises the frequency of the cathode circuit and its range is then broad enough to cover the full span from channel 7 through channel 13.

The coil switching which takes place in the remainder of the circuit is more conventional and easier to follow.

First R-F Amplifier. The plate circuit of the first r-f stage is tuned to each channel frequency individually as the channel-selector switch is rotated. In the channel 13 position only L107 is in the circuit and the remainder of the coils, L108 through L113, are shorted out. As the switch is rotated from channel 13 toward channel 2, an additional coil section is added to L107 with each channel position so that, at channel 2, all coils are used.

The plate coil is shunted by resistor R116 in order to broaden the response so that the coil will cover the full 6-mc span of each channel. The condenser C104 is the general-coverage tuner and, like the ones described earlier in similar circuit positions, is adjusted to make channel 13 come out right. After that, the added coils shift the frequency the correct amount in each channel position to provide correct channel coverage.

Several of the individual coil sections are adjustable so that perfect alignment can be obtained. This is done in channel 6 (with L112) and in channel 3 (with L109).

Second R-F Amplifier. The grid circuit of the second r-f amplifier, V102, is quite similar to the circuit just described. It includes a series of coils, L115 through L120, which are added, channel by channel, to L121 to provide the desired frequency response in each channel. It includes two extra resistors, R117 shunted across L117, and R101 shunted across L115. The purpose of these resistors is to offset the tendency of the coil system to become too narrow in bandwidth in the lower channels.

The plate coil of V101 and the grid coil of V102 are coupled together through a common "bottom impedance" composed of L114 and C105.

The plate circuit of the second r-f stage is almost identical with that of the first. It includes the series of coils L123 through L128, which are added to L122 by means of the channel switch.

Converter. No grid coil is used in the converter grid circuit. Instead, the signal is capacity-coupled into the converter (V103B) grid through C113.

The oscillator coil system contains coils L129 through L135. Unlike the r-f coils, the oscillator coil sections are individually adjustable in each channel, as they are in all television tuners. Figure 7 shows how the adjusters are accessible through the front of the tuner. The fine-tuning control is a variable condenser, C118, connected from the oscillator grid to ground.

The oscillator signal is injected into the converter grid through C117. The point marked A on the diagram is an alignment test point.

An i-f transformer, T104, is included in the tuner unit. The transformer is tuned to the i-f frequency, roughly from 42 to 46 mc. The i-f signal is fed from the secondary of T104 to the main chassis through a short length of transmission line.

Tuner Power. The power circuits for the tuner unit are shown in the lower right-hand corner of Fig. 6. The r-f chokes L138, L139, L142, and L143 are used to isolate the tuner circuits from the main chassis wiring.

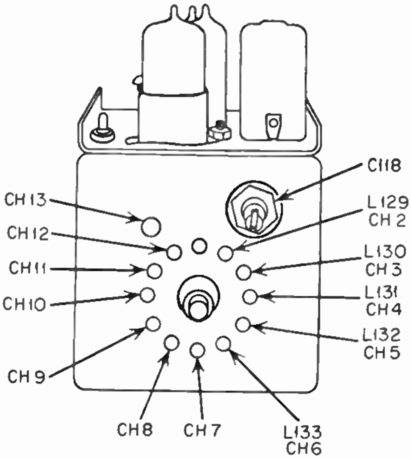


Fig. 7. Location of oscillator adjusters for the tuner shown in Figs. 1 and 6

Automatic-gain-control voltage is fed through L138 to the grid of the second r-f stage. The first stage is operated at a fixed bias, developed by R100. The converter is self-biased by grid current through R112 and R113. The oscillator is also self-biased by means of the grid leak R109 and condenser C114.

Antenna Input Circuits. Antenna input circuits are not always as simple as those used in the tuners described above. These are designed primarily for use with the conventional 300-ohm ribbon transmission line. Some tuners make provision for using coaxial antenna transmission line as well. The two types of line are quite different from each other, not only in impedance (one is 73-ohm and the other 300-ohm) but also in that coaxial lines are single-ended or unbalanced while 300-ohm lines are balanced.

Balanced Input. The tuners described above use balanced primary coils in the antenna transformer to maintain the balance of the transmission line. This cancels out pickup on the line itself as illustrated in Fig. 8. Part A illustrates, by means of arrows, the path taken by signals picked up *by the line*. The signals travel in the *same* direction in both lines. The signals enter the primary coil at opposite ends and flow in opposite directions and thus cancel out.

The signal delivered into the transmission line by the antenna, on the other hand, flows in each side of the line in *opposite* phase; that is, the signal travels down one conductor and up the other. This is illustrated in part *B* of Fig. 8. The two signals enter opposite ends of the primary coil, consequently they act *together* and induce the signal into the secondary.

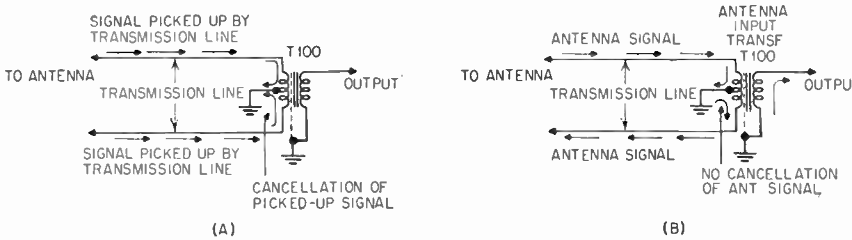


Fig. 8. The sketch at the left shows how the balanced antenna transformer cancels out pickup from the line. The sketch at the right shows how the signal picked up by the antenna transfers energy into the set

Tuner-input Variations. Some tuners use different methods of balancing transmission lines; some also provide for the use of unbalanced coaxial line. You may find a different kind of coil assembly between the antenna terminals and the first r-f amplifier of the tuner but the purpose is essentially the same.

Some tuners insert special traps or high-pass filters between the antenna terminals of the television set and the input to the tuner. The purpose of these filters is to keep out certain interfering signals such as local amateur signals or police communication signals.

One of the variations which occur in practice, shown in Fig. 19, involves use of resistor-condenser network C173-174 and R181-182 in series with the antenna leads. The principal purpose of this network is to prevent direct coupling from the tuner to the antenna, because the tuner chassis is directly connected to one side of the power line. You can see that direct connection in the lower left-hand corner of Fig. 19; one side of the power line goes from the power switch S401 to the chassis, directly under the filament transformer, T401.

I-f traps are not needed in the antenna leads of the tuner because such a trap (C103-106) is built into the tuner itself. The tuners shown in Figs. 2 and 5, however, do not include such traps. The television sets in which they are used might well have i-f traps added in series with the antenna leads.

Later versions of the same tuners shown in Figs. 2 and 5, made for an i-f frequency in the 40- to 45-mc range, do incorporate a built-in i-f trap similar to the one used with the tuner shown in Fig. 6. It consists of a series condenser and tunable coil connected between ground and the junction of C9 and R9 in Fig. 5. This makes it unnecessary to add traps in the antenna leads.

Alignment of Tuners. There are many individual adjustments in the tuners described above. To help you identify them, they are listed in Table 1.

Because of the great number of adjusters used in the typical tuner and because tuners made for different sets are very different from each other, the serviceman is not expected to figure out the adjustment procedure for himself. As a matter of fact, this is poor practice and can lead to trouble.

Instead, manufacturers make a point of providing step-by-step instructions for aligning tuner units in their service manuals. Alignment should not be attempted without such instructions, except perhaps for general-coverage and oscillator adjustments.

UHF Tuners. Uhf tuners are made in a variety of forms. Many television sets are made primarily with vhf tuners and the uhf tuner is then considered to be an added accessory. The uhf tuner may be built in so that, from the user's point of view, he simply has a set with more television channels. Electrically, however, the typical uhf tuner is usually a completely separate device. The user's operating controls provide a means of switching between the uhf and vhf tuners.

Most uhf tuners convert the uhf signals to frequencies in the vhf channel and feed that signal through the television set just as though it were a vhf station. In this case, the uhf antenna is permanently connected to the uhf tuner while the vhf antenna is connected to the set through a vhf-uhf switch. In the vhf position, this switch disconnects power from the uhf tuner and connects the vhf antenna into the vhf antenna input terminals and the set then works as a conventional vhf set.

In the uhf position of the switch, power is applied to the uhf tuner, the vhf antenna is disconnected from the set, and the output of the uhf tuner is connected in its place, feeding its signal into the vhf tuner. The latter is turned to a given vhf channel (usually channel 5 or 6, depending upon which is free of signals in the local geographic area).

Table 1

Adjusters in Tuner of Figure 2

General-coverage—r-f grid—C1—tuned in channel 13
General-coverage—r-f plate—C3—tuned in channel 13
General-coverage—mixer grid—C6—tuned in channel 13
Oscillator general-coverage—C2—tuned in channel 13
I-f adjuster—L11—aligned as part of the i-f alignment procedure
Oscillator adjusters—12 adjusters for L5—tuned individually in each channel

In addition to the above, all r-f coils are adjustable by spreading turns.

Adjusters in Tuner of Figure 5

General-coverage—r-f grid—C13—tuned in channel 13
General-coverage—r-f plate—C3—tuned in channel 13
General-coverage—mixer grid—C6—tuned in channel 13
General-coverage—oscillator—C11—tuned in channel 13
I-f adjuster—L9—aligned as part of the i-f alignment procedure
Oscillator adjusters—12 adjusters for L5—tuned individually in each channel

In addition to the above, all r-f coils are adjustable by spreading turns.

Adjusters in Tuner of Figure 6

General-coverage—first i-f plate—C104—tuned in channel 13
General-coverage—second r-f grid—C106—tuned in channel 13
General-coverage—second r-f plate—C108—tuned in channel 13
First to second r-f coupling—L114 and C105—coil in channel 6, condenser in channel 13
I-f trap—L106—to eliminate i-f interference, if present
Oscillator adjusters—12, L129 through L134—tuned individually in each channel
General-coverage oscillator—L135—tuned in channel 13
I-f adjuster—T104—aligned as part of the i-f alignment procedure

In addition to the above, many of the individual r-f coil sections are adjustable by spreading turns of the coils.

UHF Tuner Circuits. The circuitry of uhf tuners in general is simpler than that of vhf tuners because r-f amplifiers are not commonly employed. Most tubes available today are extremely poor amplifiers and mixers at uhf frequencies. Consequently, crystal mixers are generally used and the incoming signal is fed through some form of r-f tuning system directly to that crystal. The oscillator is necessarily a vacuum-tube oscillator; the type 6AF4 tube is the most popular uhf oscillator. This tube is especially designed for the purpose.

Example of UHF Tuner. A typical uhf tuner is shown in Fig. 9. This tuner converts signals to the channel 5 and channel 6 frequencies so that the vhf tuner must be set in either one of these two positions when uhf reception is desired.

The uhf antenna is connected to the tuner at the left side of the diagram. The vhf antenna is connected into the uhf-vhf switch, 9. The switch simply transfers the vhf input connections from the vhf antenna to the secondary of the transformer, 6, when uhf reception is desired and also closes the uhf power switch. The vhf antenna is then out of the circuit.

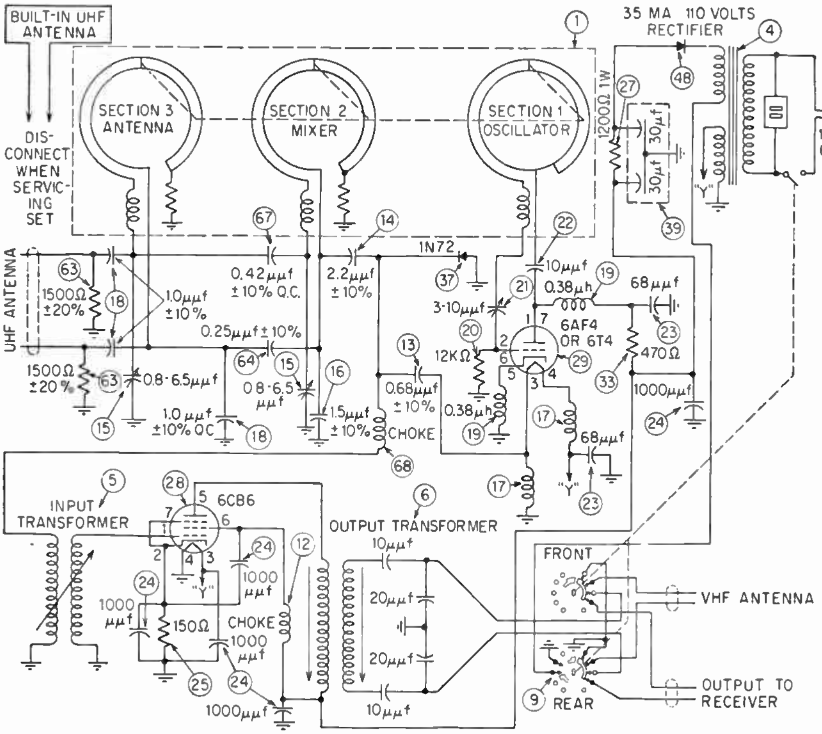


Fig. 9. Schematic diagram of a typical uhf tuner. The crystal mixer is item 37

In the vhf position, the vhf antenna is transferred to the input of the receiver and the uhf power switch is turned off.

UHF Tuning Mechanism. Station selection is done by means of a continuous 3-gang tuner, represented by the circular elements in Fig. 9. These are lengths of transmission line, open at the counterclockwise end and shorted together at the opposite end. Movable sliders, indicated at the terminations of the dotted lines, short the two lines together, so as to change the effective length of the line. When the full line is used, it is resonant at 470 mc; when the line is shortest, it is resonant at 890 mc.

The physical construction is similar to the schematic drawing in that each section is composed of a pair of side-by-side rings of metal; a shorting bar, operated by the station-selector shaft, jumps between the rings so as to change the electrical length and thus the tuning.

The uhf antenna is connected to a two-section bandpass tuner composed of two of the circular elements which are identified as sections 2 and 3. They are coupled together by means of condensers 64 and 67. Two tuned circuits are used in order to get good selectivity and good image rejection. The output of the tuned circuits is fed through condenser 14 to a 1N72 crystal detector.

UHF Oscillator. The oscillator employs a 6AF4 triode tube whose tuned circuit is the third transmission-line element, section 1. The line is connected between grid and plate in order to get feedback.

The oscillator signal is coupled to section 2 primarily through stray capacitive coupling (the two sections, 1 and 2, are adjacent to each other). The oscillator signal consequently also appears at the crystal detector and mixes with the incoming signal. The oscillator signal is about 80 mc away from the incoming signal, thus produces an 80-mc beat to which the input transformer, 5, is tuned.

UHF Tuner Output. A pentode amplifier, 28, amplifies the beat and couples it through output transformer 6 to the vhf tuner where it is handled as though it were an ordinary vhf signal.

The 80-mc figure is nominal. Actually, the frequency difference is tunable, by means of the uhf tuning control, 21, through a range of from about 76 to 88 mc. Transformers 5 and 6 are likewise tuned to cover the 76- to 88-mc range. The exact setting of the tuning control depends upon whether the vhf tuner is set to channel 5 or 6 when receiving uhf stations. One or the other is generally free of local signals.

A choice of channels 5 or 6 is provided so that the user may employ whichever channel is free in his locality. If an *occupied* channel is used and the vhf signal in that channel is moderately strong, it may be picked up directly by the vhf tuner along with the uhf signal and will cause interference.

Single Conversion UHF Tuner. Another type of uhf tuner is shown in Fig. 10, along with the uhf-vhf switch, S101, and the vhf antenna connections. This tuner uses the vhf tuner as an extra i-f stage for uhf operation.

The circuitry in the box identified as N202 is a high-pass filter which prevents signals lower in frequency than channel 2 from entering the vhf tuner. This eliminates interference from strong local signals in the i-f range of the receiver.

The vhf tuner used with this particular uhf tuner is a turret-type cascode tuner similar to those described earlier, but with an i-f frequency in the 40-mc range. The tuner is provided with a uhf position in which position the tuner acts as a straight-through 40-mc amplifier and thus adds to the normal i-f amplification. This is done by using r-f coils tuned to the i-f range instead of a television channel and by omitting the oscillator coil, so that the oscillator is dead.

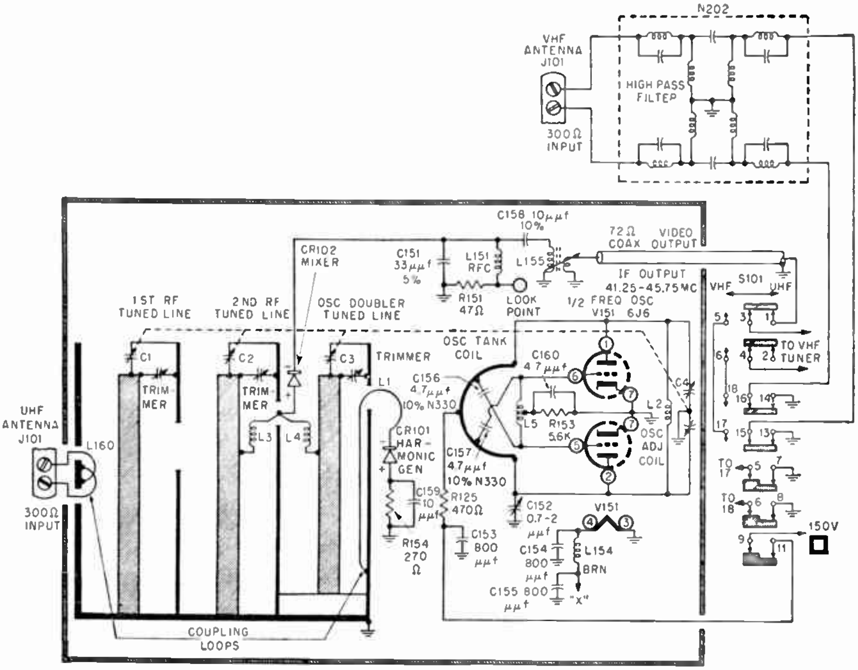


Fig. 10. Schematic diagram of a tuner which supplies direct i-f output. The oscillator works at half frequency. Its output is doubled for mixing purposes

When S101 is in the uhf position as shown, the vhf antenna is disconnected from the set and grounded through the second and third switch sections from the bottom. The bottom section provides plate power to the uhf oscillator. The output of the uhf tuner is coupled through the top switch section to the vhf tuner.

Tuned Lines. The three vhf tuned elements used in this tuner are identified as tuned lines and are represented by the shaded areas in Fig. 10. The top of each line is hot and each is grounded at the bottom. The trimmers and tuning condensers, C1, C2, and C3, are across each tuned element, going from the hot end to ground, and serve to tune each line through the 470- to 890-mc uhf range. The lines are high-Q tuned circuits.

Coupling from the antenna into the first line is done inductively, the antenna loop L160 being close enough to the line to transfer a signal into it. Coupling to the second line is done by providing an opening in the shield which separates lines 1 and 2.

UHF Crystal Mixer. The r-f signals are coupled into the crystal mixer through L3 along with the oscillator signal through L4 from the oscillator-tuned line.

The oscillator is rather unusual in this tuner and deserves some explanation. A push-pull oscillator is used and employs a conventional tube, type 6J6. The frequency of oscillation, however, is *one-half* the frequency required; this is done to obtain better oscillator stability and performance. It covers a range of from 215 to 425 mc and is tuned by means of the station-selector condenser C4 which is ganged with the tuned-line condensers C1, C2, and C3. The oscillator tank coil is the heavy half-circle between tube plates.

UHF Crystal Harmonic Generator. The oscillator signal is inductively coupled into the loop L1 which contains a crystal, CR101, in series with the circuit. The resistor R154 and condenser C159 serve primarily to limit the crystal current; they also serve as a load for the oscillator. The purpose of crystal CR101 is to produce harmonics, which it does as a natural result of its rectifying action. The r-f currents flowing in the loop are therefore much richer in harmonics of the oscillator frequency than those present at the oscillator itself.

The loop is not only coupled to the oscillator tank but also to the third tuned line, identified as the oscillator-doubler tuned line. Coupling takes place because the loop is carried into the shield containing the line and along the line in inductive relation to it. The line is gang-tuned through the range of 430 to 850 mc (40 mc lower than the uhf frequencies so as to produce a 40-mc i-f frequency). The line is a high-Q circuit; consequently, it responds only to the second harmonic of the oscillator to which it is tuned. (430 to 850 is twice 215 to 425 mc.)

Action of Tuner. As explained, the oscillator signal is coupled along with the uhf signals to the crystal mixer, CR102, where the 40-mc beat is selected because L155 with C158 is tuned to that frequency. The 40-mc output is fed through a coaxial cable to the uhf-vhf switch and then to the vhf tuner where it is further amplified before passing into the normal i-f amplifier of the television set.

A photograph of the tuner is shown in Fig. 11 to give you an idea of how the tuning mechanism looks. The pair of conventional-looking tuning condensers at the left comprise the oscillator tuning condenser C4. The next three sections contain special low-capacity tuning condensers C3, C2, and C1, in that order from left to right. The common shaft rotates all of these condensers simultaneously, providing continuous coverage of the uhf range; the single shaft performs the functions both of station selection and fine tuning.

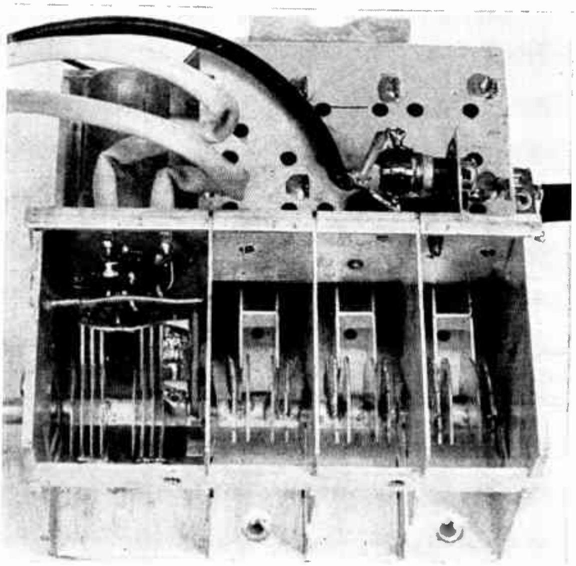


Fig. 11. Photograph of the uhf tuner shown in Fig. 10. (Allen B. Du Mont photo)

UHF Strips for Turret Tuners. Uhf conversion strips are available for some turret tuners. They can be used to replace unused vhf coils and thus permit the substitution of one uhf channel for each vhf channel that is not required. A uhf strip is shown in Fig. 12.

The circuit of the uhf strip is more complex than the set of vhf coils which it replaces. The vhf coils are shown within the dash boxes in Fig. 5. They connect to the circuits of the tuner by means of the eleven contacts numbered 1 through 11, and include coils L1, 2, 3, 4, and 5. The circuit of the uhf strip is shown in Fig. 13 where the same eleven contacts are identified by number.

The uhf strip is really a miniature converter which converts the uhf signal to some frequency between 100 and 174 mc, depending upon the particular uhf channel involved. The balance of the tuner circuits then convert that signal again, this time to the required i-f frequency for the set.

Operation of UHF Strip. In order to illustrate how the uhf strip works, it will be assumed that the receiver i-f is 40 mc and that a uhf signal at 530 mc is to be received. In this case the oscillator coil, L6, is tuned to 70 mc. The oscillator signal is coupled through R1 and C5 into a harmonic generator which is a crystal. The rectifying action of the crystal causes many harmonics of the 70-mc signal to be generated.

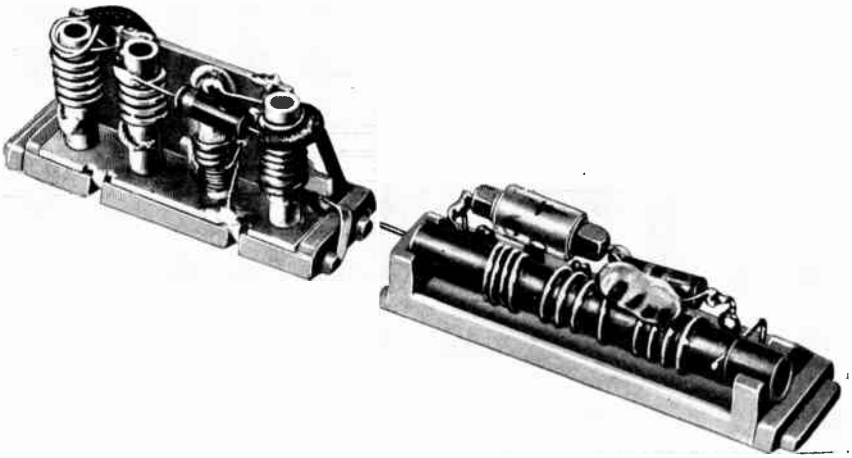


Fig. 12. A set of uhf coils for the turret tuner shown in Figs. 3 and 4. (Standard Coil Products photo)

The harmonic generator is coupled into L4 which, with C3, is tuned to 420 mc, the sixth harmonic of 70 mc. Thus a fairly strong 420-mc signal is coupled into the mixer crystal via L5.

The incoming uhf signal is also coupled into the mixer crystal through the antenna coil L1 and through the preselector coils L2 and L3. These coils are tuned to the desired signal frequency of 530 mc.

The beat between the 530-mc signal and the 420-mc oscillator signal is 110 mc, to which T1 is tuned. This signal is fed the grid of the first r-f amplifier in the tuner which now acts as a 110-mc i-f stage. The output coil of the second r-f amplifier and the input coil of the mixer (the coils identified as T2) are also tuned to 110 mc.

The original oscillator signal is 70 mc as explained above. It beats with the 110-mc signal and produces a second conversion in the mixer, this time down to 40 mc to which the i-f amplifier of the set is tuned.

Video I-F Amplifier. The video i-f amplifier of the E chassis employs three type 6CB6 tubes, V104, V105, and V106. (See Fig. 19.) The over-all response of the amplifier is shown in Fig. 14. This curve is about 3.2 mc wide, which is somewhat less than the 4-mc theoretical maximum but which is nevertheless wide enough to produce excellent picture detail.

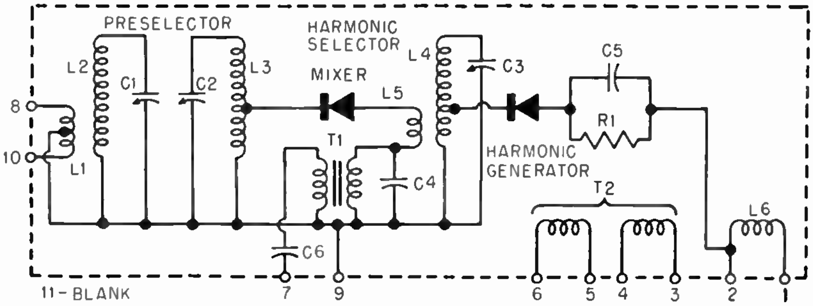


Fig. 13. Schematic diagram of the uhf coils shown in Fig. 12

The curve is inverted or negative-going because it represents the output obtained from the video detector, whose output is negative. It is common to find television curves drawn this way; the curves are interpreted in the same way as right-side-up or positive-going curves except that peaks are understood to go *downward* and dips are understood to go *upward.*

The picture carrier is intended to fall at 45.75 mc, and the sound carrier at 41.25 mc. The latter may appear to be at zero amplitude (no response) but this is really not so; the curve at 41.25 mc is simply *close* to the zero base line. This is deliberately done in order to keep the sound signal so weak as to present no interference problem in the picture. There is, nevertheless, enough signal to produce a good intercarrier beat. The carrier frequency for the video signal is halfway down the slope in order to realize sesqui-sideband operation.

The curve of Fig. 14 is actually the resultant curve produced by all of the coils in the video i-f amplifier acting together. It is interesting to see how the individual coils act and how they are tuned in order to get the desired end result. This not only serves to show how the amplifier works, but also suggests what is involved in i-f alignment.

Stagger-tuned I-F Coils. In order to build up the final response curve, the last three sets of tuned coils, L153, 155, and 157, will be considered first and will be treated as a group, since they comprise a natural "stagger-tuned" combination. The responses for these coils are shown in Fig. 15.

The response of the last coil, L157, with its trap, L158, is the solid line in Fig. 15. The coil L157 is tuned to about 44.6 mc while the trap L158 is tuned to 38.0 mc. The trap absorbs signal from the coil and puts a hole or notch in the response at that frequency.

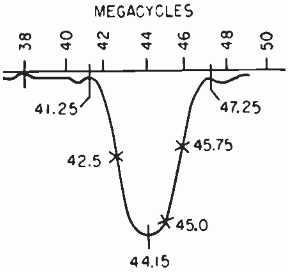


Fig. 14. Over-all i-f response curve for the set shown in Fig. 19

This particular notch is provided in order to permit the receiver to work well with a weak signal when another television station is on the air in the adjacent channel. It is called an adjacent-channel video trap and is intended to prevent the video signal of the adjacent (higher) channel from riding through and interfering with the desired signal.

Adjacent-channel Video Trap. The frequency of 38.0 mc is really an odd frequency for adjacent-channel video elimination when you consider channel allocations, because the video frequencies of two *adjacent* stations are actually 6 mc apart. To put it another way, when the video carrier of the desired signal is at 45.75 mc (the position indicated in Fig. 14), the undesired video carrier of the adjacent station is at 39.75 mc. The trap would then have to be tuned to 39.75 mc in order to eliminate interference.

The situation which prevails in most cases is that the local signal is strong and the adjacent signal is from a television station *at a distance*, consequently interference is no problem. The situation is different when fringe reception is obtained because the desired signal may be no stronger than the adjacent-channel signal.

When *weak* signals are received, the carrier is usually tuned up the curve somewhat. In this particular set, best weak-signal results are obtained when the set is tuned so that the video i-f frequency is at 44.0 mc. In this case, the adjacent video signal turns out to be 38.0 mc. It is under these weak-signal conditions that the greatest danger of adjacent-channel interference exists, thus the trap is tuned to 38.0 mc.

The solid curve of Fig. 15 shows clearly that the trap L158 suppresses 38.0 mc very effectively.

Sound I-F Trap. The second video i-f plate coil L155 and trap L156 produce the response shown in the dash-dot line of Fig. 15. The coil is peaked at 43.6 mc while the trap is tuned to suppress the sound i-f signal which is at 41.25 mc. The object of the trap, as suggested earlier, is to suppress the sound signal so as to keep it from interfering with the picture. Note that the trap does not cut out the signal completely. It is made to act in this way by coupling it loosely to L155; the coil is built with loose coupling by the manufacturer. The object is to make certain that a little sound *does* get through to the video detector so that a useful intercarrier beat can be produced.

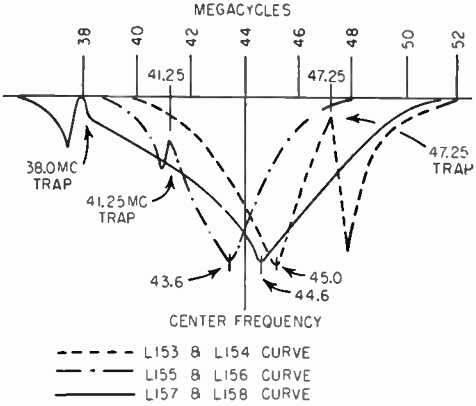


Fig. 15. Response of the individual stagger-tuned stages

The first video i-f plate coil L153 and trap L154 produce the response curve shown by the dashed line in Fig. 15. The coil is peaked at 45.0 mc while the trap is tuned to produce a notch at 47.25 mc, the frequency of the adjacent sound signal of the next lower channel. The purpose of the trap is not so much to eliminate adjacent sound interference (because the adjacent signal is usually weak) but more to shape the resultant i-f curve so that the correct slope is obtained for the video carrier to sit on. It is this slope which produces the required sesqui-sideband response discussed earlier in this book.

Over-all Video I-F Response. The sum of the three responses shown in Fig. 15 is shown in Fig. 16. (Note that the sound signal frequency, 41.25 mc, is not all the way down to zero.) This curve, however, is not the over-all response of the set because transformers T104 and T155 with trap L151 also play a part in determining over-all response. As a matter of fact, the curve is too rounded for high-quality results and requires further flattening of the top and steepening of the sides.

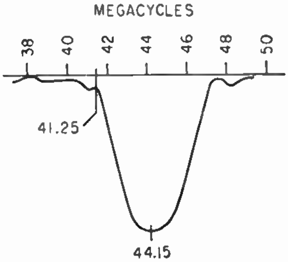


Fig. 16. Over-all response of the stagger-tuned stages

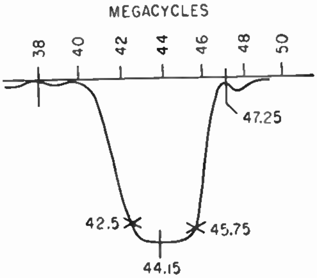


Fig. 17. Response of the first two i-f transformers

The correct over-all effect is obtained by producing a response in the first two transformers such as is shown in Fig. 17. It is extremely flat because the transformers are carefully overcoupled and loaded with suitable resistors. In addition, two traps are used to suppress further the frequencies of 38.0 and 47.25 mc for the reasons given above.

The response of the first two transformers, when combined with the response of the next three stages shown in Fig. 16, produces the over-all characteristic shown in Fig. 14.

The over-all curve given here applies to the circuit of Fig. 19. Each manufacturer will show the correct response curve for his particular set in his service manual.

Video I-F Alignment. The alignment procedure in service manuals gives specific step-by-step procedures for aligning the i-f coils, transformers, and traps to produce the desired response. The proper curves are obtained by using a sweep generator and watching the response curve on an oscilloscope while adjustments are made. Marker oscillators are used to locate the significant frequencies to identify points along the curve and the locations for the notches produced by the traps.

Video I-F Circuits. The video i-f amplifier contains two gain-controlled stages, V104 and V105 (see Fig. 19). The grid circuit of the first stage is returned through R152 to the agc voltage. The second stage is returned to the same point through R155. The source of agc voltage is at the arm of the signal-control adjuster, R171 (near tube V113B).

The last video i-f amplifier is operated at fixed bias provided by R159, because the stage is required to deliver appreciable power into the crystal detector. This is common practice; agc is rarely applied to the last stage because it can easily become overloaded on strong signals when the agc bias is very high. Fixed bias eliminates the problem of overloading on all but the very strongest signals, usually stronger than are obtained in practice.

Video Detector. The video detector in Fig. 19 employs a germanium crystal diode, Y151. The detector circuit is similar to conventional a-m diode-detector circuits except for the fact that several inductances are used in addition to the diode load resistor, R162.

The inductance L168 together with C179 serves as an r-f filter for the i-f signal as well as its harmonics which are unavoidably generated by the crystal. The filter confines the r-f to the shielded area around the coil and crystal, and prevents these signals from being sprayed out to other circuits.

The coils L159, L161, and L162 together with R164 and R162 constitute a network which is designed to provide good frequency fidelity over the range of from 0 to almost 4 mc so that the video signal will be faithfully reproduced. If this detector were intended only for audio work, these coils would not be needed; only the resistor R162 would be necessary, and it could be very much higher than 3,900 ohms.

Video Detector Circuit. The use of a low value of diode load resistance (R162) boosts the high-frequency response greatly, perhaps to 1 mc or more at a sacrifice in output; the addition of properly designed coils in a carefully calculated network raises the frequency response up to the 4-mc region required for good picture reproduction.

The electrical characteristics of the coils as well as of the other components contained in the network are rather critical. They are designed to compensate for the effects of the various unavoidable shunt capacities in the circuit such as in the crystal and in the input circuit of V107A. The selection of proper values is a problem in engineering so you can readily see that the coils should not be replaced with anything but exact duplicates if they should fail.

The detected video signal is about one volt in amplitude at the grid of V107A.

Sound Take-off. A *sound take-off* circuit, composed of C166, C167, and L160, is connected to the output of the detector. The condenser, C166, serves as a coupling condenser to the tuned circuit represented by L160 and C167. This circuit is tuned to 4.5 mc, the frequency of the intercarrier beat. Thus the intercarrier signal appears across the coil. It is fed from this point to the sound i-f amplifier, V109.

The video signal is also coupled through L167 and R180 to the sync amplifier and noise canceller, both of which will be described in a later chapter.

The sound take-off and sync circuits are really branch circuits; the picture-producing signal is the main signal at the detector. It appears in the network across L162-R162 and is coupled through L161-R164 to the grid of the first video amplifier, V107A.

Crystal-diode Polarity. The crystal diode Y151 is polarized as though it were a conventional diode with the cathode (marked minus) grounded and the plate (marked plus) at the upper part of the diagram. This produces *negative* output across the diode load network. The detected signal, in other words, appears as a voltage which is negative with respect to ground and it goes *further* negative as the i-f carrier *increases* in amplitude. The video signal thus appears as shown in Fig. 18, with the sync pulses pointed downward instead of upward.

The polarity characteristic is important in television because the signal is used ultimately to control the cathode-ray beam current and it must be going in the right direction to do its job properly.

Amplification Reverses Polarity. Video detectors do not *have* to be negative-going as this one is, because the detected signal is not applied directly to the cathode-ray tube. It is amplified in one or more video stages, each of which inverts the signal in the course of amplification.

Thus, the signal may be flipped over one or more times before it gets to the cathode-ray tube; but it must be properly polarized when it gets *there*. It is therefore necessary to start out with the signal in a given polarization in each particular design of receiver.

In the circuit of Fig. 19, negative detection results in the proper polarization at the cathode-ray tube. In other sets, positive detection may be needed, in which event the diode detector would be connected in the opposite direction. Most television sets employ negative detection, as shown.

Video Amplifier. Two stages of video amplification are used in Fig. 19, employing both sections of a twin-triode tube, V107.

The first stage has a variable resistor, R188, in its cathode circuit to act as a video gain control. It serves as the contrast control for the user of the set. The control is essential because the detected video signal is at constant amplitude and at a high level at the input of the video amplifier. The video signal level must be adjustable to suit viewing conditions as well as the personal preferences of the user.

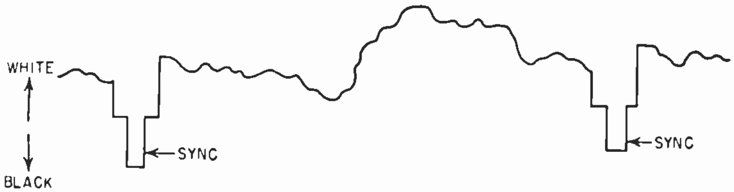


Fig. 18. Negative-going video signal. The sync pulses point downward, in the negative direction

The two video amplifier stages are direct-coupled. The plate of the first stage, in other words, connects to the grid of the second stage through a continuous d-c path (through L163 and L164). This is done in order to simplify the circuit and obtain good low-frequency response. Plate voltage for the first stage is obtained from the cathode of the second stage, which is about 70 volts positive with respect to ground.

Video Amplifier Circuit Details. The load resistor of the first stage is R167, which is 1,500 ohms. The resistor R186 is added to this circuit only to boost the plate voltage a little higher so as to get a little more gain; otherwise it has little influence on operation. For all practical purposes, you can pretend that it is not there. As a matter of fact, this amplifier will work reasonably well without it.

The low value of plate resistor is used in order to get good high-frequency response. The situation is similar to that described above with respect to the detector. A higher plate resistor would provide much more amplification but the high frequencies would fall off badly and good picture quality would not be possible. The 1,500 ohm resistor permits a stage gain of about 4 or 5 to be obtained when the contrast control is fully advanced.

The load resistor, in itself, does not provide the proper high-frequency response characteristic. The effect of shunt condensers in the two tubes and in the wiring is enough to require further compensation. This is done with L164 and R168 which, with R167 and with the shunt capacities of V107A (plate-to-ground) and V107B (grid-to-ground), comprise a filter network. It extends the response of the amplifier to around 4 mc. The video signal is therefore faithfully applied to the grid of the second video amplifier. Its level is about 4 or 5 volts (and incidentally is now a positive-going signal, having been inverted by the first amplifier tube).

Intercarrier Beat Trap. Reference to L163 and C178 was purposely avoided because this circuit plays little part in the functions just described. The purpose of this circuit is to trap the intercarrier beat and thus to prevent it from passing on to the cathode-ray tube. The circuit is a parallel resonant circuit tuned to 4.5 mc and, as such, it presents a high impedance to the beat, keeping it out of the second-stage grid. The circuit is tuned by means of an adjuster, accessible to the serviceman.

Second Video Amplifier. The second video amplifier employs a 6,800-ohm resistor, R170, as its plate load. It is higher than the other load resistors in order to provide higher gain in this stage (an over-all video gain of about 60 is needed). The second-stage gain is about 15 so that the video signal is built up to around 60 volts at maximum contrast-control setting. This is more than enough to drive the grid of the cathode-ray tube from cutoff (black) to maximum intensity (full white). The video signal is coupled, through C171 and L166-R172, to the grid of the cathode-ray tube.

The compensating network is more complex in the second video amplifier plate circuit to offset the effects of the higher value of load resistor. The resistor, being higher in value, provides poorer high-frequency response of itself, and requires more help to bring about the desired 4-mc characteristic. The network includes L165, R172, and L166 along with the shunt capacity of V107B (plate to ground) and the input capacity of V108 (grid to ground).

The output of the second video stage is once again negative-going because, like the first stage, it inverts the signal in the course of amplification. The signal is thus similar in general form to that shown in Fig. 18.

The sync pulses and blanking pulses are negative-going and serve to cut off beam current in the cathode-ray tube. This is exactly what is required; the black region must be downward (negative) as shown in Fig. 18.

Summary of Primary Picture Signal Circuits. The circuits traced up to this point are those involved in taking a television signal from an antenna and ultimately feeding it to the cathode-ray tube where it serves to modulate the brightness of the beam.

The tuner circuit provides channel selection and signal amplification at the fundamental frequencies of the television station. The tuner then converts the signal to predetermined i-f frequencies. The video i-f amplifier amplifies the signal in the i-f frequency band. It employs coil and trap circuits which serve to shape the i-f response characteristic to a form which will provide good clear picture reception.

The video detector demodulates, or detects, the video signal and makes it available to serve three separate purposes. Two of these are secondary in nature, one being to provide sound and the other to provide synchronizing information. The third is the main purpose in the sense that the signal serves directly to construct the picture by controlling the moment-to-moment brightness of the electron beam in the cathode-ray tube.

The detected signal is only about one volt in amplitude while from 35 to 60 volts are needed to drive the cathode-ray tube properly. The video amplifier provides the needed amplification. The circuits are designed with the signal polarization clearly in mind so that the video signal finally comes out in the proper direction (negative) to make blacks black and whites white at the cathode-ray tube.

The detector and video amplifier load circuits are more complex than simple resistance-coupled audio amplifiers because a frequency response of from almost 0 to about 4 mc is needed for the faithful reproduction of the video signal. The complexity takes the form of compensating coil networks which are carefully designed to provide the needed fidelity.

Tuner Circuit Variations. The popular circuit variations in vhf and uhf tuners are covered in some detail earlier in this chapter. The tuners described represent the basic forms found in practice.

The principal differences which you will find will be in physical construction and layout. Although each tuner employs its own particular circuit, it will be smiliar enough to the basic circuits to permit you to understand it without much difficulty.

A radically different form of vhf tuner was intentionally omitted from the text, partly because it has disappeared from popular use. It is the continuous type of tuner employed in earlier Du Mont receivers and identified as the Inputuner. It was also marketed under the brand name of the manufacturer, Mallory.

The prime reason for omission of this tuner from the circuit descriptions is that its electrical circuit is quite simple and easy to understand. The tuner employs an ingenious mechanical-electrical arrangement for tuning a single set of coils continuously from channel 2 through channel 13. The manufacturer's service manuals covering sets using this tuner are complete in their descriptions because of the unique character of the tuner.

Video I-F Amplifier Variations. Video i-f amplifiers vary in several respects but these variations are principally a matter of detail. They can be expressed as differences (1) in operating frequency, (2) in types of tubes used, (3) in the number of stages employed, and (4) in the kind of tuned circuits used to provide the response characteristic.

Specific i-f operating frequencies are selected by the manufacturer. In general terms, two different frequency bands are employed, although there are more than two sets of i-f frequency specifications when exact frequencies are taken into account. One of the bands is sometimes referred to as the 20- or 24-mc i-f band; the other as the 40- or 45-mc band.

In the former, one manufacturer may use 21.75 mc as the sound i-f frequency and 26.25 mc as the picture i-f frequency. Other manufacturers may use 21.8 or 21.9 mc as the sound i-f frequencies and thus 26.3 or 26.4 mc as the picture i-f frequency. The exact frequencies are, of course, clearly specified in service manuals and are of special interest primarily in alignment work.

There is similar variation in the 40- or 45-mc band. A typical receiver might use 41.25 mc for the sound i-f frequency and 45.75 mc for the picture i-f frequency. Other receivers may use frequencies a little above or below these. Here again, exact data are obtained by reference to the appropriate service manual.

Video I-F Tube Variations. Appreciable variation will be found in the types of video i-f amplifier tubes used in television sets. The major variations occur from year to year of manufacture as new types of tubes become available. There is little need to dwell upon the variations which do occur since virtually all video i-f amplifier tubes are pentodes and look very much the same on the schematic diagram. The principal differences are in minor details which are of little interest to servicemen. Tube replacement is done type-for-type; thus there is no need to study the differences between video i-f amplifier tubes used in different sets.

Most television sets use three video i-f amplifier stages although some employ four or even five. More stages do not necessarily mean higher quality or better performance. Often, more stages are used to bring about certain advantages which the manufacturer considers important. They may be used, for example, to simplify the i-f coil design or alignment, or to obtain a better response characteristic with a given type of coil design, or to obtain better over-all gain.

Video I-F Coil Variations. The greatest variations in television video i-f amplifiers are found in coil design, including the traps. The circuit of Fig. 19 includes some of the major variations which are found in practice. The first stage employs transformer coupling while the balance employ impedance coupling.

Some sets use more, and possibly all, stages as transformer-coupled stages. In this case, each stage employs a transformer similar on the schematic diagram to T104, having a primary and secondary. Sometimes both primary and secondary are tuned; sometimes they are wound together (bifilar construction) and tuned together.

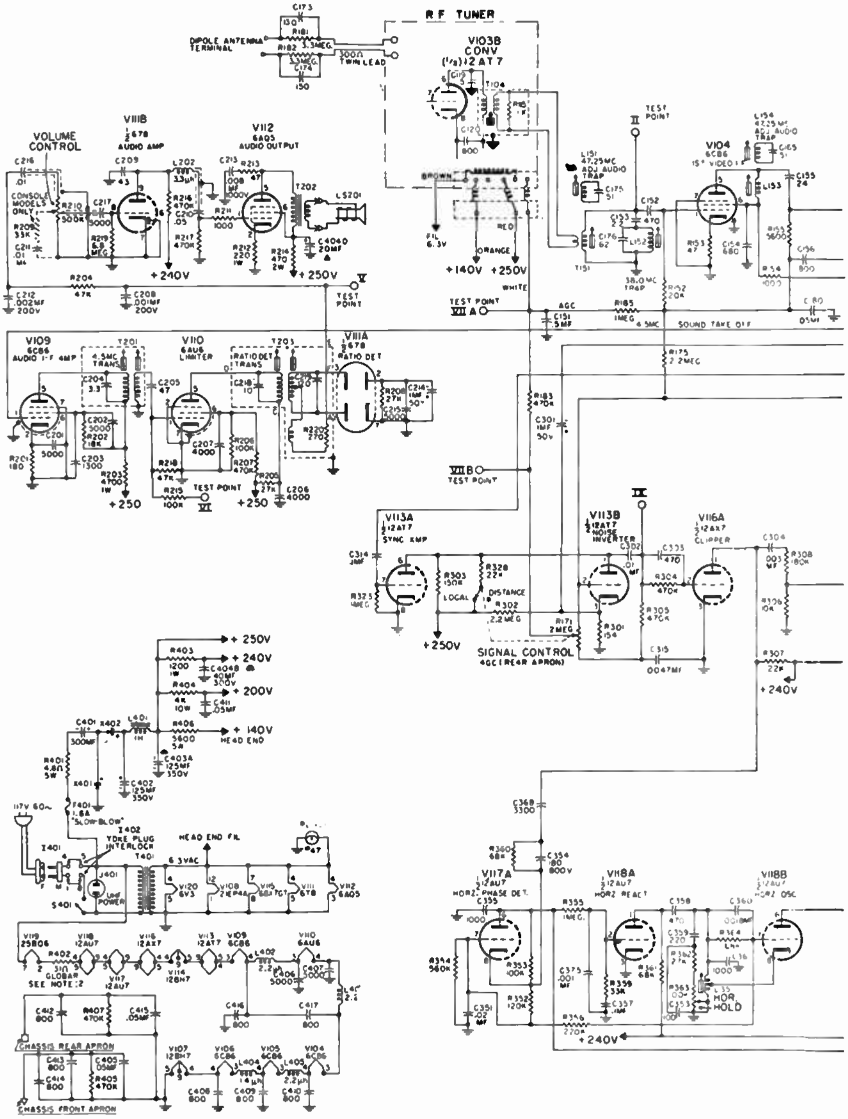
Video I-F Trap Variations. Traps are most frequently coupled into the i-f coils as absorption traps, like L154, L156, and L158 in Fig. 19. Sometimes they are capacitively coupled like the 38-mc trap, L152-C153, in the grid circuit of V104. In other instances a trap may be inserted in series with the grid or cathode of an i-f amplifier tube. The placement of traps, in other words, as well as the type of i-f coils used, is a matter of individual design preference.

These facts should not prove troublesome for the serviceman since the only service work which is affected by video i-f circuit design to any material degree is i-f alignment; and alignment can be done properly only by using the manufacturer's specific service data for each given set.

Video Detector Variations. The variations which occur from receiver to receiver in the video detector circuit are only in minor details. Some sets use vacuum-tube diodes instead of crystal diodes, but these work the same way.

The compensating network in the diode load circuit may vary greatly from set to set depending upon the manner in which branch circuits are fed, upon the type of video amplifier which follows, upon the picture quality desired, and upon whether or not sound traps are used at this point.

There is little need to study each individual circuit with its own peculiar variations. To be able to service a set satisfactorily, it is essential only to be able to identify the detector circuit and to appreciate the critical nature of its components.



Video Amplifier Variations. Two principal forms of video amplifiers are used in common practice. One is illustrated in Fig. 19; it consists of two triode stages. The other form is a single-stage video amplifier employing a high-gain pentode.

The single-stage pentode amplifier will generally appear to be simpler because it employs only one input compensating network (the detector

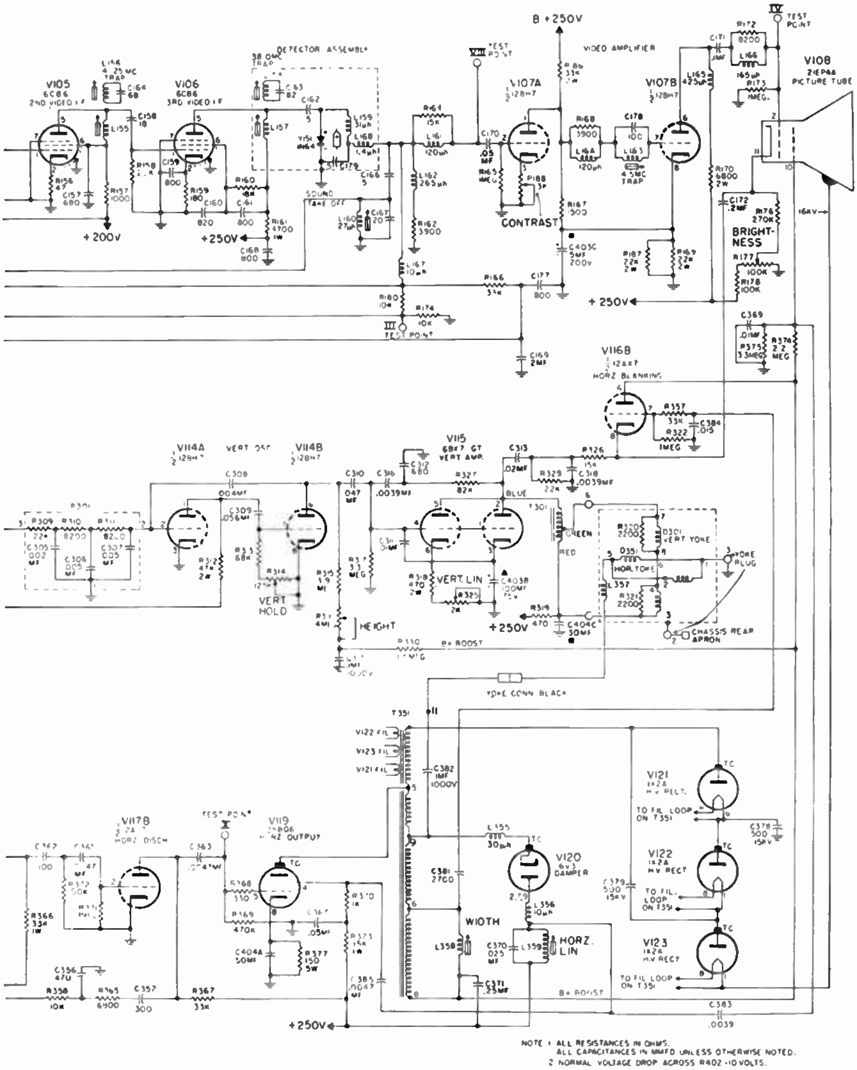


Fig. 19. Schematic diagram of the General Electric E chassis

load circuit) and one output compensating network in its plate circuit.

As a rule, the single-stage amplifier is used with a negative-going input signal, as in Fig. 19, so that its output is positive-going. This is opposite in polarity to the signal required to drive the *grid* of the picture tube. This is taken into account by feeding the video signal into the *cathode* of the picture tube instead of the grid so that its effect on beam current is reversed, and correct drive is obtained.

QUESTIONS

1. What are the principal differences between turret tuners and tuners using standard rotary switches for selecting channels?
2. In what channel should "general coverage" trimmers be tuned? Why?
3. What would you look for on the circuit diagram if you were trying to find out whether a tuner uses a cascode amplifier?
4. How is oscillation prevented in a grounded-grid r-f amplifier?
5. Draw a simple sketch showing how channels are changed in a tuner using a conventional rotary switch. (Only a single switch section need be shown.)
6. What is the nature of the signal coming *out* of a conventional uhf tuner? How is this signal handled in the television receiver?
7. How are channels changed in a uhf tuner?
8. Why are traps used in video i-f amplifiers?
9. What is the difference between a positive-going and a negative-going video signal? Why would you expect to find both forms in a television set?
10. Why is the polarity of the video signal of special concern?
11. What are the two functions usually performed by a sound take-off circuit?
12. What frequency bands are commonly employed for video i-f amplifiers?
13. How is a positive-going video signal fed into a cathode-ray tube?

11

Sound Circuits

Sound I-F Amplifier and Limiter. The sound i-f and detector circuits of the E chassis are shown in Fig. 1. The input to the first i-f amplifier is obtained from L160, the sound take-off coil in the diode circuit. The coil is tuned to 4.5 mc by means of C167. It contains the composite intercarrier signal, composed of the a-m picture signal mixed with the f-m sound signal.

The first i-f amplifier, V109, employs a conventional amplifier circuit. It serves to build up the intercarrier beat to a level high enough to drive the limiter.

The second i-f stage, V110, is a limiter stage. Its principal function is to remove most of the amplitude variations which appear in the signal, just as is done in conventional f-m receivers.

Operation of Limiter. The basic operation of a limiter is relatively simple. In a broad sense it is an i-f amplifier but it differs from the conventional amplifier in that it is capable of delivering only a fairly low level of output voltage. This condition is obtained by using low values of plate and screen voltage. Note that in Fig. 1, the screen of the limiter has a 470,000-ohm series resistor R207 which, by itself, permits only a low screen voltage. In addition, a bleed resistor, R206, of 100,000 ohms is connected from screen to ground. This reduces the screen voltage further. The operating level is in the order of 40 to 50 volts. The plate voltage is also reduced by employing a high value of resistance, 27,000 ohms (R205), in series with the plate.

The limiter is driven to its maximum output level with fairly low grid-driving voltage; once the maximum level is reached, no increase in grid-driving voltage will produce more output. The stage, in other words, overloads when excessive grid-driving voltage is supplied.

The limiter stage is provided with an input signal from V109 which exceeds the overload level by a wide margin, consequently the output remains constant even though the input signal may have wide amplitude variations. In this way, the major amplitude variations caused by the picture signal and by noise are wiped off the composite signal, leaving only the f-m characteristic of the sound signal. This signal is then fed into the detector transformer, T203.

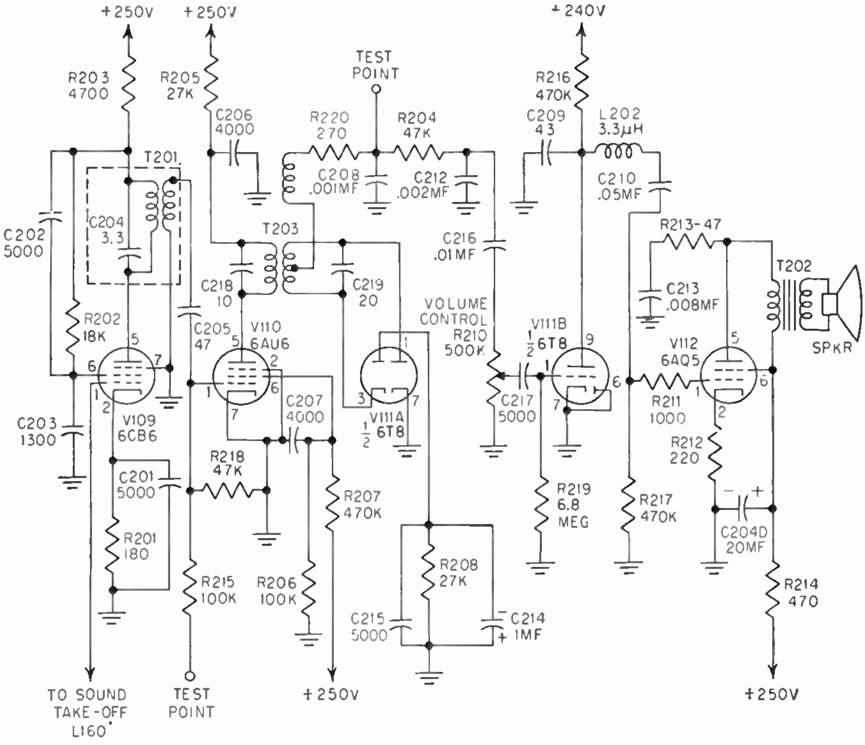


Fig. 1. Schematic diagram of the E chassis sound section

Limiter Grid Bias. The limiting characteristic is aided by the method used to obtain grid bias. Bias is provided by the grid-leak method. Condenser C205 blocks the grid from the ground return circuit through the secondary of T201. Resistor R218 serves as the grid return to ground and acts as a grid leak. Grid bias is absent when no signal is fed the tube; when signals are applied, negative bias automatically develops across R218. The stronger the signal, the higher the bias.

At normal signal levels, the bias is high enough to cut the tube off and plate current flows only during a *portion* of the *positive half-cycle* of the grid swing. After driving the tube so that plate current can flow, the positive swing in grid voltage continues and drives the tube to its maximum possible plate current. The grid voltage rises further, but for the reasons given earlier, *no further increase* in output is obtained. Thus the limiting action is effectively a top and bottom action.

The grid bias is an automatically developed voltage since it is proportional to the signal strength. If the signal increases in amplitude, the bias increases and vice versa. The net result is that the output of V110 remains almost constant even though wide amplitude variations, due to noise and to the picture signal, are mixed with the input signal.

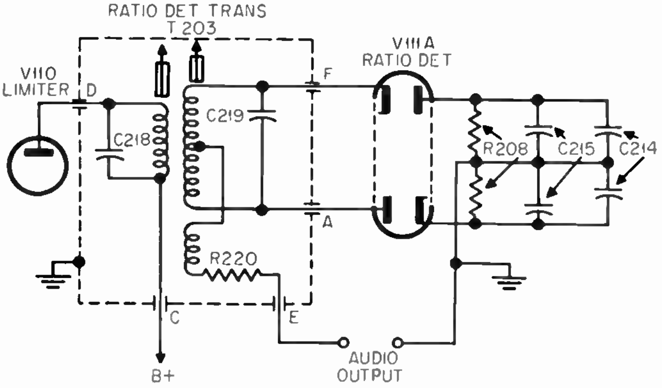


Fig. 2. Simplified diagram of the ratio detector

Ratio Detector. The sound i-f signal fed into T203 by V110 in Fig. 1 is relatively free of amplitude variations. There may be a little left, but as will be explained, the detector eliminates whatever amplitude modulation remains and gives good clean audio signals after detection.

A simplified version of the ratio detector circuit, which lends itself better to an explanation of its operation, is given in Fig. 2.

The two diodes are connected in opposite directions. The diode load circuit, composed of R208, C215, and C214, is balanced with respect to ground. The resistors, together, are 27,000 ohms. Condenser C215 consists of two 0.01-mfd units. Its purpose is to filter out the sound i-f frequency after detection. Condenser C214 consists of two 2-mfd units. The purpose of C214 is to filter out any amplitude modulation which might remain on the signal fed to the detector.

Audio output is obtained between the two terminals on the bottom of Fig. 2.

Input Circuit of Ratio Detector. The sound i-f signal is applied to the diodes in two different ways simultaneously. First, the i-f signal is induced from the primary into the center-tapped secondary. This feeds opposite but equal voltages to the two diodes. Second, the primary induces the i-f signal in the smaller coil which is connected to the center tap of the secondary. This applies equal voltages to both diodes, through the center-tap connection. (The lower end of the smaller coil may be assumed to be grounded since R220 and the audio output circuit provide a ground.)

The *net voltages* on the diodes may be equal or they may be different, depending upon the *frequency* of the sound i-f signal. This variation occurs because of the manner in which the coils are interconnected and coupled to each other. It is this characteristic which permits the detector to respond to f-m modulation. The operation is explained in the following paragraphs.

Ratio Detector Action—No Modulation. When no modulation is present the r-f voltage between terminal F and ground is equal and opposite to that between A and ground. Because the diodes are connected in opposite directions, each carries current, and those currents are equal to each other because of the balance which prevails. Under these conditions, no current flows out of the center tap through R220 and the audio circuit. The diode current travels in a circle, through the upper diode, the full secondary of T203, the lower diode, and both sections of R208 and back through the upper diode again.

The current flowing through both halves of R208 produce rectified d-c voltages which are equal. Condensers C214 and C215 are charged by these voltages. The lower cathode may be 5 volts *positive* with respect to ground and the upper plate may be 5 volts *negative* with respect to ground. Ten volts therefore appears between the end points. This voltage would indicate, incidentally, that the total r-f voltage from terminal A to F is also 10 volts (actually a little more to make up for the drop through the diodes and other small circuits losses).

This establishes one condition: When no modulation is applied, the i-f frequency is at its zero center frequency and no audio output voltage is obtained.

Ratio Detector Action—Increasing Frequency. When modulation causes the i-f *frequency* to swing *higher*, the voltages at terminals A and F are no longer equal. Now, the voltage at F is *higher* while the voltage at A is *lower*. As a consequence, the upper diode carries more current than the lower, and balance no longer exists. The total current can no longer travel around the circuit as described above. The current flowing through the lower diode flows around the circuit as in the preceding case but this accounts for only a portion of the current flowing through the upper diode. The remainder of that current flows through the upper diode, the upper half of the center-tapped secondary, out of the center tap, through the other coil, R220, the audio output circuit, and finally through the upper half of R208. Thus audio output current flows, and in such a direction that the left-hand terminal of the audio output circuit is positive.

Any shift in voltage on the two diodes is such that the *total* i-f voltage from A to F remains at the assumed level of 10 volts (the limiter is holding the amplitude of the signal constant). The *division* of voltage however, is unbalanced as explained. Terminal F may have 7 volts while terminal A has 3 volts. The audio output voltage is the difference, or 4 volts. The total voltage across both sections of C214 remains 10 volts, being the algebraic sum of the two rectified voltages, the lower 3 volts and the upper 7 volts.

A wider excursion in i-f frequency due to greater modulation may produce an 8-to-2 distribution or a 9-to-1, with proportional increases in audio output voltage.

Ratio Detector Action—Decreasing Frequency. When modulation causes the i-f *frequency* to swing *lower*, the conditions reverse. The lower diode obtains a higher i-f voltage and carries the greater current. The direction of current flow out of the center tap and through the audio circuit is now reversed and *negative* audio voltage is obtained. The voltages across each half of R208 are also unbalanced, this time with the greater voltage appearing across the lower section, but the total remains at 10 volts across the whole load circuit.

Audio Output of Ratio Detector. These facts establish the dynamic conditions of the circuit: As the i-f frequency swings in one direction, positive audio output voltage is obtained. As it swings in the other direction, negative audio output voltage is obtained. The greater the swing, the higher the output. As a result, the audio output voltage is a perfect replica of the audio voltage which was used originally to modulate the f-m signal.

It is of interest now to observe what happens when some amplitude modulation appears on the f-m signal, because this happens in practice. The limiter removes *most* a-m but some may remain.

Suppression of Amplitude Modulation. The ratio detector acts in such a way as to eliminate the amplitude modulation from the audio output. It does this by means of the very principle which provides the name ratio detector to the circuit. As has been explained, the rectified i-f current charges both halves of C214 to a total (end-to-end) voltage which is equal to the end-to-end (A to F) voltage appearing in the i-f transformer. In the assumed case, that was 10 volts.

Condensers C214 are large condensers, being 2 mfd each, and cannot be charged instantaneously. Instead, it takes a finite time to charge them to full value. The possible rate of change is so slow as to be below the audible frequency range. Any amplitude changes which occur quickly enough to be hearable are unable to affect the voltage across C214 to any material degree. It remains, for all practical purposes, at 10 volts. Thus, the audio output voltage *due to f-m* remains as a given *proportion*, or *ratio*, of the *ten volts*.

The ratio detector, for the reasons given above, is immune to reasonable changes in signal *amplitude* and responds only to changes in carrier frequency, as is desired.

Practical Ratio Detector. The actual circuit used, in Fig. 1, is a practical variation of the circuit shown in Fig. 2. There is no compelling reason to preserve the circuit balance in the diode load circuit. The balance is helpful only to illustrate more clearly how the circuit works. In the actual circuit, the lower diode cathode is grounded, and resistor R208 and condensers C215 and C214 are single, rather than center-tapped units.

The condenser values in the actual circuit are 5,000 mmfd for C215 which is equivalent to the two 0.01-mfd condensers in series, and 1 mfd for C214, equivalent to the 2-mfd condensers in series.

The circuit works in exactly the same manner as described except that it is more difficult to *see* how the unbalance audio current flows. It flows through R220, R204, and R210. This current is actually very small because of the high resistance in the audio output circuit (over 500,000 ohms), so that the predominant effect is a swing in audio *voltage*, with little audio current flow. As a consequence, no harm is done by using the unbalanced circuit because the unbalance current is so small as to have no effect upon the basic operation of the circuit.

Audio Deemphasis Filter. There is one feature with respect to the sound signal which was not mentioned earlier in this book because of its purely incidental nature to the television system as a whole. That feature is *high-frequency preemphasis,* a principle which is used in conventional f-m broadcasting as well as in the sound signal of a television station. At this point, however, the feature is of interest because it affects the circuit of the audio amplifier.

High-frequency preemphasis consists of the deliberate boosting of the higher audio frequencies at the f-m transmitter. The boost is made to follow a standard characteristic. The object is to permit receivers to suppress higher audio frequency response without losing the original characteristics of the sound.

The advantage of using a high-frequency deemphasis filter (a high-frequency suppressor) in the receiver is that tube noise and atmospherics are suppressed in the process and this provides a much quieter background for the sound. This advantage would not be possible if the audio were not initially boosted in the high-frequency range at the transmitter.

Standard Deemphasis. The high-frequency deemphasis filter is designed to provide a suppression characteristic which is equal but opposite to the boost provided at the transmitter. The filter in Fig. 1 is composed of C208, C212, and R204. The values of the components are selected to provide standard deemphasis of high frequencies in the audio circuit.

It is sometimes helpful to know the purpose of this filter, particularly if you intend to use the audio amplifier of a television set with a phonograph pickup or with an external radio receiver. As has been explained, the filter is intended to deal only with the kind of audio signal delivered by the f-m detector (a high-frequency preemphasized signal) and thus should not be used with a phonograph, for example. Instead, the phonograph, or other audio input, should be connected directly to the volume control in this particular set, and the lead between C216 and C212 should be broken.

The high-frequency deemphasis filter will be found in the same location in virtually all television sets; it will follow the detector immediately and will precede the input to the first audio amplifier stage.

Audio Amplifier. The audio amplifier in Fig. 1 is conventional. It employs a voltage amplifier, V111B, followed by a power amplifier, V112. The variations which occur between sets are much the same as occur in ordinary broadcast receivers. Some sets employ simple single-ended power amplifiers while others employ more elaborate amplifiers for greater power output and better audio quality.

This particular amplifier uses one component not found in ordinary amplifiers. It is the r-f choke L202.

The choke is used to suppress the 4.5-mc sound i-f frequency. An appreciable amount of the sound i-f signal and its harmonics appear in the first audio amplifier because the tube is contained in the same envelope with the two detector diodes. If this r-f signal were to be amplified further by the audio power amplifier, noticeable distortion might result. More important, the amplified 4.5-mc signal could be radiated by the audio and loudspeaker wiring. This type of radiation can easily be picked up by the video circuits and might cause background interference patterns on the picture. The choke suppresses the r-f and prevents it from causing difficulty.

Some kind of r-f filtering is not uncommon in audio amplifiers for television sets, especially when the detector diodes and first audio amplifier are contained in a single envelope. Similar precautions are not nearly as important in radio receivers because there are no picture circuits to be affected by radiation of the i-f signal. The distortion effects on the sound are relatively unimportant, because they are small.

Sound I-F Circuit Variations. The sound i-f system described above is by far the most popular form used in television sets. Most sets obtain the intercarrier beat directly from the video detector diode and employ one i-f amplifier followed by a limiter stage and then by a ratio detector. To illustrate, this general circuitry is employed in television models manufactured by Bendix, Magnavox, Sparton, Sylvania, Stromberg Carlson, General Electric, RCA, Olympic, Philco, and others.

Sound Take-off After Video Amplifier. A somewhat less popular arrangement consists of a sound i-f system which obtains the intercarrier signal *after* the video amplifier, then uses only a limiter which feeds directly into the ratio detector. Examples of this circuitry are found in certain models of General Electric, Du Mont, Motorola, and Hallicrafters.

The latter type of sound i-f system is generally limited to sets employing a single *pentode* video amplifier stage. The reasons for this are interesting: Video amplifiers which employ two triode stages are easily driven to clipping (cutoff) levels when high contrast is employed. The video amplifier, in other words, can be driven hard enough under some conditions to cut off the video signal peaks. The result is called sync compression or sync-peak clipping. In the latter case, one of the video amplifier tubes actually *goes into cutoff conditions on sync pulses.* This has little noticeable effect on the *picture* because the sync pulses are not visible anyway, and no harm is done there.

This type of video amplifier is not well suited to amplification of the intercarrier beat. The reason is that when one of the video amplifier tubes cuts off, *no signal of any form passes through,* and the amplifier is momentarily dead. Since the amplifier cuts off on sync peaks, a hole is left in the intercarrier signal with each sync pulse. If the output of this amplifier is used to provide the intercarrier signal, severe buzz will be heard when strong picture signals are employed. The buzz is the audible result of the 60-cycle vertical sync pulse holes in the sound signal. (You can't hear the 15,750-cps horizontal pulses.)

As a consequence, when a television set employs a clipping-type of video amplifier (usually two-stage triode amplifier, as stated above), the intercarrier beat must be picked up at the video detector diode, *before* the video amplifier. At that point, the intercarrier signal is continuous and thus capable of producing good results.

Pentode Video Amplifier. Certain pentode video amplifier tubes are capable of providing as much video output signal as is necessary for the cathode-ray tube, without danger of buzz. The intercarrier signal level is, of course, greatly amplified along with the video signal. It can therefore be used to drive a sound i-f limiter directly without using a separate sound i-f amplifier. The intercarrier signal is usually taken directly from the plate of this type of video amplifier. A 4.5-mc trap is inserted *after* this point to keep the intercarrier beat from passing on to the cathode-ray tube.

Gated-beam Limiter-Detector. Some television receivers use a gated-beam tube (type 6BN6) to serve the combined functions of limiting and detection. This particular tube is quite different in design, construction, and operation from the run-of-the-mill amplifier tubes.

The theory of the tube and its circuitry is rather involved. Many pages could be used to describe it fully. Since it is only a variation of standard television circuits, being used in a minority of sets, it will be described only briefly in this text. More detailed information can be found in the publications of tube manufacturers.

Gated-beam Detector Circuit. The circuit diagram of a typical gated-beam detector is shown in Fig. 3. The input signal, which is the sound i-f signal plus a-m interference, is fed into the *limiter grid,* pin 2. Audio output is taken from the plate, pin 7.

In order to get a rough idea of how the tube works, the limiting action should be considered first. It will therefore be assumed that the *quadrature grid,* pin 6, is grounded because in that condition the tube acts only as a limiter.

The control grid (2) acts like the sharp cutoff grid of a conventional limiter tube. That is, it cuts off plate current at fairly small negative grid swing. Plate current is limited by the bias built up across the cathode resistor R1, so that saturation easily occurs when the grid swings positive.

These two actions together constitute top-and-bottom limiting action, very much as in the conventional limiter circuit described earlier.

Action of Quadrature Grid. When a tuned circuit is connected to the *quadrature grid* (6) as shown in the diagram, some new things begin to happen.

The coil is tuned to the sound i-f signal frequency (4.5 mc in intercarrier sets). Because grid 6 is in the path of the plate current it picks up some of the 4.5-mc energy and feeds it to the coil. This causes the coil to oscillate at that frequency.

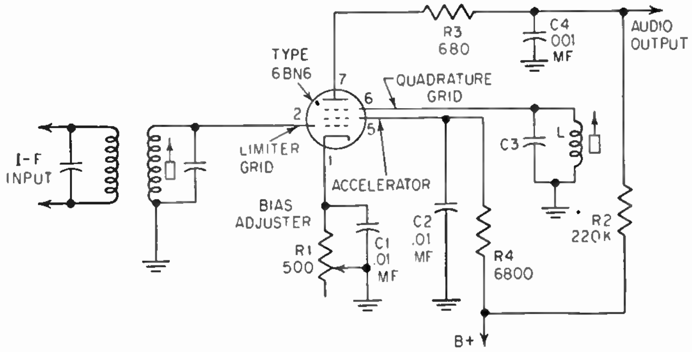


Fig. 3. Simplified diagram of a gated-beam f-m detector

So long as the input signal remains at 4.5 mc, the tube acts essentially as it did when grid 6 was grounded. This is so because the oscillations of the coil adjust themselves in such a way as to be passing through zero voltage (ground) whenever a pulse of plate current flows.

When the signal frequency increases, however, so that it is *above* 4.5 mc, the quadrature coil L is no longer tuned to this new frequency (being fixed-tuned to 4.5 mc), and consequently it no longer oscillates in the same manner. Now it swings through a *negative* excursion of oscillation during the pulse of plate current and thereby *reduces* the plate current.

The opposite happens when the signal frequency decreases. The quadrature coil swings through a *positive* excursion during the pulse of plate current and causes it to *increase*.

The net result is that the plate current rises and falls with a *frequency* shift in input signal. This constitutes *detection of f-m* since it reproduces the audio waveform which originally produced the frequency deviations in the f-m signal.

The incoming *amplitude* variations, however, are eliminated because of the limiting action of grid 2 as explained above.

Gated-beam Tube Output. Audio output is developed across the plate resistor R2 in much the same way as it appears across the plate resistor of an audio amplifier. The resistor R3 and condenser C4 serve as an i-f and deemphasis filter, bypassing the i-f signal to ground and keeping it out of the audio circuits which follow.

Adjustments in Gated-beam Detector. In practice, the adjustment of the gated-beam detector is sometimes critical, especially so far as its bias is concerned. The bias adjuster, R1, is usually located with the internal adjusters of the television set and may be identified as the BUZZ CONTROL. It is really a limiter-action control. If it is set too high or too low, limiting action is poor and the intercarrier buzz can be heard. The adjuster may be set up by ear to produce a minimum of buzz on a normal signal.

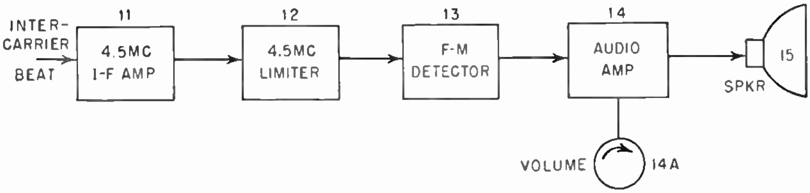


Fig. 4. Block diagram of a television receiver sound circuit

The tuning of the quadrature coil is less critical but may also require adjustment from time to time. It is tuned to provide the strongest sound signal consistent with good audio quality. You can usually tell when it needs adjustment because the audio signal gets weaker and (more important) sounds distorted.

Summary. The sound section of the television receiver which has been covered in the preceding paragraphs is shown in block form in Fig. 4. It consists of a 4.5-mc i-f amplifier, limiter, some form of f-m detector, audio amplifier, and speaker.

These circuits really constitute the major portion of an f-m receiver, lacking only a tuning unit of some form to be a complete f-m set. Figure 5 illustrates the added circuits needed to do this. From this you can see that servicing the sound section of a television set is very much like servicing a conventional f-m set, except that there are fewer f-m circuits in the television set.

The principal differences between the television sound section and an f-m receiver are that in the latter, the i-f frequency is usually 10.7 mc instead of 4.5 mc, and the f-m receiver employs suitable tuning circuits to pick up and convert signals in the 88- to 108-mc f-m band to the 10.7-mc frequency.

F-M Tuning Section. The majority of f-m sets employ a separate r-f amplifier stage followed by a mixer. These are tuned by means of a ganged condenser (usually) through the range of from 88 to 108 mc, in which band the f-m stations are located. This band starts where television channel 6 leaves off and occupies a part of the spectrum between that channel and channel 7.

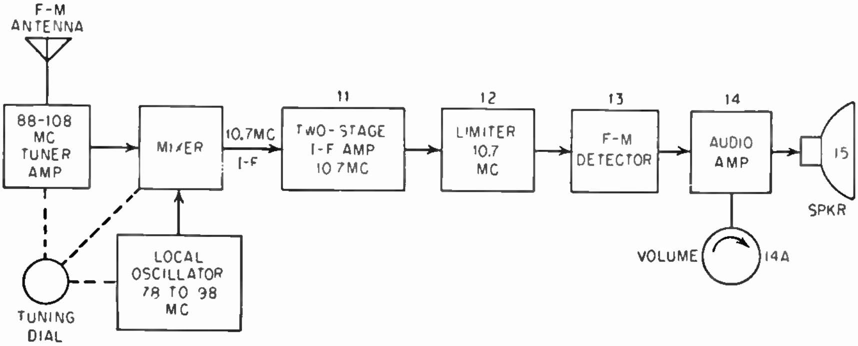


Fig. 5. Block diagram of a complete f-m receiver

The local oscillator is tuned by a third section of the tuning condenser. It is usually tuned lower in frequency than the f-m signals in order to obtain the highest degree of oscillator stability. The frequency is made to fall exactly 10.7 mc lower so as to produce an i-f signal of 10.7 mc. The oscillator range is thus 77.3 to 97.3 mc.

F-M Receiver I-F Stages. The popular types of f-m receivers employ two i-f amplifier stages and a limiter stage as shown in Fig. 5 (when a phase detector is used) or a three-stage i-f amplifier and no limiter (when a ratio detector is used). Some of the less elaborate receivers may use only two i-f stages before the f-m detector.

The i-f amplifier and limiter stages perform the same functions in an f-m receiver as those described above for the sound circuits in a television set. The problem of a-m elimination, however, is somewhat easier in a conventional f-m set because it deals with a relatively clean signal; that is, the signal is a pure f-m signal with no amplitude modulation except that which is due to the incidental noise picked up with the signal and generated by the tubes. This noise is appreciably less than the video modulation which rides along with the f-m signal in the intercarrier beat of a television set.

F-M Receiver Detectors. Two types of f-m detectors are in popular use in f-m sets. One is the ratio detector described earlier; the other is called a phase detector or discriminator. The most significant difference between these types is that the former is almost immune to a-m while the latter is capable of both a-m and f-m response.

When a ratio detector is employed, limiters are rarely used because the detector itself acts to eliminate the a-m modulation which is caused by noise. As indicated above, the amplitude modulation contained in an f-m receiver is ordinarily quite low compared with that contained in an intercarrier television sound signal. This accounts for the fact that it is rather common practice to use a limiter in the television sound section even though a ratio detector is used, whereas this is not done in standard f-m sets.

The phase detector is rarely used in modern television receivers, primarily because it is sensitive to a-m. The use of such a detector would only make it more difficult to eliminate the a-m video modulation from the intercarrier signal; the possibility of hearing picture buzz would then be much greater.

The phase detector is credited with better fidelity characteristics than the ratio detector although the difference is indeed hard to discern in well-designed sets. Some manufacturers, nevertheless, consider the advantage to be sufficient to use a phase detector, even though it requires complete limiting ahead of the detector. The lower a-m noise level of f-m sets, compared with that of television sets, makes this more practical in the former.

The Phase Detector. The typical circuit of a phase detector is shown in Fig. 6. The values given are representative of those found in common practice.

If you compare this circuit with the circuit of the ratio detector given in Fig. 2, the major differences should be apparent. The most obvious difference is that the phase detector has the i-f signal fed into both diode plates in a true push-pull arrangement, whereas this signal feeds into one plate and one cathode of the ratio detector.

An equally significant difference, but one which is less obvious, is that the audio output is taken from the diode load circuit of the phase detector, with this circuit being only lightly bypassed (C4 is 100 mmfd).

A less significant but common difference is in the coil arrangement. The phase discriminator rarely uses the third coil but instead uses a condenser (C2) to couple the i-f signal directly into the center tap of the secondary.

The operation of the phase detector, like that of the ratio detector, is based upon the manner in which the i-f signal amplitude shifts between the two diodes as the frequency of the signal changes. At zero deviation, both diodes are driven equally. With increasing frequency, one diode voltage increases and the other decreases; with decreasing frequency, the action is reversed.

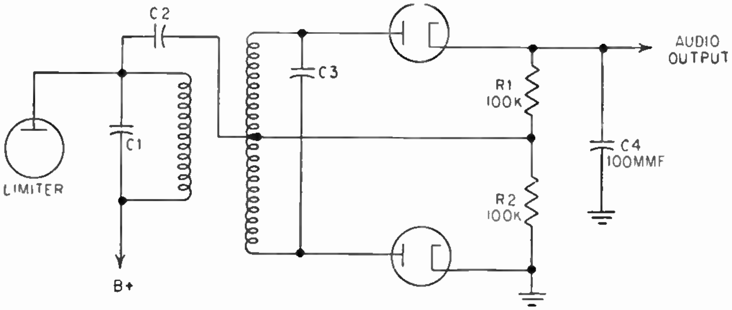


Fig. 6. Schematic diagram of a phase detector for f-m

The rectified result of these frequency shifts appears across the diode load resistors and this constitutes detection of the f-m signal.

Unlike the ratio detector, the phase detector does not include a large shunt condenser in its output to hold the amplitude constant. The detector consequently responds to a-m as well as f-m, and thus depends entirely upon the limiter to wash out amplitude modulation. Note that a large condenser cannot be added to the phase detector without shorting out the audio output.

QUESTIONS

1. What is the content of an intercarrier signal?
2. What is the function of the limiter?
3. Explain how the output voltage of a ratio detector is related to frequency variations in the input signal.

4. What is *high-frequency preemphasis* and how is it handled in a receiver?
5. Why is the intercarrier signal picked up ahead of the video amplifier when that amplifier employs two triode stages?
6. What is the BUZZ CONTROL and with what kind of circuit is it used?
7. What is the major difference between the sound i-f system of a television set and a standard f-m set?
8. Why are limiters commonly used with ratio detectors in television sets and not in standard f-m sets?
9. What are the major differences between ratio detectors and phase detectors?

12

Sweep Circuits

Over-all Vertical System. The over-all vertical sweep system of the typical intercarrier receiver under study is shown in Fig. 1. The two sections of V114 act together as the vertical sweep oscillator (also called the vertical sweep generator, the vertical multivibrator, or simply the vertical oscillator). The two sections of V115 act together as the vertical sweep output amplifier. The vertical deflection signal is fed through the output transformer T301 into the vertical deflection coils of the deflection yoke.

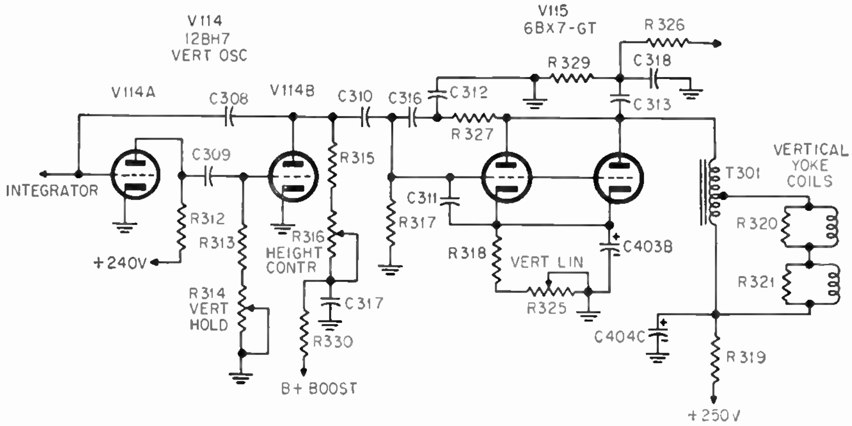


Fig. 1. Schematic diagram of the vertical sweep system

The sweep speed is synchronized by means of vertical synchronizing pulses which are applied to the oscillator through an *integrator,* not shown in Fig. 1. The integrator will be described later. The speed is locked with the synchronizing pulses by adjustment of the vertical hold control, R314.

The amplitude of oscillations, and consequently the height of the picture, is adjusted by means of the height control, R316. The linearity of the vertical sweep is adjustable by means of the vertical linearity control, R325.

Three input voltages are used to supply plate power to the circuit as shown in Fig. 1. Two of them are easily identified, being marked +240 volts and +250 volts respectively. The third input is a higher d-c voltage. It is marked *B+ Boost* which is a d-c voltage of about 600 volts. This voltage is derived from the horizontal sweep circuit.

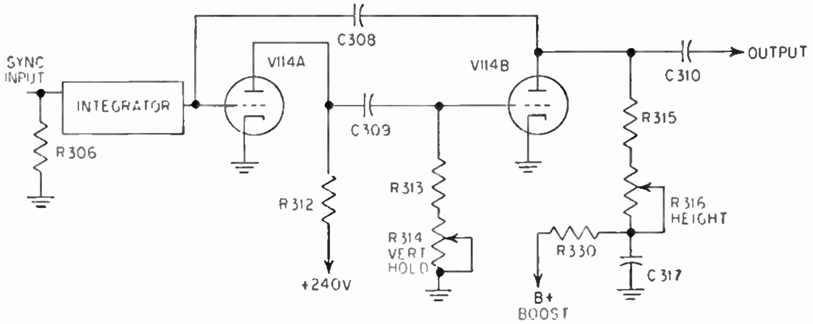


Fig. 2. The vertical sweep oscillator

The circuit in the upper right-hand corner of the illustration delivers part of the vertical sweep signal through R326 to the cathode-ray tube where it serves to blank out the vertical retrace.

Vertical Sweep Oscillator. The vertical sweep oscillator alone is shown in Fig. 2. The condenser C310 is the output coupling condenser. The oscillator is a form of multivibrator circuit.

The general multivibrator employs two tubes connected in a loop; that is, the output of the first tube is fed to the input of the second and the output of the second is fed back to the input of the first. The feedback is at high amplitude so that the tubes are overdriven during the normal cycle of operation, sometimes being cut off and sometimes carrying heavy current. Multivibrators employ resistors and condensers to determine the frequency of oscillation rather than tuned circuits, consequently the output is composed of pulses instead of sine-wave a-c.

In this particular multivibrator, the output of V114A is coupled through C309 into V114B. The output of V114B, in turn, is coupled back through C308 into the input of V114A.

If you neglect the presence of condenser C308, the circuit is really that of a two-stage resistance-coupled amplifier. It would, in fact, work as an audio amplifier were C308 omitted. The condenser, however, couples the output back to the input and causes violent oscillation to take place.

How a Multivibrator Works. In order to see how this happens, it will be assumed that very small negative pulse of voltage is applied to the grid of V114A (which is normally at zero potential since the grid circuit is returned to ground through the integrator circuit). The assumption is a valid one because, as will be shown later, negative synchronization pulse voltages are fed to this grid through the integrator.

The small negative pulse is amplified by V114A and it appears at its plate as a stronger positive pulse. It is positive because the negative grid pulse *reduces* plate current, causes the plate voltage to *rise* in value, and that produces *positive* output.

The positive output is applied, through C309, to the grid of the second tube. Because the cathode of the second tube is grounded, its grid draws current as it is driven in the positive direction. (The grid and cathode act like a diode in this condition.) This prevents the grid voltage from rising more than just slightly positive and instead causes condenser C309 to become heavily charged by the grid current which flows into it. The nature and significance of the charge on C309 will be explained later; at the moment, the effect produced by the small positive grid voltage on V114B is of more concern.

The effect produced by the positive grid voltage is to cause V114B to carry heavy plate current. This results in a heavy *negative* pulse at the plate of V114B which is now many times greater than the negative pulse which originally started the action back at the grid of the first tube. The output of V114B is coupled back to that grid through C308, thus adding the amplified output to the original input signal, which now drives V114A harder; and the action is increased, gaining amplitude each time the signal passes around the loop. This is a regenerative action and because of its very nature, it takes place quickly, almost instantaneously for all practical purposes; almost the very instant that a small negative pulse is applied to the grid of V114A, it explodes into a strong, high-amplitude negative pulse.

How a Multivibrator Stops. The explosion is the result of the regenerative action just described. The initial voltage pulse is amplified, added to the original, amplified again, added to the already-amplified original, amplified again, and so on, adding amplitude with each go-round. There is a limit as to how far this action can go, otherwise the pulse would continue to grow until it attained an amplitude of millions of volts, a situation which is obviously ridiculous. It is interesting and significant to see what stops the action.

The limiting factor is the condition of cutoff in V114A. As its grid continues to be driven more negatively, it quickly reaches the value at which plate current drops to zero and no further reduction is possible. This breaks the loop and stops the regenerative action. It leaves the grid of V114A with a high negative voltage and the tube, in effect, is now dead. The tube, however, cannot remain dead indefinitely because the grid-blocking voltage is maintained by the charge in a condenser (C308). The grid voltage, therefore, starts to drift back toward zero as the condenser discharges toward its equilibrium state. Equilibrium is established when the grid voltage of V114B is once again zero.

Start of Next Cycle. On its way to the equilibrium state, the grid voltage leaks off in the positive direction until it finally permits V114A to carry plate current again. This causes a *drop* in its plate voltage and produces an output voltage in the *negative* direction. This voltage is coupled through C309 to the grid of V114B, *reducing* its plate current. This, in turn, causes the plate voltage of V114B to rise. The result is a positive pulse which is coupled, through C308, to the grid of V114A. This immediately speeds up the original positive-going voltage at that grid and the loop is again in violent action, but this time in the opposite direction.

Once again the action is sudden and violent and it continues until it reaches a limit somewhere in the loop. The limit, this time, is found in V114B, which, being driven negatively, goes into cutoff (it is now dead) and the action stops. Once again the circuit comes to rest and waits until the cutoff grid (now the grid of V114B) can coast back to the conduction condition.

Dead-time of Multivibrator. When it reaches that point, and V114B again starts to conduct, it develops a negative voltage in its plate circuit which is coupled through C308 back to the grid of V114A. The negative voltage at this point is the condition at which we first started and thus the entire cycle is repeated again from the beginning. In the process, the plate of V114B is swung, first in the negative direction where it rests during the dead-time of V114A, and then in the positive direction where it rests during the dead-time of V114B. The dead periods, or at-rest periods, can be likened to a state of shock which exists after each explosion, one of which occurs in each direction alternately.

Multivibrators are designed to remain in the two opposite at-rest conditions for specified periods of time. The transient conditions (the explosions mentioned in the above paragraphs) are virtually instantaneous, and therefore serve only to switch the at-rest conditions back and forth. The real work done by the multivibrator is directly related to its periods of rest.

Purpose of Multivibrator. In the case of television, the multivibrator is intended to produce sweep. The requirements of this sweep are that it scan across the face of the tube at a smooth rate and then that it snap back quickly to the starting point and repeat the cycle. The total action must be accomplished in the vertical multivibrator in $\frac{1}{60}$th second, to allow for 60 sweeps per second.

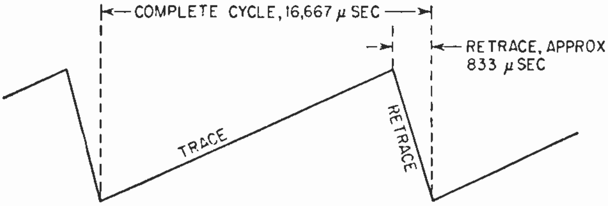


Fig. 3. The vertical sweep cycle

In more convenient terms, $\frac{1}{60}$th of a second is 16,667 microseconds (millionths of a second). Practical compromise provides for a trace which takes 15,834 microseconds, thus allowing 833 microseconds (about 5 per cent of the total time) for retrace. This is shown in Fig. 3. The two portions of the cycle are identified as the *trace* portion and the *retrace* portion. The first is used as the picture-scanning sweep and the other is simply the necessary retrace back to the start of sweep for the next scan.

Trace and Retrace Times. The durations expressed above need not be duplicated perfectly so long as the total cycle is equal to 16,667 microseconds. As you will see later, the hold control serves to lock the oscillator so that the total cycle does come out right. The trace, however, may be longer than 15,834 microseconds and the retrace correspondingly shorter than 833 microseconds. In fact, this condition is desirable since the retrace serves no useful purpose beyond getting the sweep back to the start.

An instantaneous return is ideal but it is not practical. Neither the yoke nor the vertical output transformer is capable of instantaneous retrace; consequently a finite time, usually about 833 microseconds, is provided for this purpose.

The multivibrator just described completes a full cycle of operation in 16,667 microseconds. This comes about because the circuit is designed so that V114A is dead for 833 microseconds and V114B is dead for 15,834 microseconds (nominally). While one tube is dead, the other carries current heavily. Output tube V114B, in other words, is dead for 15,834 microseconds and conducts heavily for 833 microseconds.

When the tube conducts, its plate voltage is low; when it is cut off (dead) its plate voltage is high. This is illustrated in Fig. 4A which shows two successive retrace (conduction) periods with a trace period between them.

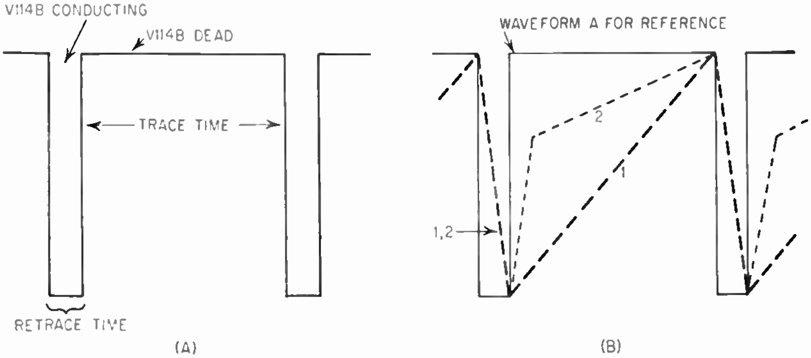


Fig. 4. Waveforms of the vertical sweep oscillator

If the multivibrator were operated alone (C310 disconnected) the output signal at the plate of V114B would look like Fig. 4A. The multivibrator, however, is connected into the filter network shown at the left side of Fig. 5. It contains C311, C312, C316, R327, and R317. This network is used to shape the output of V114B so that it can serve as a sweep waveform. The effect of the network is shown in Fig. 4B.

The waveform denoted by the number 1 is the desired sweep characteristic; it is the same as the one shown in Fig. 3. As will be explained later, the amplifier tube requires a waveform like the one denoted by number 2 in order to get, finally, a sweep *current* like waveform 1 at the yoke of the cathode-ray tube.

The network in the grid of the amplifier tube distorts the otherwise rectangular output of V114B (Fig. 4A) so that it takes the shape of waveform 2.

Changing Oscillator Speed. The speed of oscillation in the multivibrator depends entirely upon the time of the retrace function plus the time of the trace function. When the former is 833 microseconds and the latter is 15,834 microseconds, the total time of the cycle is 16,667 microseconds. This is $\frac{1}{60}$th of a second, which is another way of saying that the sweep speed is 60 per second. Lengthening or shortening either function will result in a change of speed.

Because it is desirable to keep the retrace time as small as possible, it is made a fixed quantity and the length of *trace* time is varied to make speed control possible.

Retrace time is fixed by the value of C308 and the resistance contained in the integrator (see Fig. 2). These values are constant and selected so as to hold V114A cut off for about 833 microseconds.

Trace time is determined by the value of C309 and the resistance of R313 and R314. Because the latter is variable, the trace time is variable. At around the midpoint of R314, the trace is 15,834 microseconds long and the sweep frequency is thus 60 sweeps per second. When the value of R314 is increased, the trace becomes longer (V114B remains cut off longer) and the sweep speed is lower. The reverse is also true. The adjustable resistor, R314, is the vertical hold control and provides a range of about 57 to 63 sweeps per second.

Vertical Height Adjustment. Plate voltage is provided for V114B through R315, R316, and R330. It is obtained from the B+ Boost voltage, which happens to contain objectionable ripple due to the action of the *horizontal* sweep circuit where this voltage is developed. Resistor R330 and C317 serve as a simple filter to smooth out the ripple and produce pure d-c voltage.

Resistor R316 is variable. It permits the plate voltage of V114B to be adjusted. This, in turn, governs the amplitude of the sweep waveform developed by the multivibrator. The end result is that the vertical size or height of the picture is variable with this control which is labelled the height control.

Vertical Synchronization. In the preceding explanation, reference to synchronization was deliberately avoided in order to illustrate how the vertical sweep oscillator is capable of running freely. The matter of synchronizing the oscillator by means of pulses is simply a refinement of this basic operation.

It was explained above that the *trace* is formed while V114B is cut off and that the longer the tube is held at cutoff, the slower will be the speed of oscillation. It was also explained that the trace is *started* when the grid voltage of V114B is driven into cutoff, after which the grid voltage drifts upward at a relatively slow rate. The trace is *ended* when the grid voltage finally reaches the value at which V114B can once again start to conduct.

From these statements you may observe that when the trace starts, V114B is solidly cut off and that near the end of the trace, the extra margin of cutoff voltage has virtually disappeared. Say, for example, that the trace is set so that it takes 16,000 microseconds from beginning to end. At the start of the trace, V114B may be more than 100 volts beyond cutoff whereas at, say, 15,950 microseconds it may be only 1 or 2 volts beyond cutoff.

Vertical Synchronizing Pulses. If some form of positive synchronizing pulse of 1- or 2-volt amplitude were to be superimposed on the grid of V114B, this pulse would be of little consequence if it happened to appear soon after the trace was started; at that time V114B is solidly cut off and the 1- or 2-volt boost in grid voltage would have no effect on the multivibrator; it could not overcome the cutoff voltage.

If the synchronizing pulse were to appear just about the time that the multivibrator is *almost* ready to trip, it will trigger the action to coincide with the pulse. This happens because 1 or 2 volts are enough, near the end of the trace, to end the cutoff condition of V114B which is then within the cutoff region by only a small margin.

The vertical synchronizing pulses are fed into the multivibrator through the integrator to the grid of V114A. They are sharp negative spikes of voltage. While V114B is cut off (and thus forming a trace), V114A is conducting. It amplifies the vertical synchronizing pulse and impresses it as a positive pulse on the grid of V114B where it acts as described above.

Dynamic Synchronization. Synchronization involves more than the single act of having one pulse act as a trigger. The pulses appear as a continuous stream at a rate of 60 pulses per second and *each* one must serve to trigger a corresponding sweep. This is accomplished as the result of proper speed adjustment of the oscillator.

Proper adjustment calls for a speed setting which is actually a little slower than the required speed. The sync pulses, of course, continue to appear at the correct speed.

The result is that when any given sync pulse acts as a trigger and thus recycles the multivibrator, the *very next* trace will tend to run a little too long. This means that V114B will not yet be ready to flip over by itself when the next sync pulse appears, but it will be *almost* ready. Because of its sensitivity to the influence of the pulse at this time, the pulse again triggers the action accurately. This sets the stage for the next cycle, and so on with each and every cycle of the multivibrator. In short, the speed of the multivibrator is locked to that of the sync pulses, and the scanning of the picture is in perfect step with the television transmitter which is sending out these sync pulses.

The conditions for synchronism may sound quite critical and, in a sense, they really are. That is why it is common practice to locate the hold control on the front panel where it is handy for adjustment. When you adjust this control, you don't think about what is happening within the set; you simply adjust it to provide the most stable picture. When you have done this, you have automatically found the right balance between the speed of the sync pulses and the (lower) free-running speed of the vertical multivibrator.

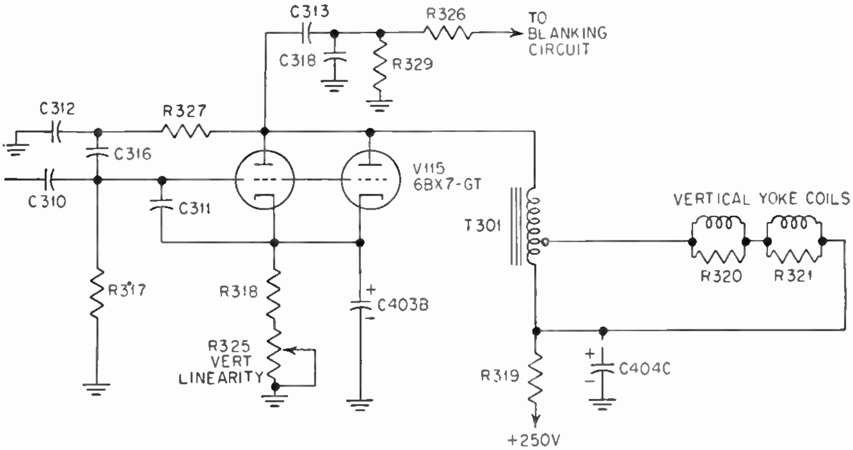


Fig. 5. The vertical sweep output amplifier

Vertical Sweep Amplifier. The vertical sweep output amplifier of the receiver under study is shown in Fig. 5. It uses a twin-triode tube with both sections in parallel to provide sufficient output power for deflection. The driving signal is obtained through C310 from the vertical sweep multivibrator.

The circuit resembles that of a conventional audio power amplifier except for the filter network in its grid circuit and the fact that it feeds its output into yoke coils instead of into a speaker.

The network which includes C313, C318, R329, and R326 is simply a branch network through which the output of the amplifier is fed to a blanking circuit. Its purpose will be described later.

The portion of the input network which includes R327, C312, and C316 comprises a negative feedback system. Feedback networks are used in audio amplifiers to improve fidelity; this particular feedback network is used to help shape the waveform of the driving signal.

Current and Voltage Waveforms. The end requirement of the vertical sweep amplifier is that it produce a sawtooth of *current*, like that shown in Fig. 3, through the yoke. This is true because it is the current which does the work in the yoke, not the voltage across its windings. This point is important to remember because the voltage and current waveforms are not identical.

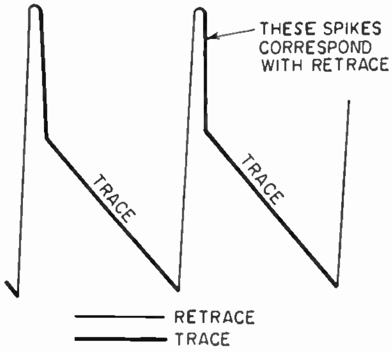


Fig. 6. The voltage waveform across the yoke coil when sawtooth current flows

Ordinarily, when dealing with audio amplifier circuits, there is no need to speak specifically of voltage or current waveforms because they both have essentially similar forms. When there is a difference, the geometry is usually of no great concern because the waveform is always changing anyway with the nature of the sound, and if you were to look at the signal on an oscilloscope it would appear to be a meaningless jumble.

In television sweep circuits, the situation is different. The sweep current and voltage have radically different characteristics. Moreover, the waveform is often viewed with an oscilloscope as a part of troubleshooting work. The difficulty which arises out of this is that an oscilloscope will display the *voltage* waveform, which will look more like the waveform shown in Fig. 6 across the yoke, when the *current* through the yoke follows the form shown in Fig. 3.

This points up the importance of manufacturers' drawings of waveforms in their service manuals. These show what you should see on an oscilloscope. (They are *voltage* waveforms.)

The waveform shown in Fig. 6 is actually the proper voltage waveform for the plate of the vertical sweep amplifier shown in Fig. 5. This calls for a grid signal voltage like waveform 2 in Fig. 4*B*. The network in the grid of the amplifier is designed to shape the output of the multivibrator into this form.

Linearity. In order to get good linearity in yoke current, the voltage waveform must be one which will bring this about; its shape must be carefully established within the set. The most rigid requirement is that the voltage waveform at the output amplifier have a linear trace function. The trace function is identified in Fig. 6; it should be straight.

It is not a simple matter to get good linearity, because there is a natural tendency for resistor-condenser networks to develop curvature. Moreover, amplifier tubes also exhibit the tendency to produce curvature.

The major slope-producing job is done by C311; however, it has a tendency to produce curvature in the trace. In order to compensate for this, the bottom end of the condenser is connected to the cathodes of the amplifier tubes where a ripple voltage of opposite curvature appears. This tends to cancel the curvature at the grid.

The ripple voltage at the cathode is due to the plate current flow through cathode resistors R318 and R325. Although heavily bypassed by C403B, enough ripple voltage remains to be effective in helping correct the curvature due to C311.

The curvature produced by the amplifier tubes varies with the average bias. By making the bias adjustable with a variable resistor, R325, the tube curvature can be shifted about and adjusted to compensate for the remaining curvature in the grid voltage. The feedback network, R327-C312-C316, also serves to reduce curvature.

The combination of components and circuitry in both the input network and the feedback network, together with the bias adjuster, act together to produce good linearity in the current through the yoke. The single adjuster, R325, is enough to take care of differences in individual output tubes and the normal changes which occur in the tubes as they decline in performance after extended use.

Vertical Blanking. The video signal transmitted by the television station includes vertical blanking pulses which are intended to blank out the cathode-ray beam so that the vertical retrace lines will not be seen. The blanking pulses do this job quite well when the set is properly adjusted and the incoming signal is clear and strong.

If strong noise is picked up, it may cause the retrace lines to become visible. If the user turns up his brightness too high, the lines will be seen. If the camera conditions at the studio change materially, the retrace lines may become visible. In short, the vertical blanking conditions are often critical. The retrace lines appear as shown in Fig. 7 when they are not properly blanked out.

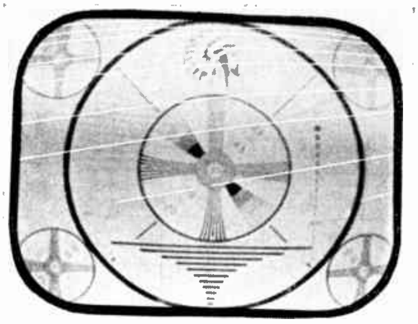


Fig. 7. How vertical retrace appears on a picture when it is not properly blanked out. (General Electric photo)

Blanking Circuit. A simple vertical blanking circuit is used in the E chassis to provide absolute blanking under almost any conditions of operation so that the blanking pulse of the video signal is not depended upon to do the job. As shown in Fig. 8, it consists of a network of resistors and condensers between the plate of the vertical sweep amplifier tube, V115, and the cathode of the cathode-ray tube, V108. The object of the network is to couple the vertical retrace spike into the cathode-ray tube where it blocks off beam current. Since the spike occurs during retrace, blanking during retrace is automatically obtained.

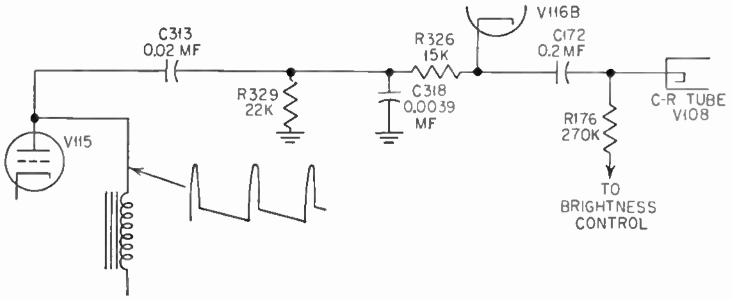


Fig. 8. The vertical blanking circuit

Condenser C313 acts as a d-c blocking condenser which blocks off the d-c plate voltage of V115 from the blanking circuit. It also acts, with R329, as a pulse-shaping filter which permits the spike in deflection voltage to be passed through without passing the gradual trace slope. The trace slope must be kept out of the blanking circuit because it would cause the picture to appear darker at the top and brighter at the bottom. The constants of R329 and C313 are selected to pass the spike and to flatten out the trace slope.

Condenser C318 and R326 and the cathode of V116B serve no purpose in the vertical blanking circuit and have no effect on its operation. They are part of the horizontal blanking circuit which will be described in a later paragraph.

Brightness-control Action. Condenser C172 acts as a blocking condenser to block off the cathode bias voltage of the cathode-ray tube from the cathode of V116B. Resistor R176 is in series with the cathode of cathode-ray tube V108 and connects to the brightness control which controls the bias and thus permits the brightness of the picture to be controlled. As the cathode is made more positive (the effect is the same as making the control grid more negative), brightness decreases.

The vertical sweep output spikes are positive. They are applied across R176 and drive the cathode voltage in the positive direction, and each spike occurs during vertical retrace. The positive voltage cuts off beam current and thereby blanks out the beam during the vertical retrace.

The spikes are of high enough amplitude to blank out retrace even when the brightness control is advanced well beyond any normal level. The result is that absolute blanking is obtained and the critical conditions of vertical blanking, mentioned above, are eliminated.

Vertical Sweep Oscillators. The vertical sweep oscillator described earlier is typical of the multivibrator type of sweep oscillator. One other type is in common use. It is called a blocking oscillator.

The blocking oscillator uses a single triode tube and a transformer. The transformer is generally small in physical size and may or may not have an iron core. Some blocking-oscillator transformers look like ordinary universal-wound broadcast receiver oscillator coils.

Figure 9 shows a typical blocking-oscillator circuit. Certain symbol numbers are repeated on this diagram from Fig. 2 to identify components which serve the same general purpose in both circuits.

The transformer is connected to provide regenerative feedback. It is designed to couple a great deal of energy from the plate circuit to the grid circuit.

How a Blocking Oscillator Works. For the purposes of describing the operation of the circuit it will be assumed that, for one reason or another, the tube has been resting in the cutoff condition and that a very small plate current starts to flow. When this happens, the rising plate current through the primary of the transformer induces a positive-going voltage on the grid, through C309. This causes a further increase in plate current, which, in turn, produces a further rise in grid voltage. The action is self-accelerating and happens quickly and violently. In very short order the grid is driven positive and very heavy plate current flows.

As in the earlier case, the action continues until a limit is reached. In this circuit, the limit is the maximum plate current which the tube can carry at the operating voltages involved. As soon as this limit is reached, the plate current stops rising and voltage which was induced in the secondary of the transformer starts to drop, driving the grid voltage moves downward in the negative direction.

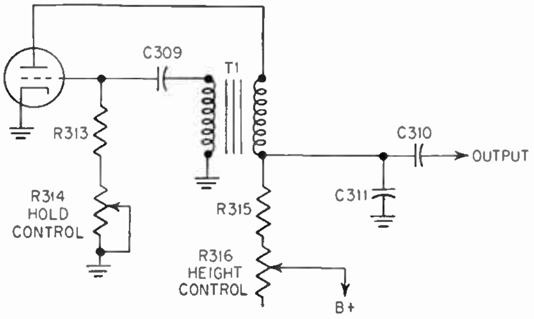


Fig. 9. A blocking oscillator as a vertical sweep generator

Once again the regenerative action goes to work; the small initial drop in grid voltage causes a drop in plate current which decreases the grid voltage further and this action continues until once again a limit is reached. The limit is now cut off; the grid voltage goes to cutoff very quickly, but reaches this point before the magnetic field in the transformer has collapsed fully. The field continues to collapse to zero and carries the grid far into the cutoff region in the process.

Vertical Hold Control Action. During the initial part of the action, the grid is driven heavily in the positive direction and heavy grid current flows, charging C309 as in the multivibrator described earlier. During the second part of the action, the grid is carried well into cutoff because of the charge on C309 and the tube then remains at cutoff while the charge leaks off through resistors R313 and R314 until plate current again starts to flow, and the cycle is repeated. As in the former case, these resistors control the speed of oscillation and the latter serves as the vertical hold control.

Waveform of Blocking Oscillator. The blocking oscillator is frequently used to do a part of the sawtooth-shaping job. Condenser C311 does this. This condenser is discharged, in fact is almost completely shorted out, when the tube carries its peak plate current. This develops the *retrace* portion of the waveform. Then, when the tube is cut off, the condenser proceeds to charge up through R315 and R316 at a fairly slow and steady rate and this forms the trace slope.

The voltage waveform of the oscillator shown here is a sawtooth, such as is shown in Fig. 3. A spiked waveform, however, such as is shown in Fig. 6 is needed. This may be provided by inserting a suitable resistor (perhaps 10,000 ohms or less) in series with C311, or by some other simple resistor-condenser network between the oscillator and the sweep amplifier.

In some sets, waveform shaping is done by using a *discharge* tube between the oscillator and the sweep amplifier. The oscillator is then used to drive the discharge tube whose sole function is to shape the waveform properly, after which it is fed to the sweep amplifier.

You should have little difficulty in identifying these circuits in different television sets. They will be identified on schematic diagrams as vertical sweep oscillator and as vertical discharge circuits (when used) or by similar, easily recognized terms.

Sync Input to Blocking Oscillator. Synchronizing connections are not shown in Fig. 9 because there is so much variation between sets as to how synchronizing pulses are injected. The pulses may be applied to almost any of the terminals of the transformer by making simple changes in this basic circuit. A common method is to feed the pulse into the bottom of the grid winding. The effect of synchronizing, as in the multivibrator, is to drive the tube out of its at-rest, cutoff, state by means of the vertical synchronizing pulses.

Over-all Horizontal System. The over-all circuit of the horizontal sweep system for the E chassis is shown in Fig. 10.

The oscillator tube is V118B which is connected as a Hartley oscillator. It is tuned to develop oscillations at 15,750 cps. Connected across the oscillator coil is a reactance tube, V118A, which provides a means of shifting the natural frequency as required to obtain proper synchronization. As the d-c grid voltage to the reactance tube is altered, the frequency is altered.

The oscillator tube feeds a signal to the discharge tube V117B which distorts the oscillations into a form which is better suited to the development of sawtooth current by the horizontal output amplifier, V119.

The amplifier delivers output energy through an autotransformer, T351, to the deflection yoke D351, to the horizontal blanking tube V116B, and to the high-voltage rectifiers (from the uppermost terminal of T351).

The damping tube V120 operates in conjunction with the horizontal amplifier in a manner which will be described later.

The speed of the horizontal oscillator is synchronized by an automatic-frequency-control (horizontal afc) system which will be described in a later chapter. For the moment it is enough to note that the speed is governed by a d-c voltage supplied to the grid of V118A. The horizontal speed is locked by means of the horizontal hold adjuster, R363.

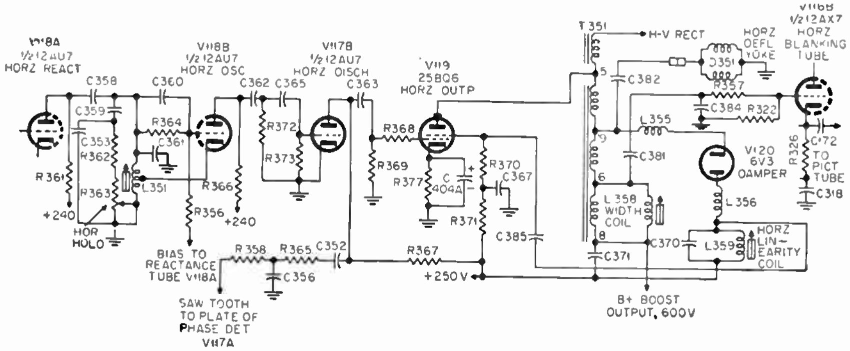


Fig. 10. The complete horizontal sconning system

The amplitude of horizontal oscillations, hence the width of the picture, is adjusted by means of L358, a coil with a movable slug. The linearity of the horizontal sweep is adjusted by means of another coil and slug, L359.

The output indicated as "BIAS TO REACTANCE TUBE V118A" is simply a d-c grid bias for the latter which is obtained as a by-product from the oscillator, V118B. It is fed to the reactance tube through R356.

The output indicated as "SAWTOOTH TO PLATE OF PHASE DETECTOR, V117A" is obtained from across C356 and fed through R358 to the phase detector. The function of this signal is in the automatic-frequency-control circuit and not of special interest at this time.

Plate power is supplied to the circuit from two different points in the power supply. The first two tubes, V118A and B, are supplied with 240 volts d-c. The point marked "B+ BOOST OUTPUT, 600 V" is an *output* point. The horizontal amplifier together with the damper develop this elevated d-c voltage, and it is used to supply plate voltage to the vertical sweep oscillator.

Horizontal Oscillator. The horizontal oscillator is a simple form of Hartley oscillator using a triode, V118B. The circuit is shown in Fig. 11.

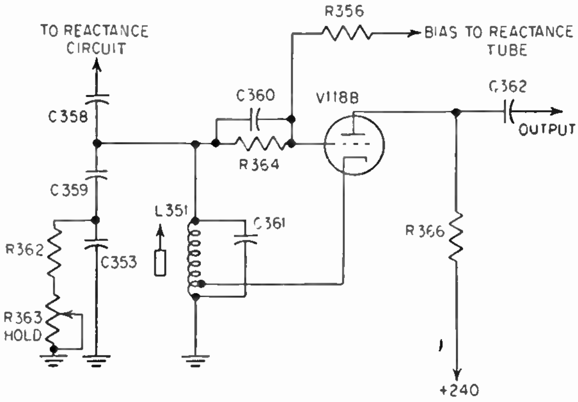


Fig. 11. The horizontal oscillator

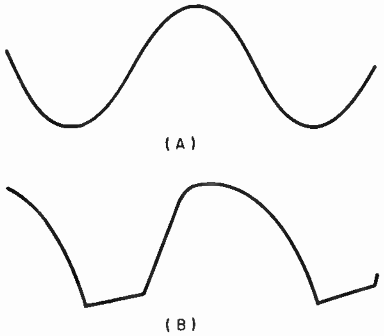


Fig. 12. Waveforms of the horizontal oscillator. The grid voltage A is a pure sine wave. The plate voltage B is a distorted sine wave

The cathode is tapped into the coil L351 to provide feedback. The coil is tuned to 15,750 cps primarily by C361, although C358, C359, R362, R363, and the reactance tube, V118A, also influence the resonant frequency. The coil is slug-tuned to permit the set to be adjusted by a serviceman in such a way as to idle at 15,750 cps when the hold control at the panel, R363, is near the center of its range.

Extremely heavy feedback is used (the coil is tapped well up from ground) to make the tube oscillate violently. This not only results in high output but also causes the waveform to be distorted into the form of pulses which is more satisfactory for the purpose than sine waves. The output waveform is shown in Fig. 12*B*. You can see how it is distorted into pulses when you compare the output with the waveform at the grid of the tube, shown in Fig. 12*A*.

In the course of oscillation, the grid draws current which flows through R364 during positive excursions of the grid voltage. Condenser C360 is charged by this current and leaves the grid with a resultant negative d-c bias. The bias voltage is used (because it is handy) to provide grid bias for the reactance tube; it is supplied to that tube through R356.

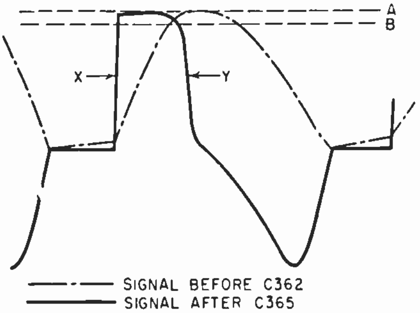


Fig. 13. The deliberate distortion of the oscillator output by differentiation

Horizontal Discharge Stage. The output of the horizontal oscillator is coupled through C362 and C365 to the grid of horizontal discharge tube V117B in Fig. 14. The networks composed of C362-R372 and C365-R373 each comprise a differentiator. They permit the high-frequency components of the waveform to pass without appreciable attenuation while the low-frequency components are suppressed. The result is further distortion of the horizontal oscillator output signal as shown in Fig. 13. The dot-dash line is the same waveform shown in Fig. 12*B* and represents the signal ahead of C362. The solid heavy line shows how the shape of the waveform at the grid of V117B is distorted after passing through the network. The purpose of the network is to obtain a well-defined and short pulse of voltage at the grid of the discharge tube. The pulse is that portion of the waveform between the letters X and Y on Fig. 13.

The amplitude of the voltage at the grid of V117B is extremely high if you compare it with the voltage needed to drive the tube fully. You can think of it as an overloading voltage because it swings much more widely than the tube is capable of following.

When the voltage first appears at the grid it causes it to draw grid current. The grid and cathode then act as a diode with the result that a negative bias voltage is built up across R373. This pushes the whole waveform downward in a negative direction until the most positive extremity is very close to zero, represented by line A in Fig. 13. The rest of the waveform is negative. Because the signal is large, most of it is so negative that it lies beyond the cutoff point of the tube. The cutoff level is shown as line B. As you can see, the discharge tube can carry current only during the X-to-Y pulse and it is cut off the rest of the time.

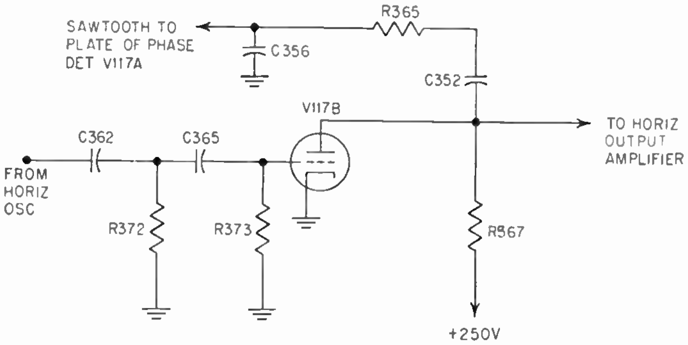


Fig. 14. The horizontal discharge stage

Switching Action. The discharge tube acts like a kind of switch because the driving signal acts alternately to cut the plate current off and then to turn it on again. This switching action takes place at a rate of 15,750 times each second.

The object of the discharge tube is to perform this switching action across the combination of resistors and condensers represented by C352, C356, R365, and R367. When the discharge tube conducts, it discharges the two condensers, thereby reducing the voltage almost to zero. This happens sharply as explained above. When the discharge tube opens (is cut off) the condensers proceed to charge up by drawing current from the plate supply through R367.

Output Waveform. The combination of C352, R365, and C356 charges and discharges in the manner shown in Fig. 15. It is called a peaked sawtooth because of the exaggerated valleys which are formed by the crooked rise characteristic. The values of the resistors and condensers in the network are carefully selected to produce this particular waveshape because it represents the form of voltage needed by the output amplifier to produce linear sweep *current*.

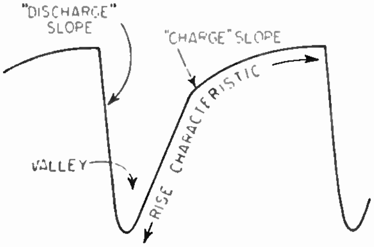


Fig. 15. Waveform used to drive the horizontal sweep output amplifier. This is a peaked sawtooth

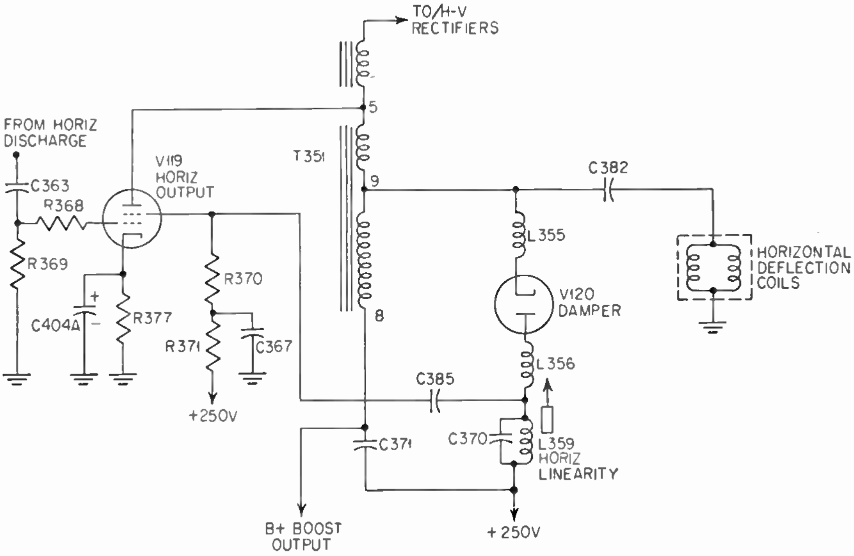


Fig. 16. The horizontal sweep output and damper circuits

Horizontal Output Amplifier and Damper. The peaked sawtooth voltage of the horizontal discharge stage is coupled through C363 in Fig. 16 to the grid of the horizontal sweep amplifier, V119, a beam-power tube. The action of this voltage is to drive the amplifier in such a way as to make it draw a pure sawtooth of *current* through the output transformer and consequently through the deflection yoke to which it is connected.

It would be no trick at all to accomplish horizontal deflection with an extremely simple amplifier circuit if a very large power tube and a correspondingly heavy power supply could be used, but the sizes needed for this kind of circuit simplicity are not economical. A great deal of power is needed to do a good linear deflection job at the rate of 15,750 sweeps per second, but the job must be done in practical television receivers with reasonably small power tubes. It is necessary to squeeze every bit of efficiency out of available and economical tubes, consequently a great deal of what looks like trick circuitry must be used. The amplifier under discussion is typical of commercial practice and includes the usual trick circuitry or, more properly, efficiency circuitry.

Horizontal Output Circuit Tricks. The most important contribution to sweep amplifier efficiency is the damping circuit; it employs a high-current diode, V120. If you trace the plate circuit of V119 from its plate to the +250-volt power supply in Fig. 16, you will see that its total current flows through V120. The damper, in other words, is in series with V119. The electron flow is from the cathode of V119 through the plate of the tube, through a portion of T351, and then in order through L355, V120, L356, and L359 to the positive end of the power supply.

The novel feature of this series circuit is that part of the *sweep output voltage* is fed back into it from terminal 9 of the transformer winding. Condenser C371 bypasses terminal 8 to an a-c ground. In order to understand how this works out you must know first what the scanning output voltage is doing and trying to do.

Sweep Output Waveform. The retrace voltage at the plate of the sweep tube appears as a sharp high-voltage positive pulse with an amplitude in the neighborhood of 5,000 volts. This is shown in Fig. 17A. This pulse is the result of the sudden interruption of current (by cutoff of the sweep tube) which causes the sweep to retrace. The action is similar to the manner in which an automobile ignition coil develops high voltage when the ignition points break the circuit.

Ordinarily, when no damping is used, this pulse starts a train of oscillatory excursions, during which time the voltage overshoots back and forth, first positive then negative, until it dies out. This is shown in Fig 17B. This would cause the cathode-ray beam to bounce back across the screen several times after the initial retrace. It would ruin the picture.

The initial high positive pulse is perfectly acceptable, in fact, is highly necessary since it serves to *retrace* the cathode-ray beam very quickly. The damping tube does not influence this pulse because it appears on its cathode as a positive voltage, and the tube cannot conduct in this direction.

Action of Damper. The first *overshoot* is in the *negative* direction, and thus it appears as a negative voltage on the cathode of the damping tube. This causes the damping tube to carry current. In effect, the damping tube shorts out the yoke during the overshoot; the tube absorbs the full brunt of the heavy overshoot. This is shown in Fig. 17C. The current flows into condenser C371 which, in effect, absorbs the full surge of the overshoot current. (In the process C371 becomes heavily charged.) The retrace is thus executed cleanly and the deflection circuit is ready for the next horizontal sweep.

The next sweep starts as the sweep tube starts to carry current again. Initially, it draws its current from the stored charge in C371 rather than through the damping tube. This is shown in Fig. 17*D*. (The charge on C371 holds the cathode of V120 positive with respect to its plate so it *cannot* carry current.) Once the charge of C371 is used up, to the degree that the cathode of V120 is again negative with respect to its plate, current is drawn from the power supply through V120 until the end of the sweep cycle, when V119 is again cut off; its plate voltage once again shoots up to about 5,000 volts. The cycle described above is then repeated.

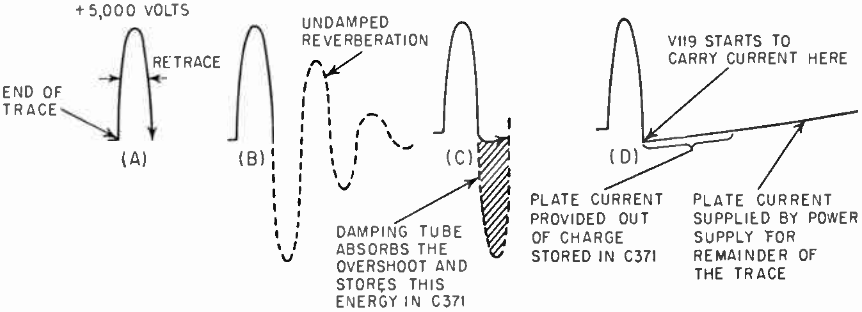


Fig. 17. Waveforms illustrating how the damper works

A great deal of efficiency is obtained with this circuit because the energy contained in the overshoot (about 30 per cent of the total power) is stored in C371 instead of being wasted. The energy is returned in the form of useful d-c power delivered out of C371. As a by-product of the operation, the voltage on C371 rises to an *average* of about 600 volts and is available as a B+ Boost voltage for other circuits.

Horizontal Sweep Linearity. Linearity is improved in an efficient manner by the way the screen voltage is provided to the amplifier tube. The voltage is obtained from one end of L359, where the voltage is pulsating in character. It pulsates because of the interrupted nature of current flow through V120, as described above.

The combination L359 and C370 forms a tuned circuit across which the pulsations of current appear. The phase and shape of these pulsations are altered when the circuit is tuned by means of an adjustable slug. Thus the screen voltage of the amplifier is a *pulsating* voltage whose phasing can be shifted with respect to the sweep. This permits a condition to be found which counteracts the normal tendency of the amplifier to produce a curvature in sweep.

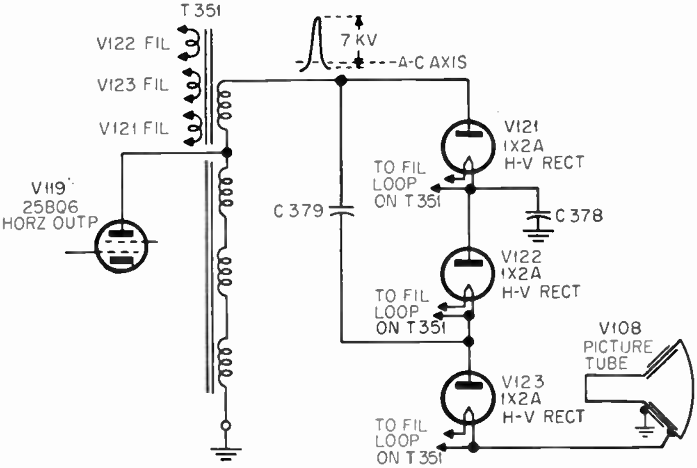


Fig. 18. The high-voltage circuit. This is a voltage-doubling circuit providing 14,000 volts of d-c output from 7,000 volt pulses

Sweep amplitude, or picture width, is adjustable by means of the width coil, L358 (not shown in Fig. 16). It is connected in shunt with a winding of the output transformer and permits the inductance to be changed. This has a direct effect on picture width.

High-voltage Supply. The cathode-ray tube calls for about 14,000 volts on its second anode. The current requirement is very small, thus its power requirement is correspondingly small. This makes it practical to use the high-voltage horizontal sweep pulses as the source of high-voltage d-c energy. The circuit in which this is accomplished is shown in Fig. 18. It is a voltage-doubling rectifier circuit.

Television high-voltage rectifier tubes are especially designed for this type of service. The most important feature of the tube (aside from its ability to handle the high voltage) is the low-power filament. The filament is designed for operation at a nominal voltage of 1.25 volts and requires only 200 milliamperes of current. This is done to permit the filament to be heated from a single-turn secondary coil on the *sweep* transformer. Figure 19 shows the general method as applied to a single tube.

One filament coil is used for each tube. The sweep transformer is actually made without the coil and simply provides clearance for it. The coil is made by looping a single turn of well-insulated wire around the core of the transformer when the set is wired up. The advantage of using the sweep transformer is that the high voltage (which appears between this filament loop and chassis) is confined to the physical area of the sweep circuit; this would not be true if the rectifier tubes were supplied with filament voltage from conventional windings on the power transformer.

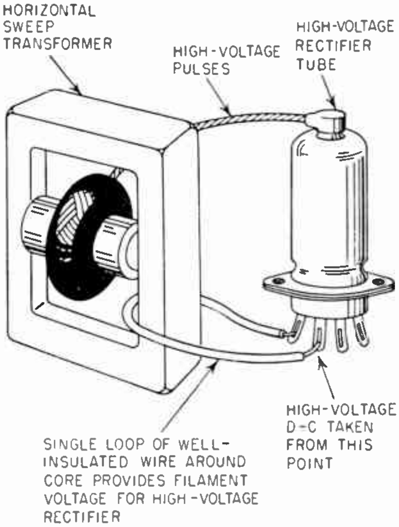


Fig. 19. How power is obtained to light the filaments of high-voltage rectifiers in television sets

The pulses at the plate of the sweep amplifier tube are stepped up in T351 to 7,000 volts before they are applied to the doubler.

Voltage Doubler. The 7,000-volt pulses are applied directly to the first rectifier, V121. They charge condenser C378 to 7,000 volts d-c. This voltage is applied through V122 to C379 and to the plate of V123, placing this point at a d-c level of 7,000 volts.

The high-voltage pulse is also applied to the plate of V123 through C379. This pulse, consequently, stands on top of the d-c voltage of 7,000, so that it rises to a 14,000-volt level on peaks. This is rectified by V123 and charges the condenser which is built into the coating of the cathode-ray tube. The total current drawn is so small that little charge is extracted from the condensers between pulses and the voltage remains steady at a 14,000-volt level.

Extra Rectifier. The middle rectifier, V122, is used to prevent condenser C378 from loading the output transformer. It works this way because the tube cannot conduct during the time that the pulse is applied. During this time, its cathode is driven upward by the pulse which reduces the plate-cathode voltage of V122 virtually to zero. Current can then flow only through V123 into the cathode-ray tube and through V121 into C378. Between pulses, current flows out of C378, through V122, and into C379 to charge the latter to the required 7,000-volt level.

At this point it would seem natural to wonder why the voltage isn't stepped directly up to 14,000 volts and then rectified by a simpler circuit. This would, no doubt, be done were it possible to do so without complicating the design of the sweep transformer more than the saving in circuitry is worth. The best compromise when more than about 10,000 and less than 20,000 volts are needed is to step the voltage only half as high as needed and then to double the voltage for the cathode-ray tube.

Horizontal Blanking. Horizontal blanking is used in the receiver under study in addition to vertical blanking. It is a circuit refinement which is not universally employed by manufacturers.

It was explained earlier in this chapter that vertical blanking is applied to the cathode of the picture tube without intermediate vacuum-tube circuits. The vertical is fed into condenser C318 in Fig. 10 and goes to the cathode of the picture tube through R326 and C172.

The blanking tube V116B serves only in the horizontal blanking function. It is connected as a cathode follower in order to provide good low-impedance drive to the picture tube. The plate of V116B is connected directly to the B+ Boost voltage.

Horizontal Blanking Action. The blanking signal consists of positive horizontal retrace spikes. These are obtained directly from terminal 6 of sweep transformer T351. Condensers C381 and C384 serve as a capacitive voltage divider, which reduces the signal on V116B to a suitable level. The series resistor R357 is used as a filter, acting with the input capacity of the tube to shape the spike so that it will do a cleaner job of blanking.

The network in the cathode of V116B, and particularly condenser C318, is used to prevent the horizontal blanking pulses from getting back into the vertical circuit where they could interfere with vertical interlace.

Despite the filter network in the grid of V116B, the horizontal blanking is still not as clean as it might be; it has a tendency to trail off after retrace, which causes the left-hand edge of the picture to be somewhat darker than it should be. This effect is cancelled by applying an opposing voltage on the accelerator element of the picture tube. The accelerator, pin 10, is connected directly to the top of the linearity coil, L359, where a counteracting voltage characteristic happens to be available. The net effect is good clean horizontal blanking.

Effect of Horizontal Blanking. The advantage of horizontal blanking is easily observed when the set is compared with one that does not employ it. When there is no horizontal blanking it is possible to get a background smear of extraneous light over a portion of the picture. The area affected may be at the left or right side, but rarely covers the whole screen. It is rather sharply defined in the vertical direction. The condition is most likely to occur when the horizontal hold control is turned one way or the other from the dead-center setting.

Horizontal Circuit Variations. There are perhaps as many variations in horizontal sweep circuitry as there are television manufacturers. Various forms of oscillator circuits are used along with different methods of controlling frequency. Basically, however, they are similar. If you have a firm understanding of the circuit which has been explained, you will have little trouble understanding the others which you come across.

There is a good deal more uniformity in the design of the sweep amplifier, damping, and high-voltage circuits. The variations between one modern set and another are mainly in smaller details.

One seemingly major change, developed over older receivers, is in the configuration of the sweep transformer and damping circuit. It is worth mentioning.

Older Sweep Output Transformers. Earlier receivers used straight transformers for sweep output; that is, the transformers had conventional primary and secondary windings. One of the principal reasons for this was that there were no suitable dampers such as the 6V3 available. (Note that the 6V3 has to be able to withstand high-voltage pulses between its cathode and heater.) It was necessary to invert the sweep voltage so that a right-side-up rectifier could be used as a damping tube, with its plate rather than its cathode fed with high-voltage pulses.

The damping circuit used was then essentially the reverse of the one used in the receiver under study but the principle is the same; that is, the direction of the voltages was reversed as well as the means of connecting the voltages to the damping tube.

New Sweep Autotransformers. The newer circuitry is more efficient in that it permits an autotransformer to be used. The autotransformer is basically a tapped coil and uses fewer physical turns of wire to get the same results. The old transformer's separate primary and secondary share the *same* turns in the newer autotransformer. As indicated, however, the autotransformer could not be used until suitable rectifiers were developed for use as dampers. The cathode-to-heater insulation had to stand pulses of 1,000 or more volts to be useful. The type 6V3 tube is typical of the new damping tubes that make the new circuit possible.

From the standpoint of general troubleshooting, there is no basic difference in the two circuits; consequently, there is no need to study both in detail.

Rectifier-circuit Variations. High-voltage rectifier circuits are all rather simple in circuitry. The circuit described above is a good example of a voltage *multiplier*. Receivers using smaller picture tubes ordinarily use a single rectifier tube. You will have the circuit diagram of such a rectifier if you mentally erase from Fig. 18 condenser C379, V122, and V123 and connect the cathode-ray tube to C378.

QUESTIONS

1. How is the vertical sweep multivibrator related to the scanning process on the picture tube?
2. How is the speed changed in a multivibrator? Express in terms of the full sweep cycle and its parts.
3. In what general area of a multivibrator circuit would you expect to find: (*a*) the HOLD CONTROL, (*b*) the HEIGHT ADJUSTER?
4. How is the free-running speed of a multivibrator related to the speed of the sync pulses and why is this relationship significant?
5. Why is it that the sweep output waveform, seen on an oscilloscope, is not a pure sawtooth?
6. What are the advantages of using a vertical blanking circuit?
7. How can you determine whether the vertical sweep oscillator uses a multivibrator or blocking oscillator circuit, if you have only the circuit diagram?
8. What function does the damper perform in the horizontal sweep circuit and what is its major contribution?
9. Why do high-voltage pulses appear at the plate of the horizontal sweep output amplifier?
10. Why is a loop used to provide filament power for the high-voltage rectifier instead of doing this with a special winding on the power transformer?

13

Synchronizing Circuits

Sync Amplifier and Noise Canceller. The circuit of the sync amplifier and noise canceller is shown in Fig. 1. V113A is the sync amplifier while V113B is the noise inverter. (The *complete circuit* is a canceller circuit—V113B alone serves only to *invert* the signal.)

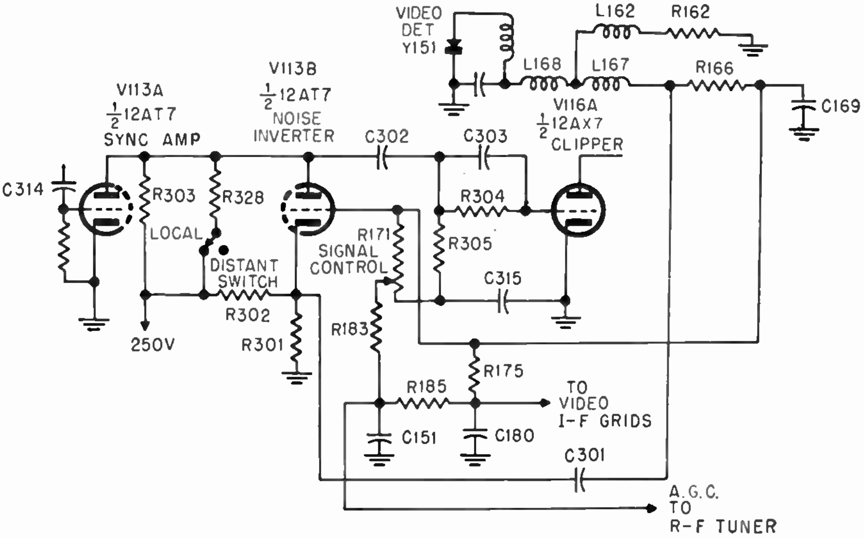


Fig. 1. The over-all sync circuit

The sync amplifier really amplifies the *video* signal rather than the sync signal alone because it is not until *after* clipping that the sync is removed from the video. The amplifier is nevertheless considered to be a sync amplifier because it serves the synchronizing circuits exclusively. The fact that the video signal is present is purely incidental to its function.

The video signal fed to C314 is obtained from the video detector at the junction of resistors R180 and R174. (See earlier schematic diagram of the E chassis.) These two resistors act as a voltage divider and provide the sync amplifier with a half-amplitude video signal through C314.

The polarity of the video signal from the video detector is negative-going. The output of the sync amplifier consequently is positive-going with the sync pulses pointing upward. The signal is amplified appreciably by V113A. It appears across the plate load resistor which is normally composed of R303 and R328 in parallel.

The output signal of the amplifier is fed through C302 and C303 to the grid of the clipper, V116A.

Operation without Noise. Under no-noise conditions, the noise inverter V113B is totally inoperative and may be considered to be absent. This is true because it is cut off by the combined action of two voltages: a positive voltage at the cathode provided by the voltage divider R301-R302, and a negative voltage applied to the grid through R166 from the diode circuit.

The cathode voltage is *fixed*. It provides the minimum voltage needed to cut off V113B, even when the diode bias voltage is very low, as it is with weak signals.

The grid voltage *varies* with the strength of the signal. The stronger the signal, the higher the negative bias, and the more solidly that V113B is cut off.

The voltage derived from the diode, incidentally, is the conventional form of agc voltage and is filtered to pure d-c by means of R166 and C169. It also passes on to the i-f and r-f circuits through R175 and the other associated resistors, where it performs conventional agc service.

The video signal is coupled to the cathode of the noise inverter through C301. Since it is negative-going and is fed into the cathode, it is in the right direction to overcome the cutoff bias, and will do this when it is strong enough. Without noise, however, the video signal is never strong enough to do this, because as the signal grows stronger, so does the negative bias applied to the grid. The relationship may be likened to the proverbial horse chasing a carrot suspended before him on a rod; he never reaches it no matter how fast he runs.

Operation with Noise. When a sudden noise burst occurs, the video voltage rises well above the level established by the bias (which can rise only slowly, following the average signal). This causes the noise inverter to break through, so that it conducts and amplifies the noise burst. The output of the inverter is developed across R303 and R328, the plate load of V113A, which it shares.

Because the video signal is fed into the *cathode* of V113B, it amplifies the signal *without* changing its polarization, and consequently develops *negative* output across the plate load.

While this is happening, the sync amplifier is also amplifying the noise burst, but its output is *positive*. Thus the two signals oppose and cancel during the noise burst. Actually, the noise inverter more than cancels the signal because it works at full video level, whereas the input signal to the sync amplifier is only half that amount, being reduced by a divider.

Loss of Sync Pulses. The idea behind this particular noise-cancelling idea is that it is better to paralyze the sync amplifier during a strong noise burst (at the risk of losing sync pulses during the momentary paralysis) rather than to let the noise get through to the synchronizing circuits where it would almost certainly cause the picture to jump either vertically or horizontally, or both. If the *hold* controls are set up properly, the sweep oscillators will tend to coast when the canceller knocks out a few sync pulses and the viewer may not notice any effect at all.

Signal Control. The noise canceller is somewhat more critical in actual operation than is described above. To be most effective, the canceller must be on the verge of operation at all times; it should tend to operate at the extreme tips of the sync pulses just as if they were noise, thereby cancelling out a little bit off the tops of these pulses, but not enough to reduce them materially.

This calls for an adjustment to be made by the serviceman at the time of installation or repair. The adjuster is R171 and is called the SIGNAL CONTROL. It is really an agc adjuster and serves to adjust the gain of the set so as to produce the correct level of video at the diode to meet the above conditions. It is adjusted to provide the most stable picture in the presence of noise. The adjustment is described fully in the manufacturer's installation and service notes.

The adjuster includes a switch which operates at the end of its travel, much like a power switch, although it happens to be at the clockwise end of rotation. This is in the increasing-sensitivity direction where the control is rotated for weaker stations. The click of the switch throws R328 out of the circuit and leaves the set in better condition to work with fringe signals. The removal of R328 increases the effective size of the plate load resistor for V113A and B by leaving only R303 in the circuit.

This increases the gain of the tubes and provides stronger sync pulses which are needed to produce good synchronizing on extremely weak signals.

Clipper and Sync Separator. The circuits of the clipper and sync separator are shown in Fig. 2. The latter is enclosed in the larger dashed box to help you identify it; the balance of the circuitry is that of the clipper.

The clipper is similar in appearance to a straight resistance-coupled amplifier stage. It works quite differently, however. The principal difference is due to the fact that the signal fed into the clipper is a great deal higher in amplitude than the tube can handle.

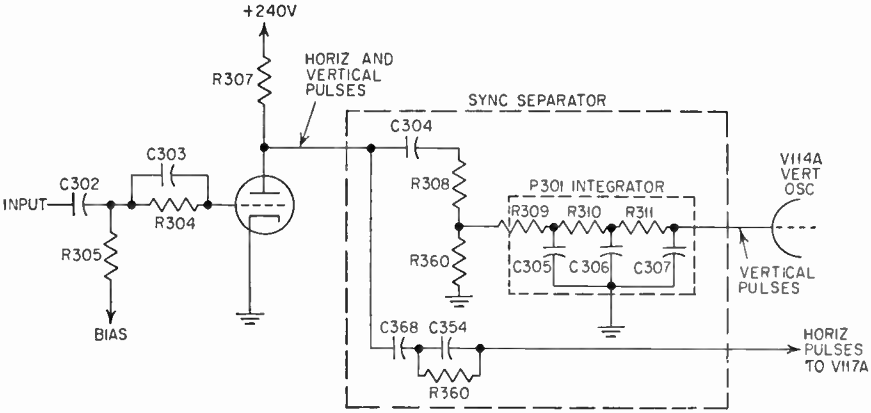


Fig. 2. The clipper and sync separator circuits

To illustrate the point, it may be assumed that the clipper can handle a signal as large as, but no larger than, 1 volt. Anything beyond this exceeds the control region of the grid since a 1-volt swing drives the tube to the limits of its output.

If, under these conditions, a 10-volt signal (for example) is applied to the grid, only 1 volt of that signal will work on the tube; the balance will be somewhere beyond the limits at which it can work. As a consequence, only a part of the input signal will be reproduced and the balance will have been simply eliminated.

Action of Clipper. The function of the clipper is to pass only the sync pulses. These stand out alone on top of the video waveform, occupying the uppermost (most positive) 25 per cent of the amplitude, as illustrated in Fig. 3A.

In order to pass these pulses, the clipper must work in such a manner as to operate only on the most positive region of the applied signal. Such a mode of operation is obtained by permitting the clipper to develop grid bias from the signal itself.

The external bias provided through R305 is small compared with the input signal. As a consequence, the positive peaks of the signal cause the tube to draw grid current. This current charges condensers C302 and C303 which assume a negative potential at the grid of the tube. This negative voltage assumes a balanced condition automatically, such that the most positive peaks of the signal are just enough to drive the grid to zero voltage. This is shown by the uppermost dotted line in Fig. 3A. (Really, the pulses drive the grid voltage minutely into the positive region and thus keep replenishing the slow loss of charge in the condensers; for all practical purposes, the signal can be assumed simply to reach zero.)

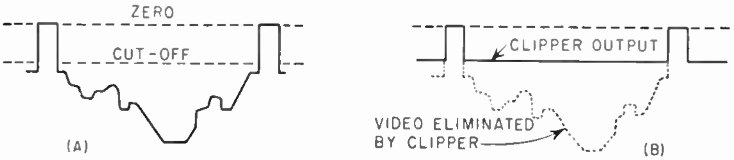


Fig. 3. Clipping action illustrated by waveforms

This balanced or compensating grid voltage displaces the entire video waveform in the negative direction so that most of it lies in the cutoff region of the tube. This is shown by the lower dotted line in Fig. 3A. The plate current of the tube is thus influenced only by the sync pulses.

Clipper Output. The output of the clipper is free of any video information and contains only the sync pulses which are needed to synchronize the sweep circuits. This is shown in Fig. 3*B*.

Because both the horizontal and vertical sync pulses lie in the uppermost 25 per cent region of the video signal, both sets of pulses appear across R307, the plate load resistor of the clipper. These must be separated from each other before they can be used.

Pulse Separation. Separation is done in the circuitry shown in the larger dashed box on Fig. 2. The basis for doing this is the difference in the characteristics of the two sets of pulses. The horizontal pulses occur at a high frequency (15,750 per second) and are each only about 6 microseconds in duration. The vertical pulses occur at a low rate (60 per second) while each pulse is about 800 microseconds long.

Pulse Differentiator. The branch of the circuit containing C368, C354, and R360 leads to the horizontal sweep section. The two condensers are relatively small, therefore offer a high impedance to the vertical pulses while passing the horizontals with little loss. The circuit is sometimes referred to as a differentiator and is distinguished for its ability to pass highs while rejecting lows. (The differentiator actually includes not only the condensers shown in Fig. 2 but also the load resistor into which the circuit works. To preserve simplicity, that portion of the circuit is not shown.)

The upper branch of the circuit contains, first, a coupling condenser C304 and voltage divider, R308-R360. These components are not involved in the work of pulse separation. They are simply a means of coupling the signal in the vertical circuit at a lower and more suitable amplitude level.

Pulse Integrator. The remainder of the components in the upper branch (those contained in the smaller dashed box) compose the integrator which works in the reverse manner of the differentiator. That is to say, it passes the vertical pulses with little loss, yet rejects the horizontal pulses completely.

The integrator is made up of three sections in sequence, each with a series resistor and shunt condenser. This is done because this form of integrator causes less distortion of the vertical pulse than would be obtained with a single or two-section integrator. Simpler integrators than the one shown, however, are used in some commercial television sets.

Sync-separator Summary. In summary, the circuits shown in Fig. 2 include the clipper which rejects the picture information from the video signal and passes on only the composite (horizontal plus vertical) sync signal. The separator circuits separate these two sync signals from each other and provide them individually to their respective sweep sections.

The vertical synchronizing pulses are used to synchronize the vertical sweep oscillator directly, as described in the preceding chapter. The horizontal sync pulses are used to synchronize the horizontal sweep by means of the automatic-frequency-control circuit, to be described below.

Effects of Noise. The means by which the vertical oscillator is synchronized has already been described. The method is simple and direct; each sync pulse triggers the start of a new field. This is called direct synchronization.

This method works out well for the vertical sweep because it is relatively immune to the effects of ordinary noise. This is true because the integrator, in performing its task of sync separation, rejects not only the horizontal sync pulses but also most of the background noise.

Unfortunately, the same is not true of the horizontal circuit. The differentiator, in providing passage for the horizontal sync pulses, also passes random noise along with them. The result, under practical conditions of receiver operation, is a string of ragged synchronizing pulses not really suitable for direct synchronization use.

Early Television. Television receivers built before World War II did, in fact, use these pulses to control the horizontal oscillator directly in the same way as is done in the vertical sync circuit described earlier. If you have seen one of these prewar receivers in operation, you will immediately understand why the method is poor. Under normal signal conditions, the edges of the picture are jagged, much like the edges of a torn piece of cloth. The edge, of course, is not in itself particularly important; what the jagged edge reveals is that the horizontal lines are not accurately placed on the screen. One line may be slightly to the left, another a little to the right, and so on. As a result, the fine picture elements fail to line up properly, and good definition is impossible.

Flywheel Sync. The modern approach is to use some form of flywheel synchronization in the horizontal circuit. The horizontal oscillator is permitted to run free, in a sense, while synchronization is obtained by holding its *average* speed at the right value.

The horizontal oscillator described in the preceding chapter is such an oscillator. It runs free to the degree that no synchronizing pulses are injected into its circuitry. Instead, a reactance tube, V118A, is provided as a means of altering the frequency of oscillation.

The phase detector, V117A, does the major part of the synchronizing job. It senses the speed and phase at which the oscillator is running and compares this with the incoming sync pulses. It then develops a d-c voltage of such a characteristic as to keep the oscillator running correctly. The elements of the afc system are symbolized in Fig. 4.

Phase Detector. The circuit of the phase detector is redrawn slightly in Fig. 5 to simplify the explanation which follows. The only change is the elimination of R354 and C351, neither of which plays a part in the basic operation of the phase detector. These components are employed only to provide a suitable operating bias for the reactance tube V118A to which the phase detector is connected.

The phase detector is operated without plate voltage. You can think of it as a grid-controlled diode if this helps. Synchronizing pulses are applied to the circuit through C368 and C354 (shown in Fig. 2) to the cathode of V117A. Two equal return-resistors R352 and R353 are shunted across to tube elements to provide a d-c return path for the diode elements, which are the grid and plate. The entire circuit is bypassed to ground by a condenser, C355.

The synchronizing pulses are negative in polarity, thus they drive the cathode downward, leaving both the grid and plate relatively positive.

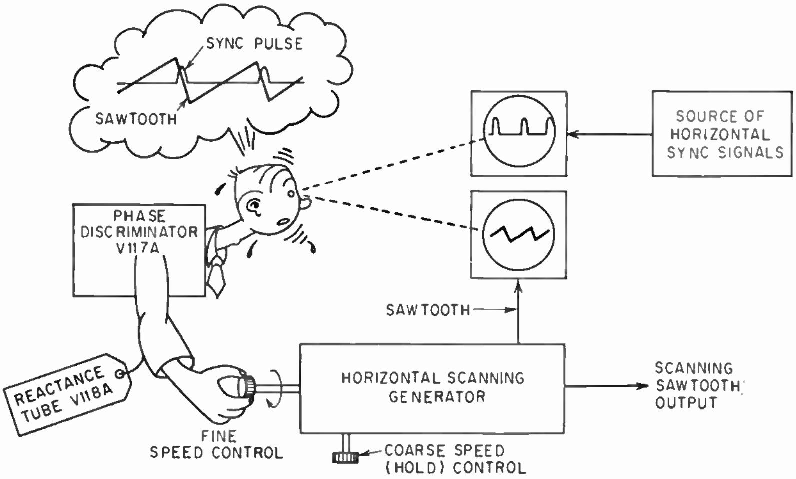


Fig. 4. Illustration showing the dynamic action of an afc system

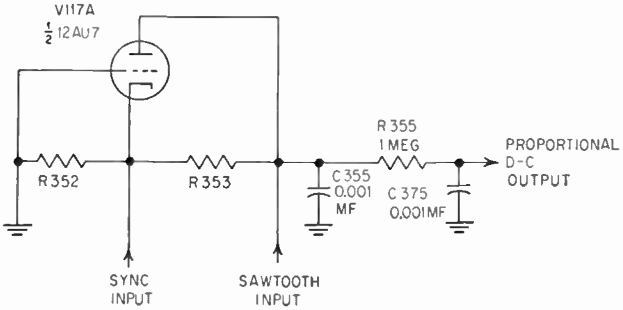


Fig. 5. The phase-detector circuit

This is a natural condition for current flow from the cathode to both elements, and grid and plate current therefore flows.

Current Paths. At the low voltages which are employed, the two currents divide out equally. Thus the plate current flowing from cathode to plate and through R353 is equal to the grid current flowing from cathode to grid and through R352. The two currents flow in *opposite* directions through the resistors because of the way in which they are connected.

(Trace out the flow.) The net result is that they cancel so far as the output voltage is concerned. In other words, there is no voltage developed across C355 or C375, no matter how many pulses are applied nor how strong they may be.

Effect of Sawtooth Input. Up to this point, the circuit produces no output and does no useful work. The operation is modified, however, when a second signal is fed into the circuit. This signal is sawtooth, obtained from the horizontal discharge tube V117B and applied to the plate of the phase detector.

A sawtooth is a balanced waveform with respect to ground, that is, it sweeps from negative to positive and back again to negative, etc. The voltage is zero at the axis of the sawtooth. This is illustrated in Fig. 6.

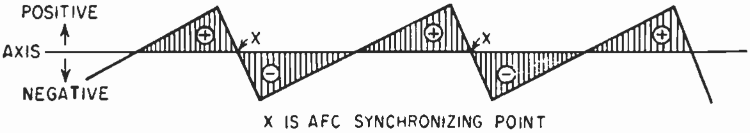


Fig. 6. This waveform shows how a sawtooth voltage disposes itself about an a-c axis. The voltage swings equally from positive to negative

Timing. If, by coincidence, the relative timing of the two signals is such that the sync pulse appears just when the sawtooth is passing through zero (the sync pulse is very sharp compared to the sawtooth) the balanced zero-output condition mentioned earlier is unchanged. That is, the sawtooth has no influence on the way the grid and plate currents divide, and no output voltage is obtained at C355.

If, on the other hand, the sawtooth should shift a little so that the pulse appears when the sawtooth is on the *positive* side of zero, the currents in V117A no longer divide equally. More plate current flows than grid current because the plate voltage is now equal to the sync pulse *plus* the voltage added by the sawtooth, whereas the grid voltage is due to the sync pulse only.

If, on the other hand, the sawtooth were to shift a little the other way so that now the sawtooth is on the *negative* side of zero when the sync pulse appears, the plate current will decrease. This result is obtained because the sync pulse on the plate is now *reduced* by the sawtooth whereas the pulse on the grid again remains unchanged.

Explanation of Sync Action. Before thinking any further about how the phase detector works, it would be most helpful to think about what the *shifting* of the sawtooth really means, because it will help you understand what is going on in the television set while this is happening. There is no need to think in abstract terms about a "shifting sawtooth."

When the television set is perfectly synchronized, the horizontal sync pulse occurs some time during retrace. The sawtooth obtained from the horizontal discharge tube (the one we are talking about) is a small but accurate sample of the horizontal deflection voltage at the cathode-ray tube.

Putting these ideas together, this can be concluded: If the horizontal sync pulse appears at the exact moment when the sawtooth is in the middle (see point X in Fig. 6) of its retrace, and does this again and again, the horizontal sweep can be assumed to be perfectly synchronized.

To go further with the idea: If the horizontal oscillator should now start to speed up ever so little, the sync pulse will, quite naturally, hit at a moment *after* the sawtooth has passed zero on its retrace, when it is somewhat negative. Conversely, should the horizontal speed slow down a little, the sync pulse would appear before the retrace has reached zero, while it is still positive.

Sliding Picture. The *tendency* to speed up or slow up might appear on the television screen as a slight shift of the picture to the left or to the right. It would be exactly centered when the speed is adjusted normally.

Thus, the shifting sawtooth effect is simply a direct manifestation of the tendency for the television picture to slip sideways, one way or another, as the horizontal oscillator starts to run off-speed.

Action of Phase Detector. This effect, as explained above, is sensed by the phase detector as an unbalance in the currents which flow through R353 and R352. When the unbalance is in one direction, the output voltage at C355 rises in the positive direction; when the unbalance is in the other direction, the output voltage falls in the negative direction. When balance prevails, the output voltage is zero.

In short, the phase detector senses whether the television picture is *phased* properly (centered), in which case the speed is then known to be correct; or whether it is trying to slip ahead or behind. The phase detector delivers an output control voltage which is representative of these conditions. The voltage is identified as the "proportional d-c output" in Fig. 5. It is a d-c voltage because R355 and C375 filter out the pulsations caused by the sawtooth and the sync pulses.

It may take several hundred pulsations one way or the other to make the d-c output voltage change; consequently the circuit is fairly immune to the small random errors caused by noise riding along with the sync pulses.

Phase Detector Output. The actual change in output voltage occurs in *either* direction because current flows in one direction through R352 and in the opposite direction through R353. At zero output, the voltage across R353 is equal but opposite to the voltage across R352. When the current through R353 is greater than the current through R352, negative output is obtained. When the current through R353 is less than the current through R252, positive output is obtained.

Reactance Tube. The d-c output voltage is fed through a filter to the grid of the reactance tube V118A. That tube is connected in shunt with the horizontal oscillator coil, L351. When the d-c control voltage permits the current to *increase* in the reactance tube, it *lowers* the frequency of the oscillator. When the control voltage *reduces* the current in the reactance tube, the oscillator frequency *increases.*

Review of Horizontal AFC Action. The complete system which includes the phase detector, horizontal reactance tube, horizontal oscillator, and horizontal discharge constitutes a form of closed loop. When sync pulses are fed into this loop, the system homes on those pulses in such a way that they come to rest in the *center of the horizontal retrace,* where they belong.

Synchronization is obtained initially because the horizontal oscillator is adjusted to run at almost the right speed by itself. This makes it easy to fall into step. If it tries to run much too fast or too slow, synchronization may take a long time or may not occur at all. You will observe this effect readily on almost any television set by setting the horizontal hold control in different positions and noting how the set pulls in, or fails to pull in, at these different settings.

Ball-balancing Analogy. In mentally reviewing the operation of the circuits just described you may wonder why synchronization does not also occur when the sync pulse appears in the center of the *sweep,* because the sawtooth voltage is zero at that point also. The answer is that it *is* possible for this to happen under very tricky conditions. (The picture will appear to be split in the middle on the television screen, with the right half on the left and vice versa.) The condition, however, is quite unstable, and is analogous to trying to balance a ball on top of another ball—it's possible, but it will fall off easily. The proper condition of synchronization, wherein the sync pulse rests in the center of the *retrace,* is very stable and is analogous to balancing a ball in the bottom of a bowl. Not only is it easy to place there, but it is hard to keep it off the bottom—the ball simply rolls back into place of its own accord.

The reason for these opposite conditions is that the slope of the retrace is *opposite* to the slope of the sweep. As a consequence, one slope (the sweep) acts to drive the pulse *away* from center because it develops error-voltages which work in the *wrong* direction to bring about a zero balance; the other (retrace) develops error voltages which work *toward* balance. Review the operation in your mind, comparing the two conditions with each other, and you will see this.

Sync Circuit Variations. The variations in general sync circuits, including the horizontal afc system, represent perhaps the widest variations found in commercial television receivers. The exception is the clipper and sync separator circuits which are very similar in most sets.

It is common in commercial television sets, for example, to feed the video signal directly into the clipper without employing a sync amplifier ahead of it. When this is done, the signal is usually taken from the output of the video amplifier where the signal level is higher than it is at the video detector.

It is also quite common to find sync amplifiers *following* the clipper, in which position they are truly sync amplifiers since they handle sync *after* the video has been removed by the clipper. The sync amplifier may be a *composite* sync amplifier, handling the composite sync signal before the horizontal and vertical signals are separated from each other; or it may be a vertical sync or horizontal sync amplifier handling these signals individually after separation; or a combination of such amplifiers may be used.

In general, these circuits are quite simple in that most of them resemble standard resistance-coupled amplifiers. They are also easy to locate and identify because, as a rule, they are clearly identified by name on the diagrams provided by the manufacturers.

Noise-cancelling circuits are not used by all manufacturers.

Horizontal AFC Variations. Horizontal afc circuits take a variety of forms. The greatest variation is in the circuit of the phase discriminator. Frequently the circuit employs a double diode tube such as the type 6AL5. The horizontal sync pulse may be fed into the discriminator in a number of different ways. The basic operation of the discriminator, however, is the same as that of the circuit described. The description provided should permit you to recognize most adjusters and controls associated with horizontal afc circuits.

All afc circuits compare the phase (position) of the horizontal sync pulse with respect to the scanning sawtooth wave generated in the set as demonstrated in Fig. 4. This latter signal may be obtained directly from the oscillator, from the discharge tube as in the circuit described, or from the horizontal sweep output stage.

The most popular method of controlling oscillator frequency is with a reactance tube as described. Pentodes are sometimes used to do this job.

There are a number of varieties of agc circuits. Some sets employ an *agc amplifier,* while others use a form of *keyed agc.* Here again, it is difficult to find a typical circuit. Any attempt to describe the general type is apt to be more confusing than helpful. It is probably much better to study the manufacturer's service data when you come across one of these circuits which you don't understand. Usually, special circuits of this nature are explained in the service data.

QUESTIONS

1. Describe in general terms, the signal: (*a*) entering the clipper, (*b*) leaving the clipper, (*c*) leaving the differentiator, (*d*) leaving the integrator.
2. How does horizontal afc differ in operation from the direct sync used in early television?
3. Describe in general terms the signals fed into the horizontal phase discriminator.
4. Describe the output of the discriminator.
5. What is the function of the reactance tube?
6. State three titles for functional stages using the word "sync" which you might find on a television schematic.
7. What signals would these stages handle?
8. On what part of the sweep sawtooth does the horizontal sync pulse lock?
9. Why is it that the sync pulse does not lock equally well on either portion of the sawtooth?

14

Troubleshooting Television Sets

Fundamental Approach. When you are dealing with a set that has no obvious defects, you can search aimlessly in a hit-or-miss fashion for a defective part, or you can apply diagnostic methods to narrow down the area of search.

Obviously, the first course is the poorer one not only because it is unprofessional but, more important, because it usually requires a great deal of time and effort. Sometimes it is almost impossible to find the defect by this means. An exception is the work sometimes done in checking all tubes in a set on the chance that one of them may be bad. This work is justified by the ease with which it is done and by the high percentage of problems which can be solved in this way. The situation is entirely different, however, when the defect is something other than a tube.

Troubleshooting Tools. The best tool at your disposal in diagnosing television defects is the knowledge you have about the basic functions performed in the set. These functions should be arranged in your mind's eye in an orderly and logical manner. To put it more directly, you should be able to visualize the basic functional block diagram of the typical receiver you have studied.

There is no need to commit the diagram to memory right from the start but you will find that, as you use it, the diagram will become more and more familiar to you. Finally, you will discover that you no longer need to have it before you; it will be firmly locked in your mind.

Block Diagram of Set. Often you will be helped by the manufacturer's service manual, because it will provide a functional block diagram for his particular set. In this case it is not only helpful but wise to use his diagram in place of your own because it will be tied more closely to the specific tubes and components used in the set.

In most cases, however, he will not provide a block diagram but will expect you to construct one in your mind. Help is almost always given on the schematic diagram or tube layout diagram by the manner in which the circuits and tubes are named. The names are functional and are similar to those used in this book. This will permit you to visualize a functional block diagram in terms of the specific set on which you are working.

The advantage of a block diagram is that it tells you *what* the set and its separate sections are supposed to do rather than *how* they do these things. You will find that most of your repairs will be made without really studying the specific circuit but rather by recognizing what function is suffering and where its components are located.

Example of Troubleshooting. To illustrate the point, the symptoms of a television set may suggest the possibility that the vertical sweep oscillator is not working. You may then locate the vertical sweep oscillator tube and make some initial voltage checks. You may discover that there is no plate voltage on the tube. In tracing the circuit, you may find that a plate resistor is open and that replacing it cures the set. The repair is completed, even though you may not have gone to the trouble to find out whether the oscillator is a multivibrator or a blocking oscillator, and there is no need to do this except perhaps to satisfy your curiosity.

The same general situation prevails with most defects. That is, it is more helpful to know what section of the set appears to be at fault than to be familiar with the circuit in detail.

There are times, of course, when knowledge of the specific circuits is helpful or even necessary. This is true when you can come across an especially difficult job. It is therefore wise to study as many circuits and read as many technical articles as you can with respect to television sets. Even in such a case you will find it best to start your diagnosis with a functional block diagram as a mental reference.

Five Basic Outputs of a Television Set. A convenient and practical way of looking at a television set is to assume that it consists of five separate parts, each with its own basic job to do. This is quite different from an ordinary radio set which has only one job to do, namely, to deliver an audio signal. When each of the five jobs is done in the television set, it will work properly. When any one is improperly performed, there will be trouble.

The first step in diagnosis is to determine *which* one of these functions is deficient. You can then use ordinary circuit-testing techniques to find out *why* it is deficient.

The five basic functions are these:

The set must deliver an audio signal.
The set must deliver a video signal.
The cathode-ray tube must be scanned vertically.
The cathode-ray tube must be scanned horizontally.
High voltage must be delivered to the cathode-ray tube.

These five functions have been selected as the basic ones because they represent a practical grouping. There might be some argument as to whether it is legitimate to consider the delivery of high voltage as a basic function. This is considered valid to troubleshooting, however, because a great number of practical problems involve this function as a separate consideration.

Each of the basic functions is performed by certain parts of the whole television set. In order to make certain that you understand how each of these applies to the matter of troubleshooting, the functions will be described below in terms of the circuits which are involved.

Audio Signal—Intercarrier Set. The audio signal is produced in an intercarrier set by the method shown in Fig. 1.

The sound signal enters the tuner through the antenna. It appears originally at the r-f frequency assigned to the sound signal of the specific television channel. It is amplified by the r-f amplifier and then converted to the sound i-f frequency used in the television set. The sound i-f signal is then amplified further by all of the *video i-f amplifier* stages.

The video signal passes through these same circuits. Both signals therefore appear together at the video detector. The signals beat against each other upon detection and produce an intercarrier beat of 4.5 mc which contains a mixture of both the picture signal (which is amplitude-modulated) and the sound signal (which is frequency-modulated).

The intercarrier beat signal is then amplified further by the *sound i-f amplifier* which is tuned to 4.5 mc. It is limited by the sound limiter where the a-m video signal is stripped off the beat signal, leaving only the f-m sound signal. This signal is detected by the f-m detector, amplified by a conventional audio amplifier and fed to the speaker where it is heard.

Reception of the sound signal requires that the video signal get through *at least* as far as the video detector. In other words, when the sound is normal in an intercarrier set, you know that the video signal has gotten through that far. If the picture should happen to be dead while the sound is normal, you know that the picture trouble must lie *beyond* the video detector.

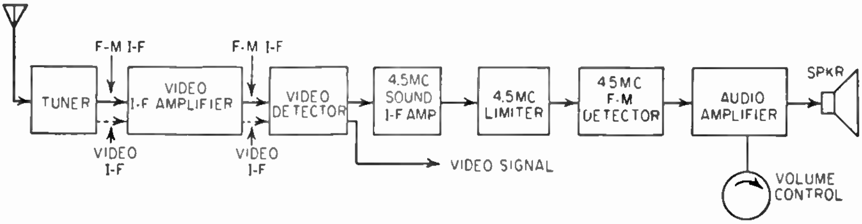


Fig. 1. Block diagram of the path taken by the sound signal in an intercarrier set. It starts as an f-m modulated r-f signal at the antenna and ends as an audio signal at the speaker

Audio Signal—Split-carrier Set. The path taken by the sound signal in a split-carrier set is illustrated in Fig. 2. The signal is handled in the tuner exactly as described above. Both the video i-f and sound i-f signals are fed into the video i-f amplifier.

The sound i-f signal may be amplified by one or two of the video amplifier stages after which it is branched off to its own i-f amplifier stage which is sharply tuned to pass only the sound i-f signal. After this branching point, the sound and video signals are handled separately. At no time do they beat against each other in any material sense.

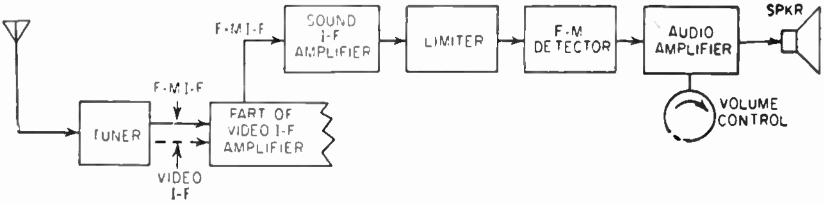


Fig. 2. Block diagram of the path taken by the sound signal in a split-carrier set. It starts as an f-m modulated r-f signal at the antenna and ends as an audio signal at the speaker

The sound i-f amplifier, limiter, and detector are very similar to the corresponding circuits in an intercarrier set, except for the fact that the operating frequency is a good deal higher than 4.5 mc. It may be around 22 mc, depending upon the exact choice of the manufacturer. The signal passing through these circuits is the sound i-f signal *only,* without video interference, but perhaps with locally picked up noise. The audio amplifier and speaker are conventional.

The sound signal depends upon only a *part* of the video i-f amplifier for operation. This part may involve one or perhaps (but rarely more than) two video i-f stages. A failure can occur in the video circuits *after* the sound take-off point without affecting the sound performance.

Video Signal. The path taken by the video signal in both intercarrier and split-carrier sets is shown in Fig. 3. The signal starts as an amplitude-modulated video signal at the assigned video r-f frequency of the specific television channel. It is amplified by the r-f amplifier in the tuner and then converted to the video i-f frequency. It is then amplified by the video i-f amplifier, through which the sound i-f signal also feeds. The sound signal is rejected from the video i-f amplifier in split-carrier sets at or after the point at which the sound signal is branched off. In intercarrier sets, the sound signal is permitted to pass all the way through to the video detector.

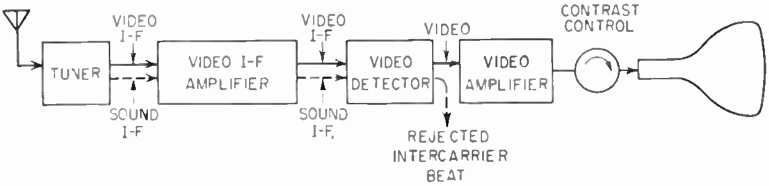


Fig. 3. Block diagram of the path taken by the video signal. It starts as an r-f signal at the antenna and ends as a video signal at the cathode-ray tube

The video i-f signal is detected by the video detector. It is then amplified by the video amplifier and fed to the control element of the cathode-ray tube where it modulates the intensity of the cathode-ray beam. The intercarrier beat is prevented from reaching the cathode-ray tube by means of a suitable trap.

Tracing the Video Signal. The mere fact that the video signal is getting through to the cathode-ray tube does not ensure your *seeing* a picture, no more than you can be certain of hearing sound just because an audio signal is fed to a speaker (the speaker may be bad). The cathode-ray tube may be bad, the scanning circuits may be inoperative, or there may be no high voltage for the cathode-ray tube.

In actual troubleshooting work you rarely come across a case in which it is necessary to check for the presence of a *video* signal by some means other than by simply looking for it on the cathode-ray tube. This is true because the video can be seen on the screen when *the other* circuits are working properly; when some other defect exists (scanning, high voltage, or cathode-ray tube) you will automatically be concerned with the other problem first. Then, after it has been taken care of, you can worry about whether or not you have a video signal.

Sometimes only the video amplifier may fail while all other circuits work properly. In this case, the cathode-ray tube will be illuminated and you will see the scanning lines, but there will be no evidence of beam modulation. The illumination will be uniform all over and will not even show noise specks. This form of presentation is called a raster or sometimes a blank raster.

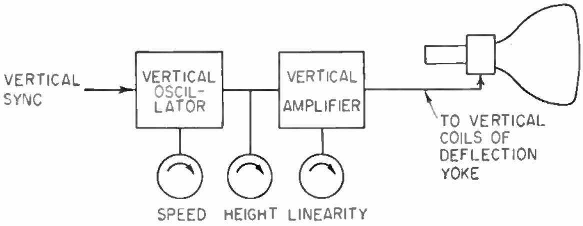


Fig. 4. Block diagram of the vertical scanning system. The signal is generated by the vertical oscillator and finally appears as sawtooth current through the yoke

Vertical Scanning. The circuits involved in the vertical scanning function are shown in Fig. 4. The scanning signal is generated *right in the television set* by the vertical sweep oscillator. It is then amplified by the vertical sweep amplifier and fed to the vertical coils of the deflection yoke where it deflects the beam along the vertical axis of the picture.

You can tell rather quickly whether the vertical scanning circuit is working just so long as the cathode-ray tube shows some light on its screen. If the beam is scanned so that it reaches from the top of the screen to the bottom, or very nearly so (no matter how *wide* or *narrow* the picture may be), the vertical scanning circuit is known to be working. The picture may be only as wide as a single line so that all you see is one vertical line. In this case, the horizontal sweep is obviously defective whereas the vertical is O.K. (This case is unusual in that the high voltage normally drops out with a failure of horizontal sweep and the cathode-ray tube goes blank, so you see nothing.)

If the vertical scanning circuit alone should fail, you will see nothing but a single *horizontal* line as shown in Fig. 6. If the vertical scanning circuit should lose only a *part* of its power output for one reason or another, the picture may look like a horizontal strip with a height of from a little more than one line up to any dimension short of filling the screen.

Horizontal Scanning. The circuits involved in the horizontal scanning function are shown in Fig. 5. The operation is quite similar to the vertical scanning circuit except that a damping stage is involved. In addition, the sweep-retrace pulse is fed to the high-voltage rectifier where it is used to provide the high d-c voltage for the cathode-ray tube.

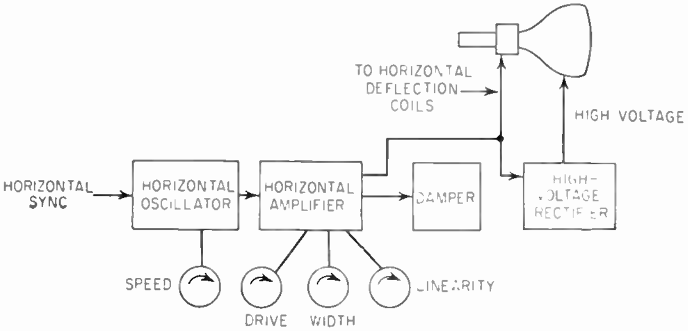


Fig. 5. Block diagram of the horizontal scanning system. The signal is generated by the oscillator and finally appears as sawtooth current through the yoke. The output voltage is also rectified to provide high-voltage d-c

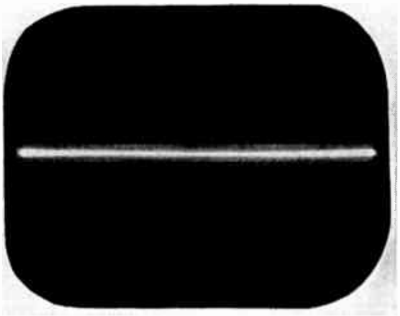


Fig. 6. Appearance of the screen when only the vertical sweep fails. (General Electric photo)

When the horizontal sweep circuit goes completely dead, the high voltage also fails and the cathode-ray tube goes blank. In most cases this is enough to suggest to you the possibility of a horizontal sweep failure which you would look for even before you look for failure in the high-voltage circuit.

When partial failure occurs, three things usually happen; the sweep width will decrease, the picture height will *increase*, and the picture will become quite dim and blurry (see Fig. 7). The latter two effects are the result of reduced high voltage.

High Voltage. The high-voltage circuit is contained in Fig. 5. This circuit is essentially a rectifier or a combined rectifier and voltage multiplier. It obtains energy from the horizontal sweep amplifier and rectifies this energy. It provides filtered d-c voltage to the cathode-ray tube at a level of from 10,000 to about 16,000 volts, depending upon the size of the picture tube and the operating conditions desired by the manufacturer.

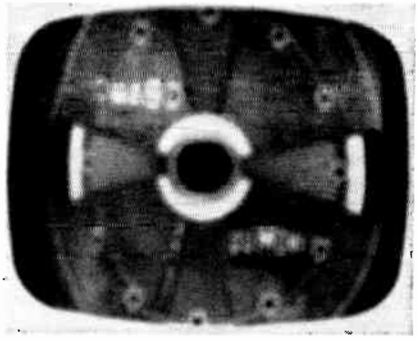


Fig. 7. Appearance of a picture when horizontal sweep output drops. The vertical becomes oversize because high voltage also drops and the picture may become dim and blurry. (Allen B. Du Mont photo)

When the high voltage fails completely, the cathode-ray tube goes blank. The most common cause for failure (outside of horizontal sweep failure) is the failure of the rectifier tube. Rarely do any other troubles arise.

Dim Picture. If the high voltage should become abnormally low for some reason, the picture grows dimmer *and* the scanning becomes *greater*. This happens because a low-voltage cathode-ray beam is much easier to bend, so the sweep circuits bend them more. The horizontal *and* vertical circuits will therefore oversweep; that is, they will sweep well beyond the edges of the screen.

Combinations of Troubles. Ordinarily, a loss in high voltage is due to a loss in horizontal sweep so that only the vertical sweep goes off-screen while the horizontal sweep may be subnormal, as shown in Fig. 7. This combination of symptoms (dim picture, subnormal width, excessive height) is a sure-fire sign of horizontal sweep trouble rather than high-voltage trouble alone. By the same token, the combined symptoms of a dim picture and excessive *height and width* point to trouble in the high-voltage circuit only. It might be caused by a bad rectifier tube.

If the picture is dim and the two sweeps appear to be correct (just fill the screen) the odds are that the high voltage is *normal,* otherwise the sweeps would have expanded. This condition would indicate a bad cathode-ray tube or trouble in the low-voltage circuits which are connected to its base pins.

Secondary Functions of a Television Set. The secondary functions of a television set which are essential to its performance and which should enter into your diagnostic methods are as follows:

The sync pulses must be clipped from the video and separated from each other.

The sync pulses must synchronize their respective sweep circuits.

All circuits must be supplied with d-c power.

Sync Pulse Circuits. The circuits involved in the development of separate vertical and horizontal sync pulses are shown in Fig. 8. The input signal at the extreme left is the video signal and is obtained anywhere between the video detector and the output of the video amplifier.

Two output signals are provided, as indicated at the extreme right. One is the vertical synchronizing signal and the other the horizontal synchronizing signal. These signals are really pulse trains, each one at its appropriate speed.

The video signal which contains sync pulses along with picture information is fed to the clipper. It may or may not be amplified by a preamplifier (A) usually called simply a *sync amplifier.*

The amplifier may or may not include a noise-canceller (C) circuit to eliminate strong noise bursts.

The clipper (B) eliminates the picture information and delivers a composite sync signal which includes both horizontal and vertical sync pulses. This composite signal may or may not be amplified further by a sync amplifier (D). The signal then passes through a separator circuit (E). This circuit uses resistors and condensers rather than tubes to do the job. The separator delivers two separate signals, one the vertical sync signal and the other the horizontal sync.

Each of these separate sync signals may or may not be amplified further (G, F) before being used in their respective scanning circuits.

Clues to Sync-system Troubles. Failures in the sync circuits are usually easy to identify because the television set continues to work properly except that the hold controls refuse to work. The controls may permit you to get the right speed, perhaps for a split second, but the speed will not remain synchronized.

A failure *before* the separator (E) causes the loss of synchronization in *both* scanning circuits. When this happens, it is a sure sign of failure in the clipper (B), in the amplifier before the clipper (A), or in the *composite* sync amplifier (D) following the clipper, but *not* in or after the amplifiers which follow the sync separator.

A failure in the vertical sync amplifier (F, if one is used) causes only the vertical scanning to run free while the horizontal locks properly. If you can get the right speed with the vertical hold control, even if only for a moment, you know that the oscillator *can* run at the correct speed, thus the oscillator is not at fault. If, on the other hand, you cannot get the right speed at *any* position of the vertical hold control, the indication is that the sync circuit may be O.K. but that the oscillator itself is at fault. It will not lock if it is incapable of running at the correct speed.

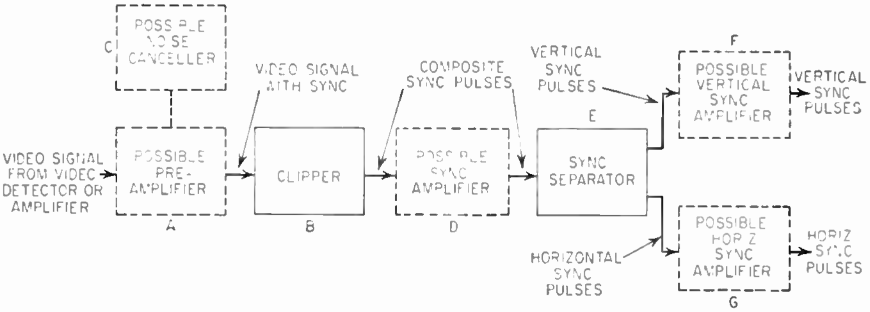


Fig. 8. Block diagram of the path taken by sync signals. The sync starts as a composite video signal and ends up as separate trains of vertical and horizontal pulses

If the vertical sweep synchronizes properly, while the horizontal sweep will not, there may be something wrong with the horizontal sync amplifier (G), especially if it is possible to get the correct speed (for only an instant) with the horizontal hold control.

Horizontal synchronization failure is a little harder to pin down, however, because the horizontal sync signal is handled by additional circuits after the sync amplifier. These compose the horizontal automatic-frequency-control circuit.

Horizontal Synchronization. The function of horizontal synchronization is performed by the afc circuit represented in Fig. 9. The afc circuit looks at two wave trains, the incoming horizontal sync pulses and the sawtooth wave generated by the horizontal sweep circuit. It compares the relative positions and controls the speed of the horizontal oscillator so as to keep the sync pulses lined up on the retraces of the sawtooth.

The input signal is the horizontal sync signal. The output is a d-c speed-control voltage which is capable of going up or down as needed to hold correct speed. The output voltage controls a reactance tube which is connected to the horizontal sweep oscillator in such a way as to change its speed either way according to the commands of the d-c control voltage.

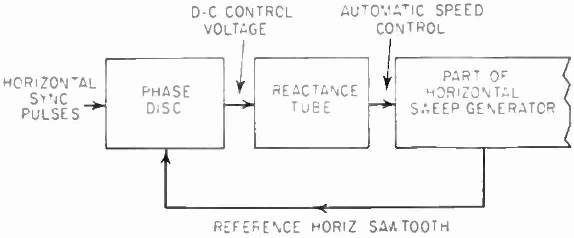


Fig. 9. Block diagram of signal paths in a horizontal afc system

Quick Test. When the horizontal oscillator fails to synchronize properly, the fault may lie in any part of the afc circuit, in the horizontal oscillator itself, or in the horizontal sync amplifier preceding the afc circuit. If the oscillator can be adjusted for a momentarily correct speed by means of the horizontal hold control, the possibility of a fault in the horizontal oscillator is largely eliminated.

Even if this cannot be done, the problem is limited to the circuits of four or fewer tubes which can be checked more easily than the circuits which you would have to check if you had not narrowed the problem down to this point. The four tubes are: the horizontal sync amplifier, the phase detector (or discriminator, as it is sometimes called), the reactance tube, and the horizontal oscillator. The typical set would call for checking only the three tubes represented in Fig. 9, because separate horizontal sync amplifier stages (Fig. 8G) are not generally used.

Power-supply Circuits. The block diagram of the low-voltage power-supply circuits is not shown because it would not mean much. In essence, the power supply provides plate voltage for *all* circuits in the television receiver including the supply of all cathode-ray tube voltages except the high voltage for the second anode. Failures in power supply nevertheless occur in television sets and require that you be able to diagnose them.

When the failure is such that only one functional circuit is affected, the problem is fairly simple, because the power failure is easily found by testing that circuit. For example, should a resistor open in the power-supply leads for the vertical oscillator, the failure will be diagnosed as a vertical oscillator failure and the defect will be automatically found by testing that oscillator circuit.

Power-supply Trouble Clues. More commonly, a failure in the power supply affects several different functions at the same time. To illustrate the point, insufficient plate voltage may cause low picture brightness, insufficient size, possibly poor focus, low sensitivity, and poor audio. It may also make synchronization difficult or impossible. When you come across a complex combination of symptoms such as this, the odds are against a combination of many *faults* and suggest, instead, a common failure which would most likely be in the power supply.

This particular combination of symptoms is encountered frequently in receivers using selenium rectifiers. After long use, these rectifiers begin to deteriorate gradually, lowering the plate voltage. The same thing happens with vacuum-tube rectifiers but it is more easily discovered because it is so easy to substitute a new rectifier tube as a quick test. The typical serviceman is not as apt to try substituting selenium rectifiers casually because they have to be disconnected from the circuit to do this.

When combined symptoms of failure appear, it is a good idea to test all power-supply voltages and to compare them with the voltages shown in the manufacturer's service notes.

Signal-tracing Methods. Until you have gained some experience and purchased special test equipment, most circuit-checking will be done by means of voltage measurement, resistance measurement, parts testing, and substitution. These techniques are exactly the same as those which are so widely employed in radio service work.

These methods will serve you well in television service work because they will take care of the vast majority of problems. Many servicemen, in fact, do not own special equipment and rely completely upon these techniques.

Oscilloscope. Plan on buying an oscilloscope as soon as you are in a financial position to do so. It can save lots of time, especially in solving tough service problems. The oscilloscope is the ultimate in a signal-tracing tool. It can be used in tracing sync pulses, sweep waveforms, and video signals.

Television manufacturers recognize the oscilloscope as a service tool and frequently provide oscilloscope waveform data in their service manuals. These consist of drawings or photographs of waveforms relating to various points in the set.

Use the oscilloscope as often as you can. In a short time you should be able to use it quite proficiently.

Signal-tracing methods for some of the special television circuits are described in the paragraphs which follow. The use of the oscilloscope is mentioned to illustrate the general application of the instrument. More detailed information is given in another chapter. Although you will not be ready to use the oscilloscope techniques right from the start, the information should be useful in helping you to plan your purchase at the right time.

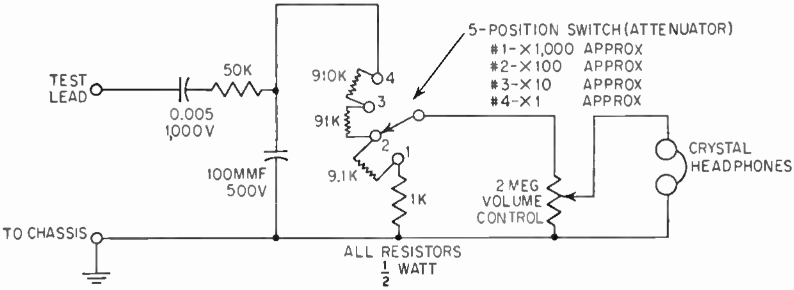


Fig. 10. A signal-tracing headphone circuit. The attenuator permits comfortable listening to a wide range of signal levels. You can listen to video signals and vertical sync and sweep signals with this tester

A simple and inexpensive technique which can be used immediately is described in the following paragraphs. It calls for the use of a pair of crystal headphones to help in the tracing of the video signal and certain pulse and scanning signals. The headphones are hooked up as shown in Fig. 10 for the signal-tracing work described.

Video Signal Tracing. Although the video signal is composed of picture information, a great deal of its energy is in the audio-frequency range. The signal, in other words, can be *heard* if it is fed to a suitable audio-reproducing device. The signal has a characteristic sound which is quite easily recognized once you have heard it.

Crystal headphones make an ideal listening device because they have a high impedance and reflect little load upon the circuits being tested.

The video signal can be heard at the output of the detector, at each significant point (grids and plates) in the video amplifier, and directly at the point where the signal is fed to the cathode-ray tube. At each point, the headphone volume control will have to be adjusted to get a suitable audio level. The signal will be relatively weak at the detector and very strong at the output of the video amplifier.

If you put a calibrated scale on the attenuator, you will be able to judge fairly accurately how strong the signal is and thus how the video circuits are working. The calibration can be a simple 0-to-10 scale.

When a set is working properly you may find that you can hear the video output signal when the attenuator is set at position 2 on the scale. If you find that you have to turn the attenuator up higher on a defective set, it is pretty safe to conclude that the video signal is very weak.

Troubleshooting with Phones. This listening technique will often come in handy when you have a set with a dead cathode-ray tube or when you suspect trouble in the video amplifier. You can find out quickly where the video signal goes dead by following it up from the detector onward, toward the cathode-ray tube.

The specific points to test for video are identified on most manufacturers' schematic diagrams which show oscilloscope waveforms. The diagram will show the video waveform as it should be *seen* on an oscilloscope, but you will be listening to it instead.

The performance of the video amplifier can of course be observed much more accurately with an oscilloscope. The precise waveform can be seen and its amplitude carefully measured.

Backward Signal Tracing. Signal tracing can also be done through the video i-f amplifier by working an i-f signal backwards. This calls for the use of a tone-modulated signal generator which can be tuned to the video i-f frequency. The standard modulation of 400 cycles is entirely satisfactory.

If this signal is fed into the video i-f amplifier, it will be detected by the video detector, amplified by the video amplifier, and impressed on the cathode-ray tube where it will show up in the form of horizontal modulation bars; it will produce a venetian blind pattern. If the cathode-ray tube is dead, the tone signal can be picked up by the headphones from the video amplifier.

For signal-tracing purposes, the test signal can be fed first into the grid of the last video i-f amplifier, and then progressively into the grid of each earlier stage until the point is found where the amplifier goes dead. This will reveal which stage, if any, is at fault.

By using a test signal tuned to a television channel r-f frequency, the testing can be continued all the way back to the antenna terminals of the set.

Sync Pulse Tracing. Because the sync signal contains the 60-cycle vertical pulses, there is appreciable energy in the audio-frequency range. Thus, the headphones can be used for some of the signal-tracing work in these circuits. Tracing cannot be carried on with headphones in the horizontal sync pulse circuits because these pulses are above the audible range of most people and because the headphones may not reproduce them even if they could be heard.

The sync signal can be traced *audibly* from the video amplifier, through the preamplifier ahead of the clipper (if one is used), through the clipper, through the *composite* sync amplifiers, and through the *vertical* sync amplifiers. You will find that the signals can be clearly heard and identified after a little advance practice on several good sets.

The significant sync signal points are identified on drawings in the manufacturer's service manual if it has waveform data. The waveforms show the signal as it would *appear* on an oscilloscope.

The headphone method of sync pulse tracing is admittedly crude, but it works. You can't tell much about the exact *shape* of the signal but you can find out whether or not it is present, and where it stops. The oscilloscope will give you a much more comprehensive test.

Horizontal sync pulse tracing can be done only with the oscilloscope.

Scanning-signal Tracing. The vertical scanning circuit contains a strong audio-frequency component, consequently it can be traced with headphones. The horizontal cannot, and should not be, particularly because it attains such high voltages at the output end of the sweep circuit.

The volume level of vertical sweep voltages will be quite high and this will require that you keep the headphone attenuator set low.

The signal can be traced audibly from the oscillator right through to the vertical coil of the yoke. As in the previous cases, the oscilloscope waveform drawings are used as the guide as to where to check for signals.

The audible check can serve only as a means of rough signal tracing and suffers the same limitations as described for sync pulse tracing with headphones. You can tell only whether the circuit is working or is dead, but you can't tell how well it is working. Often this makes little difference, because the problem may be a dead circuit.

The oscilloscope must be used if you want to know how the waveforms appear. This may be required, for example, if the vertical scanning circuit is working but something is causing a loss in amplitude or distortion of linearity.

Signal tracing in the horizontal sweep circuits will have to be done with an oscilloscope. Without the oscilloscope, defects must be hunted with your multimeter using conventional circuit-testing techniques.

Testing Voltages. The testing of voltages in a television set is one of the methods used to locate troubles. The testing may be confined to a specific circuit which you suspect as the result of analyzing the symptoms of operation or it may be extended to include all significant points in the set in an effort to discover where the trouble lies. Many failures can be located by this method; it is especially useful if you have no idea of the cause of difficulty.

Preliminary voltage testing need not be done with a service manual as a guide. This should permit you to locate glaring errors if they are present. This approach simply calls for checking to find out whether there is any B+ voltage in the set and whether all tubes have plate and screen grid voltages which appear to be reasonable. A surprising number of defects are located in this manner.

More careful checking is done by using the voltage chart in the proper service manual as a reference. The chart identifies each significant point and tells what the voltage should be at that point in a normal set.

When doing this work you compare your reading with that shown in the chart. This requires that you duplicate the condition of test as closely as possible. If the chart tells you the setting of certain controls or switches, follow these instructions. Most important, use a meter which has the same sensitivity and the same range setting, if the instructions give this information.

If no information is given about the meter sensitivity or the range setting, you can assume that the readings were taken with a 20,000-ohm-per-volt meter. The range setting is always the *highest* one which permits a moderately accurate reading.

When the chart calls for a reading with a vacuum-tube voltmeter, you should use this kind of meter if you want to make a comparative reading. If you do not own a vacuum-tube voltmeter, you may take a reading with your multimeter, but the reading will probably be lower than it should be and will not be close enough for you to draw any conclusions as to its condition.

High-voltage Testing. The standard television set has only one voltage check point which can truly be classified as a high-voltage test. That is the second anode connection to the cathode-ray tube.

This check requires the use of a high-voltage test probe to provide the kind of insulation needed to keep you from getting a shock and to provide the necessary series resistance to extend the voltage scale of your meter. High-voltage probes are available from most parts or meter suppliers. Figure 11 shows such a probe in use.

The test is made by removing the second anode cap from the cathode-ray tube while the power is off. The cap is turned up into a handy position as shown. Then the power is turned on, the probe is brought up to the terminal, and the reading is made.

Voltage Tolerances. The voltages given in tables or charts in service manuals should not be interpreted as exact readings which must be duplicated. There are so many factors which act to alter these readings that exact values cannot be given. Some of these factors are: the accuracy of the meter used in making the original check, the accuracy of your meter, variations in power-line voltage, the condition of the tubes and the variation in tolerance of components in the set. In addition, manufacturers frequently make up the tables from checks on only one or two sets which may not represent a real average. This does not suggest carelessness on their part but rather a practical recognition of the fact that they cannot provide exact values anyway.

If you ignore the errors in meters and the difference in testing conditions, the highest degree of accuracy that might be expected would be no better than 10 per cent. When you take other variables into account, and especially the normal tolerance in meters, you cannot expect results which will be closer than about 20 per cent. A practical guide is around 25 per cent in judging whether a voltage is definitely too low or too high.

To illustrate the point, if the voltage table calls for a reading of 100 volts and your reading is between 75 volts and 125 volts, you can consider it temporarily O.K. Not until it is obviously lower than 75 or higher than 125 should you start looking for a reason right then and there.

Because the main voltage delivered by the power supply is least affected by variables, it should normally be within 20 per cent of the value given in the voltage chart. Most others, and especially voltages at the plates of tubes having resistor loads, are subject to the greater variation mentioned above.

Voltages which are derived from the rectification of signals frequently vary as much as 50 per cent and even more. This relates to grid-bias voltages developed by means of grid leaks (example: clipper grid) and voltages developed in diode circuits (example: afc diodes).

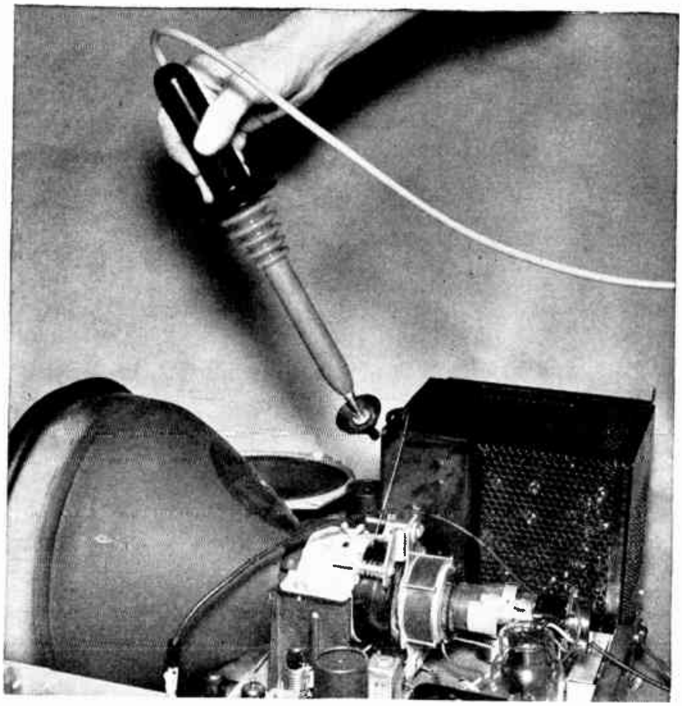


Fig. 11. Using a high-voltage probe to measure high voltage. (RCA photo)

If you come across a borderline measurement and you are not sure whether this indicates a defect or not, make a note of the point checked and the reading and assume for the moment that it is satisfactory. Then proceed to make other measurements. This may reveal a positive error elsewhere which is the real cause of trouble. If you cannot find any other doubtful readings, you can come back to the original circuit and check it out more carefully. Try changing any tubes which might have an effect on the reading. This may give you a real clue as to the problem.

If you have located a point at which the voltage is obviously in error, locate the circuit on the schematic, and trace it out. This may immediately suggest what the trouble could be. In any event, it will give you a good idea of what components should be tested individually.

Testing I-F Coils and Transformers. The i-f coils and transformers in television sets work at such high frequency that they require very few turns, and thus represent only a short length of wire. A check of these units is therefore limited to a continuity test. If the coil is good, it will test out as a virtual short circuit; if it is open, no continuity reading will be obtained.

If a coil tests O.K. by this method but you have reason to believe that it is defective (the coil may be shorted out) the best procedure is to examine it visually. You should be able to see where it is, or might be, shorted out. There may be solder across the terminals or the two end leads may be dressed right up against each other. Coils rarely short out in such a way that there is no visible evidence.

Testing High-inductance Coils. There are many coils used in television sets which are wound with a large number of turns of fine wire. These include the small, compact compensating coils in the video amplifier; the oscillator, width, and linearity coils in horizontal sweep circuits; focus coils; power-supply filter chokes (wound on an iron core); and the coils of audio and sweep output transformers.

Ordinarily, it is enough simply to test such coils for continuity to find out whether or not they are open. A further test, however, is frequently possible and that is to measure a coil's resistance. This can be done comprehensively only if the service notes show what the resistance should be.

The tolerance to be expected is at least as great as with voltage readings, principally because most ohmmeters have fairly low accuracy. This is so because the accuracy varies appreciably with the condition of the ohmmeter battery. Ordinarily you should expect readings within 35 per cent and should not be greatly concerned if your reading is within this range. Not until your reading is about half or twice what the manual gives should you seriously suspect a defect in the component.

Testing Resistors. Ordinary carbon resistors do not often fail unless they have been overheated to the extent that the color code rings appear to be scorched. When this has happened, the resistor may have changed in value drastically. If it has been blackened by overheating, it may even be open.

Do not rule out the possibility that a resistor which appears to be perfectly good may be bad; this sometimes does happen.

The object in testing resistors may be to see if one of them is responsible for a circuit fault. An incorrect voltage reading may have provided the original clue.

Many resistors can be checked right in the set without disconnecting them; others may have to be disconnected at one end before you can do this. The best way to find out if this is necessary is to trace out the circuit on the diagram to find out whether anything (other than a condenser) is connected across the resistor.

If you are not sure, you may check the resistance with the resistor connected into the circuit. If it reads near the correct value, chances are that it is O.K. If it reads much higher, the resistance is obviously higher than it should be. If it reads much lower, it may be too low in value, or something may be connected across it in the circuit. To make sure you will have to disconnect one end and then check the resistance.

Don't check resistors indiscriminately through the whole set because too many of them have to be disconnected to be checked properly. This will only result in a sloppy job and may result in your leaving a poor connection somewhere. Do this kind of checking only after you have narrowed the trouble down to a specific circuit. You will then reduce the number of disconnections to perhaps only one or two.

Resistor tolerances vary widely and you should expect appreciable variation in your readings. A large part will be due to the errors in your meter, the balance to the tolerance of the resistor. It's a good idea to find out how near to correct your meter is before you start. Do this by checking a few new 5 per cent resistors out of your kit and noting how closely you read them. If the readings appear to be accurate, you will be safe in allowing from 5 to 10 per cent tolerance for your meter on the *same ohmmeter range* on which you made your check.

In view of this, you should expect to get readings which are within 15 per cent when you check 5 per cent resistors (coded with a gold band); within 25 per cent when you check 10 per cent resistors (coded with a silver band); and within 35 per cent when you check 20 per cent resistors (no tolerance color-code ring).

Testing Potentiometers. The change of resistance is rarely a problem in potentiometers. The common troubles are that they may open, short to ground, or become noisy.

Potentiometers are checked for noise by turning them and noting the effect. If the control is in a sound circuit, scratching will be heard. If it is in a picture circuit, flashing or picture jitter may be seen.

Noisy controls do not always need replacement. Most cases can be cured by letting a drop or two of carbon tet or contact-cleaner fluid run into the control, after which is it turned back and forth a half dozen times or so.

Potentiometers should be checked for an open with an ohmmeter. To be sure of your check it is a good idea to disconnect the leads from all but one terminal. Opens are rather common if a temporary short circuit occurs somewhere in the wiring to a potentiometer which is connected to a source of voltage. Most potentiometers are unable to carry a heavy overload, even for a moment, and they simply burn out.

Less commonly, potentiometers short to ground internally. This condition is discovered by making resistance checks to ground (with the potentiometer leads disconnected).

Checking Condensers. There is little need for a true condenser checker, that is, one which measures capacity. Most service needs are satisfied by means of resistance checks (for shorts and leakage) and tests by substitution (for opens).

Most direct shorts are found by a simple continuity check across the condenser without disconnecting either of the condenser leads. If you think you have located a shorted condenser, withhold your decision until after you have disconnected one terminal and checked again. If it still shows continuity, there is no further doubt about it. If it no longer shows up bad, the original continuity reading was no doubt a normal reading for the circuit in which the condenser is connected.

If you suspect leakage (a high-resistance short) the best bet is to disconnect one terminal of the condenser and check for continuity with the highest resistance range of your ohmmeter. With all but electrolytic condensers *any* reading means a bad condenser. Electrolytic condensers will always show high-resistance leakage and are not considered bad until the resistance reading becomes rather low.

When making leakage tests you may notice that the ohmmeter needle will show a reading the moment you make contact, after which the needle drops back. The needle should drop back to zero to signify a good condenser. Electrolytic condensers will exhibit the same effect but will usually take several seconds to drop back and, as mentioned above, the reading will then show a finite resistance. The normal leakage may be from 10,000 to 250,000 ohms depending upon the capacity and rated voltage. Low-voltage condensers will show lower values of leakage resistance. The usual B+ filter condenser may run around 100,000 ohms or more.

It is important to check electrolytic condensers with ohmmeter leads properly polarized. To be sure, make the check, then repeat it with reversed test leads. The condition that shows the lower reading is the correct one because it indicates that the positive meter lead is on the positive terminal of the condenser.

If you suspect that a condenser may be open, check it by jumping a similar condenser right across it and seeing whether this makes the set work properly. There are many valid reasons for suspecting that a condenser may be open. A bad hum in the set, for example, immediately suggests that a filter condenser may be open. A dead audio amplifier in which all voltages are correct suggests that an audio coupling condenser may be open. These are not sure signs but they are reason enough to make the jump-across test.

If you should find an open condenser by this method, remove the bad one if you can, or at least disconnect it completely from the circuit.

Practical Troubleshooting Examples. Typical cases of television failures are described in the following paragraphs, together with significant conditions and symptoms. The method of diagnosis is then described, basing the diagnosis on a general functional block diagram of a television set.

After this, the problem is boiled down more specifically by relating it to the particular circuit of the set and by making certain additional tests and observations. The cure is then given.

Purpose of Examples. The object in describing these cases is to illustrate some practical examples of troubleshooting work, and especially to illustrate how the understanding of the general functional diagram is used in this work. Circuits are not shown because the cases are intended to deal with general problems rather than those occurring in specific television sets on the market. After this, a troubleshooting table is given to help you solve many common service problems.

Service publications available on the market cover specific troubles in popular television sets. They are broken down by brand name and model of set to help you locate data about any particular set you may be working on. You may find these publications helpful although they will not serve as a substitute for your own diagnosis, because they ordinarily cover unusual problems primarily, rather than common problems. As a matter of fact, many of these publications deliberately deal only with unusual problems because it is assumed that most servicemen will be able to diagnose the more common problems such as are presented in this chapter.

VIDEO AND SOUND PROBLEMS

Case 1—Video and Sound Dead. The set is an intercarrier set. The set has been working well and the antenna system is in good condition.

Symptoms. The video and sound are dead on all channels. The raster is of normal size and brightness.

Diagnosis. The scanning circuits and high-voltage supply are obviously O.K. because normal sweep and brightness are obtained. A general failure in the power supply is therefore eliminated as the possible cause.

Because the set is an intercarrier set, the failure must be somewhere between the antenna input and the point at which the intercarrier beat is branched off to the sound i-f amplifier. It may be in the tuner, in the video detector, or in the video amplifier (if the intercarrier beat is taken off *after* that amplifier).

Procedure. The circuit diagram is examined to find out where the intercarrier beat is branched off to the sound circuits. It is found to be taken off right after the video detector. This rules out a failure in the video amplifier. The sound i-f amplifier, incidentally, is labeled 4.5-mc amplifier. This is recognized to be the *sound i-f amplifier* circuit.

It is concluded that the trouble lies in the video *i-f* amplifier or in the tuner.

It is decided to make a quick and rough over-all test of the video i-f amplifier because this is easily done. It is reasoned that if the *converter* tube is pulled out of its socket and reinserted several times, the electrical disturbance should pass through the set as a click. Because the *carriers* (sound and picture) are not present it is doubtful that the click can be *heard*, but it should be *seen* on the screen *if the video i-f amplifier is working*. The contrast control is advanced fully to give as much video gain as possible.

The converter tube (or mixer) is found by using the manufacturer's diagram. The tube is pushed in and out of its socket several times. Flashing is observed on the screen. It appears that the video i-f is working, to some extent anyway. It will be assumed to be O.K. for the time being, and that the trouble is in the tuner.

(If the flashes had not appeared, tests would have been made in the video i-f amplifier.)

A guess is made that perhaps the oscillator is dead. A new tube is tried, but this does not help.

Tests of voltage are made in the tuner and it is discovered that there is no voltage on the oscillator. Upon visual examination, a resistor is found which is obviously burned. It is discovered that a shorted condenser has caused the burn-out. Both the resistor and condenser are replaced with temporary substitutes to see if this takes care of the trouble. The set is found to operate properly.

The *temporary* substitutions were made because exact replacements are not handy. The condenser is a special ceramic unit and should be replaced with an exact duplicate. The purchase is made and the parts are permanently replaced in the set.

Variations in Tests. A better way to check out the video i-f amplifier is often necessary or desirable but it requires that you remove the chassis and have a general-purpose signal generator available (as you may have in your shop). The quick method described above works most of the time and can be a great timesaver. If the flashes are seen, you can be pretty certain that the video i-f amplifier is O.K.; if the flashes are *not* seen, there is a chance that the disturbance of removing the tube and reinserting it is not enough to show up and the video i-f amplifier *may* be O.K. You can't be fully certain.

The more reliable test is to feed an a-m signal of proper frequency into the video amplifier and see whether the modulation appears on the screen. The signal frequency should correspond with the video i-f frequency of the set pretty closely. The signal is fed into the plate of the converter through a small condenser (something under 5 mmfd will do) so as not to detune the i-f coil too much and also to keep from shorting out the plate voltage through the signal generator lead.

If it is difficult to get at the converter plate terminal because it is buried inside the tuner, you can feed the signal into the grid of the first i-f amplifier. An alternative is to remove the converter tube and feed the signal from above the socket into the plate terminal.

With series-filament sets you can't leave the tube out without having more tubes get cold. In this case you should try to feed the signal into the set while the tubes are all in place. This usually means removing the chassis to get at tube-socket terminals.

The signal generator method is good because you can move the signal, stage by stage, to each video i-f amplifier grid. This will permit you to locate the faulty stage, if there is one.

Case 2—Video Is Dead. The set is an intercarrier set.

Symptoms. The sound is normal, but the picture is dead. The raster is of normal size and brightness.

Diagnosis. The conclusions with respect to scanning, high voltage, and general power supply are the same as in Case 1, but the similarity ends here.

Because the sound is normal, it is known that *both* the video and sound signals are getting through all circuits up to the sound branch-off point. The defect must, therefore, be between this point and the cathode-ray tube.

Procedure. The circuit diagram is studied to locate the point at which the intercarrier signal is branched off to the sound i-f amplifier. It is found to be taken off *ahead* of the video amplifier tube. It is concluded that the trouble lies in this stage.

The video amplifier tube is replaced but this does not help, so tests are made on the circuit. It is discovered that a compensating coil in series with the plate is open. To make a quick check, a jumper is placed across the coil. The set then works normally although the picture is somewhat smeared. It is assumed that the smear is due to the absence of the coil.

The proper coil is procured and installed. This places the receiver in normal operation.

Case 3—Sound Is Dead. The set is an intercarrier set.

Symptoms. The sound is dead, but the picture is entirely normal.

Diagnosis. The fault must lie somewhere in the sound circuits *after* the point at which the intercarrier signal is branched off from the video circuit. It may be in the sound i-f circuits or in the audio amplifier or speaker.

Procedure. It is decided to narrow down the possibilities. The speaker circuit is first checked simply by pulling the audio power-amplifier tube out of its socket and reinserting it. A loud click is heard which indicates at least that the speaker is not at fault.

It is decided next to rule out the audio amplifier if it is operating properly. This is done by placing a finger on the grid terminal of the *first* audio tube while the volume control is turned fully on. A loud hum is heard; this indicates that the audio amplifier is probably operating normally.

As a result of these checks, the fault is assumed to lie in the sound i-f circuits. Multimeter checks reveal that a bypass condenser is shorted in the first sound i-f stage. It is replaced and the set operates normally.

Comments. The speaker and audio amplifier are not really known to be in *good* operating condition by the above tests. It is simply observed that neither one would cause the *complete* loss of the audio signal. Perhaps, after the set is restored to operating condition, it may be found that the audio is distorted due to some latent defect in the audio amplifier, or that the speaker cone is off center. If this is found to be the case, appropiate repairs can be made in their proper turn.

Case 4—Loud Buzz with Sound. The set is an intercarrier set.

Symptoms. The set works normally in all respects except that a loud buzz is heard in the sound. The buzz seems to be influenced by the picture, in that the buzz gets stronger or weaker as the station is tuned and as scenes change in the video program.

Diagnosis. The defect is assumed to exist in the sound i-f system, probably in the limiter or in the f-m detector.

Procedure. Because the tuning of the f-m detector coil is known to be the most frequent cause for trouble of this sort, the coil is located with the help of the manufacturer's service notes. The coil may be called a transformer (which it is) or may be called the 4.5-mc discriminator transformer, or simply, the ratio-detector coil. In almost every case, the identification will be quite obvious.

The set is tuned in so as to hear the buzz clearly and the adjuster of the f-m detector coil is tuned by ear. It is found to have a great effect on buzz. A quiet point is found at which the audio is loud and clear. The set is retuned to find out whether the buzz can be made to appear again. If it does, the set is left in that position and the f-m detector coil is tuned more carefully for the zero-buzz condition.

Comments. If the set uses a gated-beam tube (type 6BN6) in the sound circuits, the most probable cure is the readjustment of the BUZZ CONTROL which is always provided when this type of tube is used. The control is carefully adjusted for minimum buzz. The set is adjusted and tuned in all possible ways to get the best all-around buzz elimination since it is not possible with all sets to eliminate it completely.

Case 5—Poor Sound. The set is a split-carrier set.

Symptoms. The set works normally except that it is not possible to tune in the sound properly on all or some of the channels. The sound may actually be completely missing in some channels.

Diagnosis. It is assumed that the problem is caused by a shift in local-oscillator frequencies in the tuner because it appears that the sound signal cannot be tuned to its proper i-f frequency in all or some channels. (The picture is obtained because the video i-f channel is so broad that the sound can be lost before the picture.)

Procedure. The manufacturer's service manual is examined carefully, first to find whether or not he has any instructions about how to retune the oscillator in each channel, and second, to find out where the adjusters are located. If instructions are provided, they are followed.

If only the location is shown, the oscillator is tuned in each channel in this way:

The set is switched to the *highest* channel in which the signal is improper. The tuning knob is then centered; that is, it is set to the position at which you would like the sound to tune in. The corresponding (channel) oscillator slug is then tuned with an insulated alignment screwdriver, first one way, then the other, to try to find the sound. In the process, the number of turns are counted so that you can return to the original setting if necessary. When the sound is found, the adjuster is carefully set to produce good sound tuning.

Working from the highest channel down, each problem channel is tuned in the same manner, leaving the panel tuning control in the same position for all.

Finally, the good channels are readjusted slightly, if necessary, to make the sound tuning agree with the common setting of the panel tuning knob, again starting with the highest channel. This will make is possible for the user of the set to switch from channel to channel without making more than just a minor panel adjustment.

SWEEP PROBLEMS

Case 6—Only Horizontal Line on Screen. The set can be either split-carrier or intercarrier for this and all other cases involving sweep trouble.

Symptoms. The sound works well but there is no picture. Only a single horizontal line is seen on the screen, as shown in Fig. 6.

Diagnosis. The failure appears to be in the vertical sweep circuit. It is assumed that the video is O.K. There is evidence of this because modulation is occasionally visible on the single horizontal line. It is decided not to worry about the video, however, until vertical sweep is obtained.

Procedure. The vertical sweep tubes are located on the manufacturer's diagrams. The corresponding circuits are tested. It is discovered that there is no plate voltage on the sweep amplifier tube. The sweep output transformer is checked for continuity and the primary is found to be open.

A new transformer is not available, but it is considered desirable to find out quickly whether the rest of the set is O.K.

To do this, the sweep output transformer is replaced, temporarily, with an ordinary audio output transformer designed to deliver audio into a loudspeaker. The transformer is selected for its physical size, because the small a-c/d-c type transformer might not stand up, even for a few minutes. The transformer chosen is one capable of handling a single 6V6, 6L6, or similar type of output tube which delivers about 3 (or more) watts of audio.

The transformer is connected like the original, using the voice-coil winding as the yoke winding. It is found to provide about 2 inches of vertical sweep, which is enough to get an idea as to how the rest of the set is working. Except for the insufficient sweep, the picture appears to be good. It is therefore assumed that the only defect is the sweep transformer.

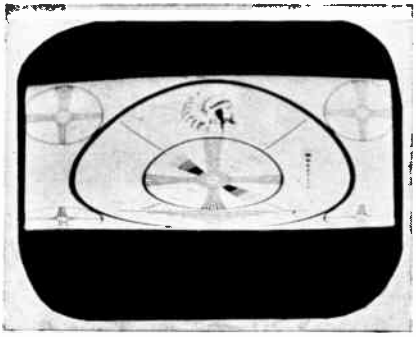


Fig. 12. Insufficient vertical sweep output. (General Electric photo)

The observations are made without concern for vertical size or linearity because these are not expected to be good with the temporary transformer. The picture looks something like Fig. 12, but with not quite as much height.

A new transformer is obtained and the repair is successfully completed.

Comments. The use of an audio output transformer is a good idea because it permits you to make checks on the rest of the set before you buy the new transformer. Most audio output transformers will give enough vertical deflection to see at least a little bit of the picture. The greatest size will be obtained if you use one of the popular universal output transformers and connect the yoke to the highest-impedance voice-coil terminals. If the transformer is push-pull, use only *half* the primary.

Case 7—Insufficient Picture Height.

Symptoms. The set works properly in all respects except that the vertical size is insufficient even at the highest setting of the height control. It looks like the picture shown in Fig. 12. The tubes have been checked and they are good. Vertical synchronization is good.

Diagnosis. It is assumed that the problem is in the vertical sweep oscillator or amplifier. The tubes are located in the chassis and voltage tests are made. All voltages are found to be normal.

Continuity checks are made and no defect is found. The tubular condensers in the circuit are checked for leakage with an ohmmeter, and for opens by substitution. Still no defects are found.

It is reasoned that the trouble could be shorted turns in the vertical deflection coils of the yoke, a bad sweep output transformer, or in one of the electrolytic condensers in the sweep output transformers since none of these would show up in the tests just completed.

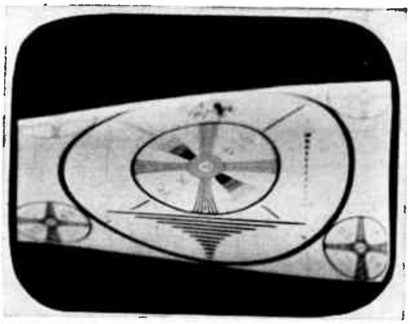


Fig. 13. Distortion of picture shape caused by a defective yoke. The significant result is that two edges of the picture depart badly from parallel. (General Electric photo)

The possibility of a defective deflection yoke is quickly eliminated by thinking about the *shape* of the picture; the edges are seen to be perfectly square so that the picture forms a good rectangle. When the *yoke* develops a partial failure it always shows up as keystone distortion of the shape of the picture, so that the sides of the picture are slanting rather than vertical. This is shown in Fig 13. The exact shape depends upon how bad the yoke is, but the keystone distortion is obvious. The picture height is smaller at one side than the other so that the top and bottom edges are out of parallel. When the edges are all parallel so that a fairly good rectangle is formed, the chances are that the yoke is good.

Because it is easier to check on the condition of the electrolytic condensers than of the sweep transformer, these checks are made first. A standard high-capacity electrolytic filter condenser (30 mfd at 450 volts will do) is jumped across the condensers in the circuit one at a time. There are two—one which filters the plate voltage for the sweep amplifier stage and one which bypasses the cathode resistor.

No effect is noticed when the plate voltage filter is jumped with the new condenser. When the cathode bypass is jumped, however, the picture size increases greatly. It therefore appears that this condenser is open.

It is not expected that the test condenser will provide adequate size until the required capacity is checked on the manufacturer's schematic diagram. The diagram calls for 100 mfd in this case. (The 30-mfd test condenser would not work well enough.) A suitable 100-mfd unit is connected into the set and the picture height is found to increase to its full dimension. The linearity and height are then adjusted properly.

Fig. 14. Vertical distortion of picture caused by a failure in the vertical sweep circuit. (Allen B. Du Mont photo)

Case 8—Poor Vertical Linearity.

Symptoms. The set works well except that it is not possible to get good vertical linearity no matter how the height and linearity controls are adjusted. The picture looks like Fig. 14.

Diagnosis. The problem obviously is in the vertical sweep oscillator or amplifier stage. The tubes are found to be good because new tubes make no material change.

The voltages and then resistances are checked as in Case 7 without the discovery of a defect. For reasons cited above, it is assumed that the deflection yoke is not at fault.

The tubular condensers are checked for leakage and none is found. They are then substituted for by temporary tubular condensers of approximately the right size. The linearity is found to change drastically when one of the condensers is replaced. Linearity and height adjustments are tried and it is found that correct adjustment is now possible. A new condenser of correct rating is permanently placed in the circuit and the adjusters are readjusted when this is completed. Apparently, the defective condenser was open.

Comment. When poor linearity is observed and tubes and voltages appear to be correct, a defective tubular, mica, or electrolytic condenser in either the oscillator or sweep amplifier is generally at fault.

Case 9—Keystone-shaped Picture.

Symptoms. The set works perfectly except that the shape of the picture is incorrect. It looks like Fig. 15. The sides are not parallel to each other, so that the picture has a keystone shape.

Fig. 15. Distortion of picture caused by a defective yoke. The horizontal coils are influenced more in this case than in Fig. 13. (Raytheon photo)

Diagnosis. For reasons given in Case 7, it is assumed that the deflection yoke is at fault, but it is decided to check this possibility before a new yoke is purchased. The *horizontal* keystoning suggests a defect in the horizontal winding of the yoke.

Procedure. The yoke leads are disconnected and the yoke resistance is carefully measured and compared with the resistances shown on the manufacturer's diagram. (If these are not shown, the check cannot be made.) The only observation which can really nail the problem down is an obviously incorrect reading. The coil may be shown to have 30 ohms on the schematic diagram while the ohmmeter reads 10 ohms, for example. If the readings are somewhere *near* being correct, *nothing* is proven, one way or another.

The yoke test proves nothing, so the B+ filter condensers in both the horizontal and vertical sweep amplifiers are checked by jumping an external condenser across them, one at a time. This test is made on the outside chance that the horizontal and vertical scanning circuits are interacting on each other (because interaction could destroy picture shape).

No effects are noticed with the condensers. A new yoke is purchased and connected into the set. It is found to work properly.

Case 10—No Raster.

Symptoms. The sound is normal but the cathode-ray tube is blank. There is no visible light at all.

Diagnosis. The cause for trouble is not a complete power failure; otherwise, the sound would also be dead. The chances are that the problem is a defective cathode-ray tube, a defect in the horizontal sweep or high-voltage rectifier circuits, or a tampered ion trap.

Procedure. It is decided to check first for high voltage because this will indicate quickly whether or not to worry about the cathode-ray tube. The high voltage is checked and found to be zero. This suggests that the cathode-ray tube and ion trap are probably in good shape since *it is expected* that no illumination would be obtained when the high voltage is missing, even though everything else is in order.

The cause for failure is now assumed to be either in the horizontal sweep circuits or in the high-voltage rectifier. It is decided to check the sweep to narrow down the possibilities quickly.

A quick test of horizontal sweep output is made by noting whether an arc can be obtained at the plate of the horizontal sweep amplifier. This is done by touching the plate terminal with a screwdriver which is insulated for 10,000 volts. Before doing this, the free hand and body are kept away from the chassis and an insulating mat is placed under the feet to be extra-safe. If the sweep circuit is working properly, a violet arc can be drawn off the plate terminal, usually up to ⅛ inch or more in length. If the sweep circuit is not working, or working poorly, no arc at all may be obtained, or a very tiny white pin point of a spark may be seen.

The test, in this case, reveals that no arc is obtained. It is therefore assumed that the defect is *not* in the *high-voltage rectifier*, but rather in the horizontal sweep circuit. More specifically, the oscillator, discharge tube (if one is used), or sweep output amplifier may be defective. No defect is expected in the sync pulse circuits or in the afc because these merely control *speed* of oscillation, but do not *produce* oscillation; the symptoms indicate that there is no oscillation or that the oscillation is not amplified properly.

The manufacturer's schematic diagram is used to locate the horizontal sweep oscillator tube, horizontal discharge tube, and horizontal sweep amplifier tube. These are substituted one at a time. It is found that the set works properly with a new horizontal oscillator tube.

Comments. The arc test for a check on the presence of horizontal sweep output is a rough but quick and positive check. It is quite easy because most horizontal sweep amplifier tubes employ plate caps which are readily accessible. Although the plate cap connector is usually insulated, it is easily slipped upward enough to permit the metal cap to be reached without breaking contact in the connector cap.

Care should be taken with this circuit because pulses up to 5,000 volts are present; however, ordinary precautions are sufficient to prevent shock. If a screwdriver is used, make certain that it is capable of withstanding at least 5,000 volts. Such screwdrivers are available at radio parts suppliers.

If you do not have a good screwdriver, you can use a high-voltage test lead designed for use with a 5,000-volt voltmeter. Place the other end of the lead in a drinking glass or in a good insulator well away from your body, or leave it plugged into your high-voltage meter with the other lead removed. Touch the test terminal to the plate terminal of the sweep amplifier tube and look for the spark.

You can improve your ability to judge whether or not an arc is indicative of good horizontal sweep by making this test on sets which you know are good. This will show you approximately what you can expect under normal conditions.

Case 11—No Raster.

Symptoms. Same as Case 10.

Diagnosis. Same as Case 10.

Procedure. Same as Case 10 up to the point that the arc test is made. An arc *is seen* and it is assumed that the horizontal sweep output is normal. The high-voltage rectifier is consequently suspected. The high-voltage rectifier tube is checked by substitution and it is found to be defective, since the set works normally with the new tube.

SYNC PROBLEMS

Case 12—No Vertical Sync.

Symptoms. The sound is normal. The picture seems to be, except that the vertical scanning cannot be synchronized. The vertical hold control is tried through its range and correct speed can be obtained momentarily, but it will not hold.

Diagnosis. Because it is possible to get correct speed manually, it is assumed that the defect is *before* the vertical sweep oscillator, somewhere in the sync amplifier circuit. It is assumed, further, that the defect is *after* the sync separator because the horizontal sweep circuits synchronize properly.

Procedure. The manufacturer's schematic diagram is studied to find out whether there is a separate vertical sync amplifier stage after the point of sync separation. None is found.

The circuit of the vertical integrator (the vertical section of the sync separator circuits) is checked with an ohmmeter since no d-c voltages are shown to be present in the manufacturer's data. One of the condensers is found to be shorted. It is replaced with a similar unit of identical rating. This cures the problem.

Case 13—No Vertical Sync.

Symptoms. Identical with Case 12 except that the correct vertical speed *cannot* be obtained manually, not even for a moment.

Diagnosis. The trouble is assumed to be *either* in the oscillator or in the vertical sync circuits. It is not known for certain that the oscillator in this particular set is capable of hitting correct speed *without* synchronization, although it is expected that it should be able to do this. It is decided to try to alter its speed to see what happens when correct speed is obtained.

The speed control circuit is examined on the manufacturer's diagram. The speed control lead is cut and an extra potentiometer is added in series with the control; it is about equal in resistance to the original control. By using both the panel control and this added adjuster, the speed of the oscillator is *reduced*. No point of correct speed is found. It is decided to try *speeding up* the oscillator.

The potentiometer is removed and the circuit studied again. The speed can be increased if a fixed resistor is found to be in series with the hold control (there usually is). A 1-megohm series resistor is found. Another 1-megohm resistor is temporarily *shunted across* it. The hold control is again tried. This time the oscillator is found to pass through correct speed, and it also locks into synchronization.

The resistors and condensers are checked to find out why the speed trouble developed. The original 1-megohm resistor is found to have changed value. It reads about 3 megohms. It is replaced with a new resistor. The temporary resistor is removed and the set works normally.

Comments. There are many ways of changing the speed of the vertical sweep oscillator. Almost any resistor or condenser in the circuit will have its effect on speed; consequently, a change in any one can cause the trouble described above. The most critical are the resistors (including the hold control) and condenser which are *connected together,* and which *also* connect to the control grid of the oscillator tube. For test purposes, in changing speed, almost any one of these components can be replaced with slightly smaller or larger units or shunted with a parallel unit to make the speed go one way or the other.

Case 14—No Horizontal Sync.

Symptoms. The sound is normal but the set seems incapable of synchronizing horizontally although the correct speed can be found momentarily with the horizontal hold control. The picture, in other words, can be brought close enough to correct horizontal speed to look something like Fig. 16. The vertical hold seems to work properly because no vertical slipping is seen on the screen.

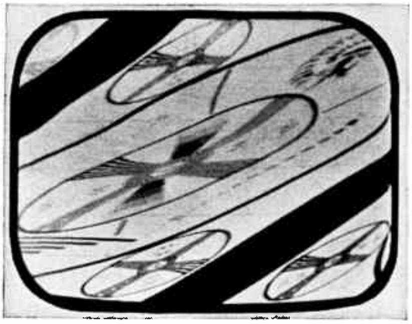


Fig. 16. Appearance of picture when the horizontal is out of sync but running at nearly the right speed. (General Electric photo)

Diagnosis. The defect is assumed to be *before* the horizontal oscillator because the oscillator is obviously capable of running at the correct speed, but lacks only synchronization to hold properly. The defect is assumed to be *after* the sync separator circuits because the vertical sync seems to be working well.

The manufacturer's circuit is examined to see what circuits lie between. It is found that there is no horizontal sync amplifier and this indicates that the defect is probably in the horizontal afc circuit.

The afc tubes (discriminator and reactance) are checked. They are found to be good. Voltage checks are then made in the associated circuits. It is found that the voltages are improper in the discriminator circuit. Resistance checks reveal that one of the terminals of the discriminator tube socket is shorted to ground. Close examination reveals the problem.

voltages are low. The 6.3-volt tubes have heater voltages as low as 4.5 volts.

Through reference to the heater-circuit diagram for the set, it is found that a series dropping resistor is used. The service manual specifies it as having a hot resistance of 20 ohms. The ohmmeter is readied for the resistance check while the set is running. Then the set is turned off and the resistance is measured before the resistor has a chance to cool off. It is found to be almost 100 ohms.

The resistor is replaced temporarily with an ordinary wire-wound resistor of 20 ohms and the set checked. It works normally; all problems are cleared up.

Fig. 18. A low-voltage condition. The picture is undersize and may be dim and blurry. (Allen B. Du Mont photo)

The original resistor is known to be a special resistor because of the way its value is specified in the service manual. The proper replacement is therefore purchased and used for the permanent repair.

Comments. Series heater circuits often use regulating resistors which guard against current surges when the set is initially turned on. These resistors start at a high value and drop in resistance slowly as they heat up. After a minute or so the tubes come up to normal temperature. Regulating resistors often fail as suggested in this example.

Case 19—Very Dim Picture. No special conditions.

Symptoms. Although the sound is good, the cathode-ray tube is very dim. The picture appears to be normal otherwise. The size, linearity, focus, and synchronization are good.

Diagnosis. Because the only problem appears to be picture brightness, it is assumed that the trouble lies directly in the cathode-ray tube or its associated circuits. This conclusion is based on the fact that a loss of high voltage would probably cause either or both sweeps to go off-size; a loss of

Table 1. Quick-reference Troubleshooting Key

	Symptoms				
Picture Symptoms	*Picture Size, Shape*	*Raster (Blank Channel)*	*Sound*	*Sync*	*No.**
Dead (screen dark)	—	Dead	OK	—	S10
Dead, all channels	—	OK	Dead, all channels	—	S4
OK	OK	OK	Dead, all channels	OK	S2
OK	OK	OK	Weak, all channels	OK	S5
Dead, all channels	—	OK	OK	—	S1
Dead, some channels	OK	OK	Dead, some channels	—	S12
Weak, all channels	OK	OK	—	—	S3
Snowy, all channels	OK	OK	—	—	S3
Snowy, some channels	OK	OK	Weak, some channels	—	S13
Excessive contrast	May wiggle	OK	OK	May be critical	S9
Too dim	OK	Too dim	OK	OK	S7
Too bright	OK	Too bright	OK	OK	S8
Brightness flutters	OK	May flutter	OK	OK	S11
Blurry, poor detail	OK	OK	OK	OK	S6
Sound bars visible	OK	OK	OK	OK	S14
Hum bars visible	OK	May show hum bars	OK	V may be unstable	S18
Interference patterns	OK	OK	Any condition	Any condition	S17
Negative picture	OK	OK	OK	OK	S15
Bas-relief picture	OK	OK	May buzz	OK	S16
Picture bounces	OK	—	OK	V unsteady	S20

Symptoms					
Picture Symptoms	*Picture Size, Shape*	*Raster (Blank Channel)*	*Sound*	*Sync*	*No.**
Picture jitters	OK	May jitter	OK	H unsteady	S21
OK	S-shaped sides	May have S shape	OK	OK	S19
OK	OK	OK	Noise, buzz, distortion	OK	S5
OK	Nonsymmetrical or trapezoidal	Shape poor	OK	OK	S22
Only horiz line	—	Only horiz line	OK	—	S26
OK	Not wide enough	—	OK	OK	S27
OK	Not high enough	—	OK	OK	S28
OK	H linearity poor	OK	OK	OK	S29
OK	V linearity poor	OK	OK	OK	S30
May be blurry	Too large	May be dim	OK	OK	S31
OK	Too small	—	OK	OK	S32
OK	OK	OK	OK	H sync dead	S23
OK	OK	OK	OK	V sync dead	S24
OK	OK	OK	OK	H and V dead	S25

* These numbers refer to the symptoms given in Table 2.

general power in the set would produce picture symptoms such as described in Cases 17 and 18.

Specifically, the possible defects could be a maladjusted ion trap, a bad cathode-ray tube, a *very* dirty screen, or improper voltages on the elements of the cathode-ray-tube gun.

Procedure. The screen is cleaned to remove the accumulated dirt. The ion-trap magnet is adjusted. After this is done, the picture is examined to see whether normal brightness is obtained. In this particular case, there is some improvement, but the picture is still much too dim.

Reference is made to the manufacturer's service data and the voltages on the gun of the cathode-ray tube are checked against the values given. The checks include the filament voltage, the accelerator voltage, and cathode-to-grid voltage. The latter is checked through the full range of the brightness control.

The voltages are found to be normal.

Although the symptoms do not suggest a high-voltage failure, the high voltage is measured as a double check. It is found to be normal.

These discoveries are reviewed mentally; the cathode-ray tube voltages are all correct; the ion trap is properly adjusted; the screen is clean. There is only one logical conclusion—the cathode-ray tube is weak.

The tube is replaced and normal operation is restored.

Case 20—Picture Quality Is Poor. The television set is located in a medium-signal area where outdoor antennas are the rule. Several channels are available.

Symptoms. The sound is normal but picture quality has deteriorated. Some channels are fair, others are snowy, blurry, or show interference, whereas reception was previously good on all channels.

Diagnosis. The conditions suggest difficulty with the antenna system because of the *changes* which have occurred in reception. Some channels are good, others are bad, and some are blurry, whereas they were once good.

The antenna system is inspected from the set to the antenna. First the antenna terminal board is checked to make certain that both leads are connected and also that they are not shorted together. The line is then examined visually. It appears to be a little weather-beaten, but good. The connections at the antenna also appear to be good.

Because part of the line is so located that it cannot be inspected closely, it is decided to test the line. The antenna connection terminals are shorted together by a jumper wire at the roof. The transmission line is then disconnected from the set and the line is checked for continuity. It is found to be open.

A new line is installed and normal receiver operation is restored.

Comments. The symptoms described can develop if either or both leads of the transmission line open; or if one of the connections at the set or the antenna comes loose; or if the line is shorted at the set or at the antenna; or if the line is shorted along its length or to a metal object.

A quick check on antenna condition can be made in moderate or strong signal areas by trying an indoor antenna as a temporary substitute. If this antenna outperforms the outdoor antenna on any of the channels, it is a pretty safe bet that there is a defect in the outdoor-antenna system.

Table 2. Troubleshooting by Symptoms

Black-and-White Intercarrier Sets

S1. *NO PICTURE—RASTER AND SOUND OK*
  - A. Problem area—Failure in the video amplifier between the video detector and the cathode-ray tube.
  - B. What to do—
    1. Check video amplifier tube.
    2. Test voltages in the video amplifier.
    3. Check video compensating coils for continuity.
    4. Check for an open video coupling condenser.

S2. *NO SOUND—RASTER AND PICTURE OK*
  - A. Problem area—Very broad, could be anything from the first sound i-f to the speaker.
  - B. What to do—Narrow down the problem area. Find out whether the audio amplifier seems to be working. Do this:
    1. Turn volume fully on.
    2. Hold screwdriver in hand so fingers touch metal shaft.
    3. Touch screwdriver to grid terminal of first audio amplifier tube. Keep other hand free of chassis.
    4. Listen for hum in speaker.
  - C. The problem is narrowed down in this way:
    1. If hum is heard, assume audio amplifier is OK and proceed to S2-2 below.
    2. If hum is not heard, audio amplifier is probably defective. Proceed to S2-1 below.

S2-1. *No Sound—Raster and Picture OK—Audio Amplifier Not Working*
  - A. Problem area—Failure in audio amplifier.
  - B. What to do—
    1. Check all audio amplifier tubes.
    2. Check voltages in audio amplifier.
    3. Check speaker by seeing if it clicks as audio power amplifier tube is moved in and out of its socket.
    4. Check for open audio coupling condensers.

S2-2. *No Sound—Raster and Picture OK—Audio Amplifier Checks OK*
  - A. Problem area—Failure in sound i-f amplifier, limiter, or f-m detector.

Table 2. Troubleshooting by Symptoms (*Continued*)

- B. What to do—
  1. Check sound i-f, limiter, and f-m detector tubes.
  2. Check voltages in these circuits.
  3. Trace signal by feeding a sound i-f test signal (4.5 mc) into each stage successively to find out where signal disappears.
  4. Check components carefully in the suspected stage.

S3. *WEAK PICTURE—RASTER OK—SOUND IS HEARD*

- A. Problem area—Very broad, could be anything from the antenna to the input of the cathode-ray tube.
- B. What to do—Narrow problem down. Try to pin down to r-f, i-f, or video amplifier. Do this:
  1. Turn picture control fully on. Check for snow or noise on any channel. If you see it, problem is most likely an r-f problem. Proceed to S3-1.
  2. If no snow is visible, proceed to S3-2.

S3-1. *Weak Picture—Raster OK—Sound Is Heard*—Snow Can Be Seen

- A. Problem area—This is an r-f problem and involves the antenna, the r-f amplifier or the channel switch.
- B. What to do—
  1. Check antenna connections, line and antenna.
  2. Check r-f amplifier tube in tuner.
  3. Check voltages in tuner, especially voltages on r-f amplifier tube.
  4. Check channel-switch contacts. Try cleaning them—all sections but oscillator.
  5. Check components in tuner.

S3-2. Weak *Picture—Raster OK—Sound Is Heard—No Snow Is* Seen

- A. Problem area—Rather broad, could be video i-f amplifier or video amplifier.
- B. What to do—Try to narrow down to video i-f or video amplifier, in this way:
  1. Observe quality of sound reception. Ask customer questions about the sound.
  2. If sound is noisy, has hiss, is distorted, or is weaker than normal, the problem is probably in video i-f. Proceed to S3-3.
  3. If sound is up to par and has suffered no noticeable deterioration, the problem is probably in the video amplifier. Proceed as though video is dead as in S1, above.

S3-3. Weak *Picture—Raster OK—Sound Is Heard—No Snow in Picture, Sound is Subnormal*

- A. Problem area—Failure probably in video i-f amplifier or in video detector.
- B. What to do—
  1. Check video i-f tubes and agc tubes (if any).
  2. Check video detector tube or crystal.
  3. Check voltages in video i-f amplifier stages.
  4. Check voltages in agc circuit.
  5. Check amplifier stage by stage with a signal generator.

S4. *NO PICTURE OR SOUND—RASTER NORMAL*

- A. Problem area—Anywhere from antenna to video detector.
- B. What to do—Narrow down as much as you can at this time. Do this:
  1. Turn contrast fully on. Notice whether any noise specks or flashes can be seen on the screen.
  2. If noise or flashes are seen, the problem is almost certainly in the tuner or antenna. Proceed to S4-1.

Table 2. Troubleshooting by Symptoms (*Continued*)

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3. If the raster is totally free of noise, the problem is probably in the video i-f. Proceed as suggested in S3-3.

S4-1. *No Picture or Sound—Raster Normal—Snow or Flashes Can Be Seen on Raster*

A. Problem area—Antenna or tuner. Best bet is failure of local oscillator.

B. What to do—

1. Check oscillator tube, then other tubes in tuner.
2. Check antenna connections and transmission line.
3. Check voltages in tuner unit.
4. Check channel-switch contacts, especially oscillator contacts. Try cleaning.
5. Check components in tuner.

S5. *SOUND DISTORTED OR NOISY—PICTURE NORMAL*

A. Problem area—Defect is most likely in the f-m detector or audio amplifier.

B. What to do—

1. Try readjusting the detector transformer in sets using ratio detector or phase detector.
2. Readjust quadrature coil in sets using gated-beam detector.
3. Adjust buzz control in sets using gated-beam detector.
4. Check detector tube.
5. Check sound i-f tubes.
6. Check audio amplifier as in S2-1 above, but omit B3.

S6. *PICTURE BLURRY OR POOR IN DETAIL, BUT NOT WEAK*

A. Problem area—No particular circuit is suggested, and trouble is difficult to narrow down quickly. Each check, however, will serve to do this and thus lead to the specific problem.

B. What to do—

1. Check and adjust focus.
2. Check video amplifier tubes (may be gassy).
3. Check whether fine tuning range is properly set so as to permit correct tuning for good detail.
4. Check antenna and transmission line for breaks or shorts.
5. Check video i-f tubes (gassy tube may cause overload).
6. Check components in video amplifier.
7. Check video i-f alignment. Realign if needed.

S7. *PICTURE DIM—SET OTHERWISE NORMAL*

A. Problem area—Fairly broad, could be any one of a number of things.

B. What to do—Try to narrow area down by identifying or eliminating the cathode-ray tube and its immediate power circuits as the source of trouble. Do this:

1. Adjust ion trap for maximum brightness.
2. Check all voltages to the cathode-ray tube including the high voltage, heater voltage, grid bias (through full range of brightness control), and first anode voltage.
3. If any individual errors are discovered, check components in the trouble area.
4. If all voltages are OK, a bad cathode-ray tube is indicated. Try a new one.
5. If all B+ voltages appear low, proceed to S7-1.

S7-1. *Picture Dim—Set Otherwise Normal but All B+ Voltages Check Low*

A. Problem area—A general power-supply condition or low-line-voltage condition.

B. What to do—

1. Check rectifier, if vacuum-tube rectifier is used.

Table 2. Troubleshooting by Symptoms (*Continued*)

2. Check line voltage.
3. Check selenium rectifiers (by substitution) if this type is used.
4. Check *first* filter condenser in power supply by jumping a new one across it.
5. Check balance of filter condensers in same manner.
6. Check for signs of unusual overheating (power transformer, filter condensers).
7. Check condensers which show signs of unusual heating (by temporary substitution).

S8. *PICTURE TOO BRIGHT—BRIGHTNESS CANNOT BE REDUCED*

A. Problem area—Limited to general area of cathode-ray tube and last video amplifier. Voltages may be in error due to a circuit failure or either of these tubes may be shorted or gassy.

B. What to do—

1. Check video amplifier tube.
2. Check all voltages at socket of cathode-ray tube, especially grid-to-cathode voltage.
3. If voltage error is found, check all d-c circuits connected to base of cathode-ray tube; check resistors for improper reading, condensers for leakage.
4. Check brightness control.
5. Try a new cathode-ray tube.

S9. *PICTURE CONTRAST EXCESSIVE—CANNOT BE REDUCED*

A. Problem area—An agc or contrast control problem. A gassy video i-f amplifier tube may be upsetting agc action. This last possibility is greatest if condition shows up only after from 10 to 30 minutes of operation.

B. What to do—

1. Check video i-f amplifier tubes (and r-f amplifier tube, to be safe) by substitution while set is hot.
2. Check agc tube, if set uses one.
3. Check voltages in contrast-control circuit.
4. Check voltages in agc circuit.
5. Check components in agc circuit.

S10. *NO LIGHT ON SCREEN—SOUND NORMAL*

A. Problem area—Fairly broad. Should be narrowed down immediately.

B. What to do—Find out whether high voltage is being properly supplied to the cathode-ray tube. This will then indicate which course to follow in further checks. Do this:

1. Check the high voltage supplied to the second anode of the cathode-ray tube, with the connector removed from the tube.
2. If the voltage is normal you can conclude that the horizontal sweep and high-voltage circuits are OK. Proceed to S10-2 below.
3. If the voltage is very low or missing, you can conclude that the problem is not in the cathode-ray tube or its low-voltage circuits. Proceed to S10-1 below.

S10-1. *No Light on Screen—Sound Normal—High Voltage Tests Bad*

A. Problem area—The problem area is limited to the horizontal sweep circuits or to the high-voltage circuit.

B. What to do—Find out which circuit is responsible for trouble, then check it out. Do this:

1. Check for horizontal sweep output at plate of horizontal output amplifier or at plate of high-voltage rectifier, by trying to draw an arc.
2. If sweep output seems normal, the high-voltage rectifier circuit is probably bad.
    a. Check high-voltage rectifier tube.

Table 2. Troubleshooting by Symptoms (*Continued*)

- b. Trace circuit with ohmmeter for opens or for leakage to ground.
  - 3. If sweep output is very low or missing, the problem is in the horizontal sweep circuit.
    - a. Check all horizontal scanning circuit tubes (oscillator, discharge, output amplifier, damper).
    - b. Check voltages in horizontal sweep circuit.
    - c. Check components in horizontal sweep circuit.
    - d. Trace sweep signal with oscilloscope.

S10-2. *No Light on Screen—Sound Normal—High-voltage Tests OK*

- A. Problem area—The problem is in the general area of the cathode-ray tube and its low-voltage circuits.
- B. What to do—
  1. Check all voltages at socket of cathode-ray tube.
  2. If a discrepancy is found, check the circuit which is abnormal. Trace the circuit and check the components.
  3. If the voltages are OK, the cathode-ray tube is probably bad. Before you remove it, try to adjust the ion trap.
  4. Check the cathode-ray tube.

S11. *PICTURE BRIGHTNESS FLUTTERS*

- A. Problem area—Aircraft reflections, waving transmission line or agc motorboating.
- B. What to do—
  1. Discuss aircraft problem with customer. Eliminate as reason for complaint before going further.
  2. Check antenna system for physical movement; observe effect on picture.
  3. Check manufacturer's service manual for references to agc oscillation or motorboating problems. Follow suggestions.
  4. Check agc tube, if one is used.
  5. Check agc circuit voltages.

S12. *SET DEAD ON ONLY SOME CHANNELS—RASTER OK*

- A. Problem area—The tuner unit.
- B. What to do—
  1. Check oscillator tube by substitution. Original may refuse to oscillate at some frequencies.
  2. Clean contacts of channel switch with a suitable contact fluid.
  3. Check local-oscillator adjustments on problem channel. Return to original settings if no results are obtained.
  4. Check voltages in tuner, especially local-oscillator voltages.
  5. Look for cold solder joints, unsoldered joints, or possible shorts which might be affected by turning the channel selector.

S13. *SNOWY PICTURE ON SOME LOCAL CHANNELS*

- A. Problem area—Antenna system or tuner unit.
- B. What to do—
  1. Inspect transmission line for breaks or shorts.
  2. Inspect transmission line for obvious violations of good practice (line next to pipes, metal surfaces) which might result in standing waves that knock out some signal frequencies.

Table 2. Troubleshooting by Symptoms (*Continued*)

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3. Check antenna for orientation and suitability for reception of all local channels.
4. Clean contacts in tuner unit.
5. Inspect tuner for cold solder joints, unsoldered joints, or possible shorts, especially in r-f and converter switch sections.

S14. *SOUND BARS IN PICTURE*

A. Problem area—Rather broad and must be narrowed down. Also involves making certain that the bars are *really* sound bars.

B. What to do—

1. Observe bars while listening to sound. Make certain that they actually flutter in perfect harmony with the sound; otherwise the problem is not sound bars.
2. Reduce sound volume to zero and note whether bars continue to be observed.
3. If bars continue to be seen, proceed to S14-1.
4. If bars disappear at zero volume, proceed to S14-2.

S14-1. *Sound Bars in Picture, Seen Even When Volume at Zero*

A. Problem area—Set improperly tuned or aligned.

B. What to do—

1. See if fine-tuning control can actually tune through the full signal. If not, readjust local oscillator in the problem channel.
2. If tuning adjustment cannot correct,
    a. Check service notes for instructions regarding trap adjustments that can be made with simple service equipment.
    b. Realign i-f circuits with sweep alignment equipment.

S14-2. *Sound Bars in Picture, Disappearing at Low Volume*

A. Problem area—Microphonics or a defect in the audio amplifier power circuit.

B. What to do—

1. Check for microphonic tubes by tapping all tubes handling the video signal (from antenna to the final video amplifier).
2. Check for open filter condensers in B+ circuit, especially for branch feeding voltage to the last audio amplifier. Try a test condenser across each filter condenser, one at a time.

S15. *NEGATIVE PICTURE*

A. Problem area—Receiver tuning or defect in circuits involving video detector and amplifier.

B. What to do—Note whether condition is intermittent or virtually continuous. If intermittent, problem probably is outside interference. If continuous, do this:

1. Check video amplifier tube.
2. Check voltages in video amplifier.
3. Check components in video amplifier, especially video coupling condensers for leakage.
4. Check cathode-ray tube for gas (with tester or by substitution).

S16. *PICTURE LOOKS LIKE STEEL ENGRAVING OR BAS-RELIEF*

A. Problem area—Receiver tuning or defect in circuits involving video detector and amplifier.

B. What to do—

1. Check local-oscillator adjustment to see if set can be tuned properly.
2. Check video detector tube or crystal by substitution.
3. Check video amplifier tube.
4. Check video compensating coils.

Table 2. Troubleshooting by Symptoms (*Continued*)

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5. Check for open video coupling condensers.
6. Check remaining condensers in video amplifier for opens.

S17. *INTERFERENCE PATTERNS ON PICTURE*

A. Problem area—Outside interference or oscillation in receiver.

B. What to do—Note whether condition is intermittent or continuous. If intermittent, problem is probably outside interference. If continuous, do this:

1. If built-in antenna is used, disconnect and try a standard indoor antenna. (Built-in antenna may encourage oscillation.)
2. Make sure all video i-f amplifier tube shields (if they are called for) are in place.
3. See if wires (line cord, transmission line, speaker wires, yoke leads, etc.) are resting near video i-f amplifier tubes. Move them away.
4. Check for open r-f bypass condensers in video i-f amplifier. (Bypass condensers on screen grids and on cold end of i-f plate coils, especially.) Check by jumping a 1,000-mmfd ceramic condenser across each, one at a time.
5. Check alignment of video i-f with sweep-alignment equipment.

S18. *HUM BARS IN PICTURE*

A. Problem area—Poor low-voltage filtering or a short from almost any signal circuit to the a-c filament circuit.

B. What to do—

1. Check all signal-handling tubes for filament-to-cathode shorts, including the cathode-ray tube.
2. Check for an open B+ filter condenser.
3. Inspect the heater-wiring circuit. Look for shorts to any point in set.

S19. *S-SHAPED SIDES ON PICTURE*

A. Problem area—Poor low-voltage filtering or a short from the a-c filament wiring to almost any circuit involving the horizontal synchronizing or sweep circuits.

B. What to do—

1. Check all sync and horizontal sweep tubes for filament-to-cathode shorts.
2. Check for an open B+ filter condenser.
3. Inspect the heater-wiring circuit. Look for shorts to any point in set.

S20. *VERTICAL SYNC UNSTABLE—PICTURE BOUNCES*

A. Problem area—Vertical synchronizing circuit.

B. What to do—

1. Make certain vertical hold control can be set at correct speed. Treat as in S24-2 below.
2. Look for signs of noise interference on the picture. This could cause improper vertical triggering.
3. Check for hum in *all* sync amplifier plate power circuits as well as in vertical sweep circuits. Jump a test condenser across each filter condenser, one at a time.
4. Check for filament shorts to circuits in sync amplifier and vertical scanning circuits.
5. Check tubes for filament-to-cathode shorts.

S21. *PICTURE JITTERS HORIZONTALLY*

A. Problem area—Horizontal sweep and high-voltage circuits.

B. What to do—

1. Adjust horizontal sync coils and hold control as described in manufacturer's service notes.

Table 2. Troubleshooting by Symptoms (*Continued*)

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2. Check horizontal sweep tube by substitution.
3. Check damping tube by substitution.
4. Look for sparking or corona in horizontal sweep output and high-voltage rectifier circuit.
5. Check all horizontal sweep tubes for internal shorts, by tapping.
6. Look for loose second anode connector on cathode-ray tube (it may be sparking).
7. Make certain that ground spring contact to outside coating on cathode-ray tube is solid.
8. Clean accumulated dust and dirt off of metal cathode-ray tubes.

S22. *PICTURE SHAPE NONSYMMETRICAL OR TRAPEZOIDAL*

A. Problem area—Magnetic fields at cathode-ray tube not correct. This could include the field of the ion trap, focus magnet, yoke, or stray fields. The problem could also involve hum in the horizontal sweep circuit.

B. What to do—

1. Check for hum interference as in S19, above.
2. Readjust ion trap.
3. Adjust focus magnet for better position if possible.
4. Check for open resistors or shorted condensers across yoke-coil windings.
5. Check for magnetized shell of metal cathode-ray tubes. (If rotation of the tube causes the picture shape to change, the tube is magnetized.)
6. Check yoke by substitution (even if resistance checks do not indicate a defect).

S23. *PICTURE WILL NOT HOLD HORIZONTALLY*

A. Problem area—Limited to horizontal sync amplifier, afc, and horizontal oscillator.

B. What to do—

1. Check horizontal sync amplifier, discriminator, reactance, and horizontal ascillator tubes.
2. Check horizontal sync adjusters.
3. Check voltages in horizontal sync, afc, and oscillator circuits.
4. Check components in these circuits.
5. Trace sync signal with oscilloscope.

S24. *PICTURE WILL NOT HOLD VERTICALLY*

A. Problem area—Vertical oscillator not capable of running at correct speed or failure in vertical sync circuit.

B. What to do—

1. Check tubes in vertical sync circuit.
2. Check speed of vertical oscillator to see if it can run at 60 cps.
3. If oscillator can run at 60 cps, proceed to S24-1 below.
4. If oscillator cannot run at 60 cps, proceed to S24-2 below.

S24-1. *Picture Will Not Hold Vertically—Vertical Oscillator Can Run at Correct Speed*

A. Problem area—Vertical sync amplifier circuit.

B. What to do—

1. Check voltages in sync amplifier circuit.
2. Check components in sync amplifier.
3. Trace sync signal with phones or oscilloscope.

S24-2. *Picture Will Not Hold Vertically—Vertical Oscillator Cannot Run at Correct Speed*

A. Problem area—Vertical oscillator circuit.

Table 2. Troubleshooting by Symptoms (Continued)

B. What to do—
  1. Check voltages in sweep-oscillator circuit.
  2. Check components in sweep oscillator. Measure resistors carefully for correct value. Check condensers for leakage, preferably by substitution with exact-value replacements.

S25. *PICTURE WILL NOT SYNCHRONIZE EITHER WAY*

A. Problem area—Limited to sync circuits from the clipper through sync amplifier stages.

B. What to do—
  1. Check clipper and sync amplifier tubes.
  2. Check voltages in clipper and sync amplifier circuits.
  3. Check components in these circuits.
  4. Trace signal with phones or oscilloscope, from video input at clipper, to sync input at vertical oscillator.

S26. *SCREEN SHOWS A SINGLE HORIZONTAL LINE*

A. Problem area—Failure in vertical sweep circuit.

B. What to do—
  1. Check vertical sweep tubes.
  2. Check voltages in vertical sweep circuit.
  3. Check wiring to yoke.
  4. Check vertical coils in yoke for open.
  5. Check vertical sweep output transformer.
  6. Trace signal from vertical oscillator to yoke with phones or oscilloscope.

S27. *PICTURE WIDTH IS SUBNORMAL*

A. Problem area—Horizontal sweep circuit from oscillator to yoke.

B. What to do—
  1. Check tubes in horizontal sweep circuits, especially horizontal output and damping tubes.
  2. Check voltages in horizontal sweep circuit.
  3. Check components in horizontal sweep circuit, especially condensers for leakage.
  4. Check horizontal output transformer.
  5. Check yoke.

S28. *PICTURE HEIGHT IS SUBNORMAL*

A. Problem area—Vertical sweep circuit from oscillator to yoke.

B. What to do—
  1. Check all tubes in vertical sweep circuit, especially vertical output amplifier.
  2. Check voltages in vertical sweep circuit.
  3. Check components, especially condensers in sawtooth generating circuit, for leakage.
  4. Check vertical output transformer.
  5. Check height control for proper resistance.
  6. Check cathode bypass condenser in vertical output amplifier for an open.

S29. *HORIZONTAL LINEARITY IS POOR*

A. Problem area—Horizontal discharge, output, and damping circuit.

B. What to do—
  1. Check horizontal output amplifier and damping tube.
  2. Test horizontal linearity coil.

Table 2. Troubleshooting by Symptoms (*Continued*)

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3. Test B+ Boost condenser for open or leakage. Try substitute.
4. Check resistors and condensers in network between discharge tube and sweep amplifier.
5. Check waveform at grid of sweep output tube with oscilloscope.

S30. *VERTICAL LINEARITY IS POOR*

A. Problem area—Vertical sweep amplifier and its driving circuit.

B. What to do—

1. Check vertical output tube by substitution.
2. Check cathode bypass condenser.
3. Check charging condenser for leakage.
4. Check resistance and range of linearity control.
5. Check waveforms in vertical sweep circuit with oscilloscope.

S31. *PICTURE TOO WIDE AND TOO HIGH*

A. Problem area—The second anode voltage on the cathode-ray tube is too low if the height and width are much too great and cannot be brought down properly.

B. What to do—

1. Check high voltage as accurately as possible, with second anode connected to the cathode-ray tube.
2. Check high-voltage rectifier.
3. Check for high-voltage leakage to ground.
4. Check high-voltage winding of horizontal sweep transformer for an open.
5. Check series resistors in high-voltage lead (if any) for an open or for excessive resistance.
6. Check cathode-ray tube (for excessive beam current).

S32. *PICTURE TOO SMALL*

A. Problem area—A general power-supply problem or insufficient horizontal sweep output.

B. What to do—

1. Replace horizontal sweep amplifier tube and readjust size controls, as a test.
2. Check line voltage.
3. Check low-voltage rectifier tube (if used).
4. Check B+ voltage.
5. Check selenium rectifiers (if used) by substitution.
6. Check filter condensers in power supply for opens and leakage.
7. Check filament voltages if set uses series filament wiring.

S33. *HIGH-VOLTAGE ARCING OR CORONA*

A. Problem area—Limited to horizontal sweep output, high voltage, and cathode-ray tube.

B. What to do—

1. Inspect for sharp bends or points on high-voltage wiring.
2. Clean out accumulated dirt in horizontal sweep output and high-voltage area.
3. Look for cracks in insulation on high-voltage wire.
4. Look for arcing between metal shell of cathode-ray tubes and its mounting assembly and chassis.
5. Inspect second anode connector for loose connection.
6. Look for broken or burnt resistors in the high-voltage wiring to the cathode-ray tube.
7. Treat high-voltage wiring with anticorona spray or replace with new wire.

QUESTIONS

1. Name five basic output signals of a television set.
2. What circuits should be suspect in an intercarrier set if sound is normal but the screen shows a blank raster?
3. How would the answer for question 2 be altered if the set were a split-carrier set?
4. What happens on the picture screen when: (*a*) the vertical sweep amplifier goes dead, (*b*) the horizontal sweep amplifier goes dead?
5. Where should you look for trouble if synchronization fails (*a*) in both scanning circuits, (*b*) in the horizontal, (*c*) in the vertical?
6. How can you tell whether the scanning circuits are capable of running at synchronous speed if synchronization has failed?
7. What troubleshooting approach is suggested if a set shows a combination of fault symptoms?
8. State two general principles which apply to the interpretation of voltage measurements in television sets.
9. What is the disadvantage of testing all resistors in a television set as a matter of routine?
10. What should be done if buzz is heard in an intercarrier set which uses a ratio detector?
11. What type of defect is suggested if the picture has a keystone or trapezoidal shape?
12. What quick test should be made if the sound is normal but the picture screen shows absolutely no light?

15

Oscilloscope and Alignment Equipment

What the Oscilloscope Does. The oscilloscope may be defined as a device that traces on a screen a line which represents the manner in which a voltage changes in amplitude from moment to moment. The conventional oscilloscope uses a cathode-ray tube to display the line or curve, and thus is capable of working at extremely high speeds. To put it another way, it is capable of displaying curves, or more properly oscillograms, of voltage variations which occur at fairly high frequencies.

The oscilloscope is used almost universally to display oscillograms of *recurring* waveforms, that is, waveforms which are developed over and over again at a regular rate. Only when this is true is it possible to see what looks like a stationary or reasonably stationary pattern on the screen. This makes the oscilloscope an ideal television test instrument because most of the functions in the set are recurring functions. This permits them to be observed and examined on an oscilloscope screen as conveniently as though they were drawings rather than the high-speed electrical phenomena they really are.

What an Oscilloscope Contains. The oscilloscope shown in Fig. 1 contains a number of basic sections or elements as in Fig. 2. They will be described below to give you an idea of the kind of instrument it is and what it can do.

The heart of the oscilloscope is the cathode-ray tube. The most popular sizes are 3 and 5 inch. The one shown in Fig. 1 is a 5-inch model. Most oscilloscopes use cathode-ray tubes with a green phosphor because this particular phosphor produces the greatest amount of light for a given amount of power.

The screen of the cathode-ray tube is covered by a transparent window on which is printed a system of lines such as can be seen in Fig. 1 or a fine grid of rectangular coordinates very much like conventional linear-coordinate graph paper. This line structure serves as a means of making measurements and comparisons of waveforms which is often valuable and sometimes necessary. If this grid were not provided, measurements might have to be made with a small ruler or with a pair of dividers.

Fig. 1. A cathode-ray oscilloscope useful for television service work. (Precision Apparatus Co. photo)

Associated with the cathode-ray tube is a suitable power supply to provide the tube with operating voltages and with appropriate controls to adjust focus and brightness of the beam (top two in Fig. 1). Unlike the television cathode-ray tube, the tube in the oscilloscope is electrostatically deflected by means of deflection elements built into the tube itself. It uses no ion trap, focus coil or magnet, or deflection yoke.

Vertical Section. The oscilloscope contains a high-gain vertical amplifier to amplify the signal under test. The amplifier may be called the signal amplifier, the video amplifier, or the Y-axis amplifier. The latter term is the mathematician's term for the vertical coordinates of graph paper and this relates to the vertical lines in the grid pattern on the screen.

The purpose of the amplifier is to provide enough gain to build up very weak test signals to a level high enough to deflect the oscilloscope beam from the top to the bottom of the screen. The amplifier includes at least a simple gain control (V. GAIN) and usually has an additional attenuator switch (V. ATTENUATOR) which extends the useful operating range from extremely weak to extremely strong signals.

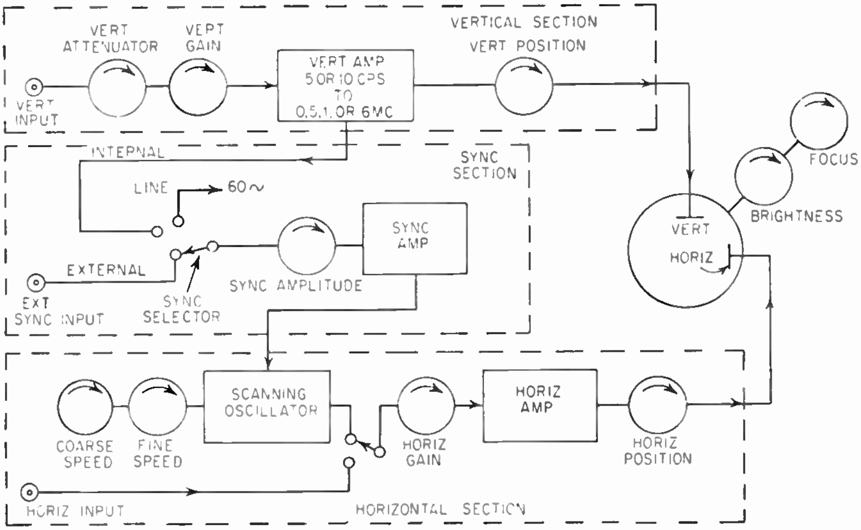


Fig. 2. Block diagram of an oscilloscope

The response of the vertical amplifier may start at a frequency as low as 5 or 10 cycles per second and extend, in general-purpose oscilloscopes, to anywhere from 500 kc to 1 mc. In the more expensive oscilloscopes, the range may extend to 6 mc or more.

The limit of 500 kc may sound very low for television service work but this is not really the case. There is a limit to how closely you can examine a waveform in general service work and you will rarely need much more than this response. True, you will not be able to see the clear, crisp outline of horizontal sync pulses on an oscilloscope having a response limited to 500 kc, but you will *see* the pulse. It may appear a little rounded rather than square, but for most purposes this is more than good enough.

Almost all other waveform checks can be made about as well with such an oscilloscope as with a more expensive extended-frequency oscilloscope.

Horizontal Section. The oscilloscope contains a variable-speed scanning oscillator and an amplifier to build up this signal so that it can deflect the beam across the face of the screen. Generally, the maximum amplitude is several times the width of the screen so that a portion of the full sweep can be expanded to fill the screen.

The horizontal scanning section may be called the scanning, the sweep, the horizontal, the time-base, or the X-axis circuit. Again, this last term refers to the coordinates of graph paper and identifies the horizontal screen coordinates specifically.

The scanning speed is adjustable by means of two controls, a coarse step-switch (SWEEP SELECTOR) and a fine-speed adjuster (SWEEP VERNIER) for exact speed setting. A typical speed range is from 10 to 50,000 sweeps per second. The purpose of the speed adjusters is to permit adjustment of the sweep to the same frequency as the basic repetition rate of the waveform under observation so that the waveform will stand still on the screen.

The horizontal section includes an amplitude or width control (H. GAIN) which permits the sweep to be collapsed to a point (at zero width) or expanded gradually until it is several times the width of the screen. In the latter case, only a portion of the trace is visible, in horizontally magnified form. A horizontal position control permits the entire sweep to be shifted to the left or to the right so that any portion of the oversize sweep can be brought into view.

Synchronizing Section. Unless the oscilloscope sweep signal is exactly the same as the repetition rate of the waveform being observed, the waveform will not stand still. If the speed is far from correct, the oscilloscope may provide a display which is nothing more than a maze of lines. Actually the scanning speed need not be equal; it may be exactly one-half the waveform rate (in which case *two* identical waveforms are seen), or it may be exactly one-third (in which case *three* complete waveforms are seen) or it may even be a smaller fraction. Whatever it is, the relationship must be exact, otherwise the waveform will travel sideways.

Sweep synchronizing is used in the oscilloscope in much the same way as in the television set except that there is no formal sync signal with which to work. Synchronizing energy may be obtained from one of three sources, selected by means of a sync-selector switch on the panel of the oscilloscope. The sources are identified as LINE, INTERNAL, and EXTERNAL.

Line Synchronization. The word "line" in this case refers to the power line. When the selector switch is in the LINE position, a-c voltage from the power line (60 cps in most areas) is fed into the horizontal synchronizing circuit. This will provide synchronization at 60, 30, 20, 15 (etc.) sweeps per second. The first is, of course, equal to the line speed. The others are ½, ⅓, ¼, etc.

The advantage of line sync lies primarily in the observation of waveforms which are related to the power line. In certain kinds of work, this is especially useful. In the case of television, line sync may be useful when you are viewing waveforms in the vertical scanning circuit or the over-all video waveform on a 60- or 30-cps base, but only when the television set is working with a station which is synchronized with the local power line. If it is not synchronized with the line, the waveforms will drift and one of the other two sources of sync (to be described) will have to be used.

The line-sync setting is almost always used for alignment work because the waveform which is viewed is generated by a sweep generator whose repetition rate is also synchronized with the power line.

External Synchronization. The word "external" signifies external to the oscilloscope. When the sync selector is turned to this position, the sync circuit is connected to a terminal at the panel of the oscilloscope to which any suitable sync signal may be applied. Suggestions as to its use will be given a little later.

Internal Synchronization. When the sync selector is turned to this position, the sync circuit is connected internally to the vertical amplifier. The sweep oscillator can then be synchronized with the waveform itself although this usually calls for more careful adjustment of sweep speed and of the synchronization amplitude control, not mentioned before. This control permits the amplitude of the sync signal to be adjusted whether it be line, external, or internal. Its purpose is to permit the sync to be adjusted to the point where there is just enough to hold and no more. Too much sync tends to spoil the sweep shape and may cause bad jitter.

Synchronizing on the internal waveform is sometimes critical because the signal may have no prominent characteristic (peak or valley) that can serve as a sync pulse or it may have several equally effective points. In this case, the sweep may jump intermittently from one to the other, making the waveform on the screen exhibit a corresponding jump. On ordinary signals, however, internal synchronization works very well.

Positioning Controls. All oscilloscopes include two positioning controls, one for the horizontal and one for the vertical. The horizontal has already been described so far as its use in shifting the waveform from left to right is concerned. The vertical position control does the same thing in the vertical direction.

The principal purpose of the controls is to permit the waveform to be centered on the screen or lined up carefully on any desired coordinates of the grid pattern over the face of the screen.

Most Popular Uses. The most popular uses of the oscilloscope in television service work fall into two general categories: alignment and troubleshooting. Alignment will be covered later on in this chapter.

The oscilloscope is extremely valuable in troubleshooting work primarily because of its application as a signal-tracing tool. There are a number of signals in a television set which can be traced accurately in no other way. This includes the video signal, the sync signals, and the sweep signals.

The video signal can be traced from its origin at the video detector through the video amplifier and right up to the control element at the cathode-ray tube.

The sync signals can be traced right from the clipper through the sync separator to the sweep oscillators.

The sweep signals can be traced from their origin in the oscillator itself, right on through to the deflection yoke.

In addition to tracing the signal for the purpose of discovering simply whether it is there or not, the shape and amplitude can be checked against the data contained in the service manual to make certain that it is correct.

The oscilloscope is not ordinarily used for direct signal tracing through the tuner unit, the video i-f amplifier, or through the sound i-f amplifier. It is likewise not used to check d-c voltages. The oscilloscope *can* be used for such tests but this calls for more experience and knowledge of the oscilloscope than the new owner is able to absorb until after he has mastered the more popular uses. It is questionable whether this kind of work would ever be done in a service shop because there are easier ways of making the same tests.

Most-used Sweep Speeds. All of the waveforms in a television set which you are likely to trace are repetitive at one of two frequencies. These are

60 cps and 15,750 cps. This means that you will be using only these two time bases for all of your work. When you examine manufacturers' service data you will discover, further, that all of the waveforms relate to one of these two speeds.

Sometimes the service notes actually identify the oscilloscope sweep speeds with each waveform. A notation near the waveform may indicate that the frequency is 60 or 15,750. Often this is not done, because it is assumed the serviceman knows that all waveforms are observed at one or the other speed. The serviceman is then expected to recognize immediately which of the two speeds is involved by the function of the particular circuit in question At worst, he won't know, and he will have to try both speeds to see which works out.

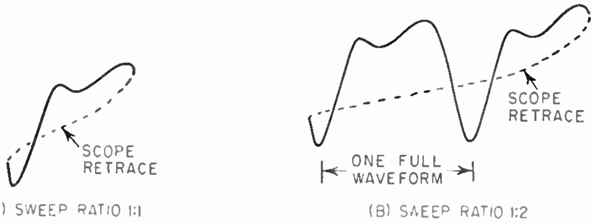


Fig. 3. These curves show the advantages of using half-speed sweep on the oscilloscope. The waveform occurs at 60 cps. The left-hand curve is seen with 60 cps sweep. The right-hand curve is seen with 30 cps sweep

Some service notes use a shorthand method of indicating oscilloscope sweep speeds. The letters H and V are used near the waveform to signify horizontal (15,750 cps) and vertical (60 cps).

The major significance in identifying sweep speeds is to tell you the repetition rate of the *waveform* and not necessarily the sweep speed to which the *oscilloscope* should be adjusted. This is to say that a 60-cps waveform need not be viewed on an oscilloscope set for a scanning speed of 60 cps. Often this is not as good as having a half-speed sweep, i.e., 30 cps. The same is true of 15,750-cps waveforms, which may be viewed better with a 7,875-cps (half-speed) sweep.

When a full-speed sweep (60-cps sweep for a 60-cps waveform) is used, only *one* waveform will be traced out on the screen of the oscilloscope as shown in the example in Fig. 3A. It can begin at almost any point and often this makes it hard to figure out exactly what you are looking at. When a half-speed sweep is used, two full waveforms are traced out, one after the other as shown in Fig. 3B. One of these will be complete and unbroken and can thus be observed in its entirety while the rest of the waveform may be ignored.

Because of this condition you will find yourself using 30 cps exclusively for waveforms which recur at a 60-cps rate and 7,875 cps for waveforms which recur at a 15,750-cps rate.

How to Synchronize Waveforms. In the general case, internal sync is employed when watching television waveforms. The speed is set at either 30 or 7,875 cps and the sync amplitude control is advanced just enough to make the waveform stand still. You will find that this calls for slight readjustment of sweep vernier to get best results. The best setting of speed and sync amplitude is the one which gives you a stationary pattern with the lowest setting of sync amplitude. The operating manual of the oscilloscope will explain the process in detail.

Under some conditions of television-set checking, the signal will not permit good oscilloscope sync to be obtained. You may be checking the video waveform, for example, and it may be distorted in such a manner that you can't make it lock on the oscilloscope. If the vertical sync in the set happens to be working properly, you can get good solid sync for your oscilloscope simply by taking advantage of the external sync setting of the sync selector. Connect a test lead from the external sync terminal to the vertical oscillator or some other part of the vertical sweep system. The vertical sweep voltage will then serve as a sync signal for the oscilloscope and the waveform which you are viewing can be made to stand still.

This idea can be extended further if the situation calls for it. You can get a sync signal from the horizontal sweep (for 15,750-cps waveforms) or from the vertical sweep (for 60-cps waveforms) of a good operating set tuned to the same station as the defective set. This will provide perfect sync for viewing waveforms in the defective set. It will not synchronize *sweep* waveforms of the defective set if the sweep oscillators in the latter are running free. This, however, is no problem because there is little difficulty in getting the internal sync to work on the oscilloscope when you are viewing sweep waveforms, thus you will not need to resort to external sync for these.

Tracing Video Waveforms. Video waveforms are commonly checked as a 60-cps waveform even though they actually contain frequency components at both speeds. Checking at 30 cps permits you to see a whole field as shown in Fig. 4*B*. The horizontal pulses will be so fine as to run together (forming the pair of parallel, horizontal lines) but this is of little consequence; the vertical sync pulse will stand out clearly and will permit you to get a good idea of how well the video circuits are performing. Figure 4A shows how a video waveform looks at a sweep speed of 7,875 cps.

Checks may be made at every significant point in the video amplifier (grids and plates) using your own knowledge as a guide if you don't have the service notes to identify the proper test points.

Because the signal is weakest at the detector and strongest at the cathode-ray tube, the oscilloscope vertical-gain setting will have to set rather high for the detector test and progressively lower as you trace through the circuit toward the cathode-ray tube.

The video waveform will point either upward or downward, depending upon the circuit you are checking. This is true because the signal is inverted by each stage of amplification and you should expect to see this effect on your oscilloscope.

Fig. 4. A video waveform as it appears on an oscilloscope. A shows horizontal pulses because the sweep speed is 7875 cps. B shows vertical pulses because the sweep speed is 30 cps

Most waveforms shown in manufacturers' service notes serve as a valuable or indispensable comparison standard to be used in evaluating what you see on your oscilloscope. Video waveforms are the exception. They have little value except as an *amplitude* guide against which checks can be made. To put it another way, about the only value in a manufacturer's sample video waveform is in telling you how strong it should be—not what it should look like.

The truth is that video waveforms should look about the same in *all* television sets. Once you are familiar with a typical video waveform you can go ahead and make checks without further reference to manufacturers' notes except to locate the points where they should be seen and to find out what the amplitude should be.

Beyond this, video waveforms vary a good deal depending upon the kind of scene being televised; they also appear differently on different oscilloscopes, varying with the frequency response of the oscilloscope.

These facts lead to the recommendation that you check video waveforms without too much concern for the exact appearance just so long as it looks like an average video waveform. You should see the sync pulse, and a jumble or smear of information between the pulses. Don't try to analyze it beyond these simple guides.

The amplitude is, of course, important, but this point will be covered later.

Tracing Sync Pulses. Sync pulses are checked at 60 (or 30) or 15,750 (or 7,875) cps depending upon whether they are vertical or horizontal sync pulses. In those circuits where the pulses are not yet separated (as at the clipper plate) checks are usually made at the slow rate, permitting you to see the vertical sync pulses primarily, unless there is some compelling reason to do otherwise.

Vertical pulses (see Fig. 5*B*) should look very much like the waveforms shown in the service notes for the set; the oscilloscope will have little material influence on their shape. Horizontal sync pulses (see Fig. 5*A*) are more difficult to reproduce accurately on an oscilloscope because they require a response of up to 4 mc for faithful reproduction. If your oscilloscope has a more limited response (as most service oscilloscopes have), it will tend to round off the pulses and thereby change their appearance. You will *see* the pulses but you should not be too critical as to their exact shape; the distortion will no doubt be due to your oscilloscope.

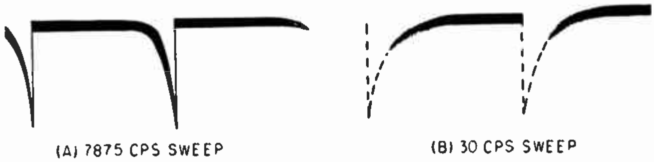


Fig. 5. Sync pulses as they might appear on an oscilloscope. *A* shows horizontal pulses; *B* shows vertical pulses

Tracing Sweep Waveforms. Sweep waveforms are viewed with either the high or low scanning speed depending upon whether you are checking the horizontal or vertical sweep circuit. The waveforms should appear fairly true to form on the ordinary service oscilloscope. Thus, the sample waveforms in service notes can be used as a good comparison check for shape.

The best guide for determining the points to check is the service manual of the set, because sets differ greatly in circuitry, waveshapes, and amplitudes. It is difficult to trace sweep waveforms without such a reference unless you are very familiar with sweep-circuit theory or are simply looking for the point at which a set goes dead.

The signal amplitude is extremely high in the output circuit of the horizontal sweep amplifier and special techniques are needed to make checks in this area. The techniques should be those recommended by the manufacturer of the oscilloscope in his operating instructions or those described by the set manufacturer in his service manual. There are no special rules which apply to all equipment because each set and each oscilloscope is different in terms of its usage in measuring high-voltage pulses.

Checks can be made right up to the grid of the horizontal sweep amplifier without the need for special precautions or techniques.

Checking Waveform Shapes. The general rules regarding waveform shapes have been mentioned above, particularly with respect to those which can be evaluated as to shape and those which are likely to be less significant so far as shape is concerned. When the shape of a waveform is to be compared with an illustration in a service guide, there are certain adjustments which you should make before you proceed further.

The pattern on the screen of an oscilloscope may be thought of as a picture printed on a rubber sheet. It can be stretched in either direction to make it change in appearance. The horizontal and vertical amplitude controls do this stretching. Before you try to make a comparison of shape you must adjust these controls to produce a pattern having proportions similar to those shown in the service manual. The width may have to be increased or reduced or this may have to be done to the height. Only when the proportions appear to be correct to the eye should comparisons of the detailed shape of the waveform be attempted.

Measuring Amplitude. The amplitude of a waveform is a significant characteristic which should be checked against the service data for a particular set. In the case of certain waveforms, such as the video waveform, this is frequently the only significant factor.

Amplitude measurements are made by calibrating the oscilloscope so that the lines on the screen represent a known number of volts in the vertical direction. The vertical gain of the oscilloscope may be set so that each inch represents 1 volt, or 10 volts, or 100 volts, or any other convenient value.

Because of the importance of making amplitude measurements, all oscilloscope instructions include detailed information on how to calibrate the instrument. The procedure is different with different oscilloscopes, so study the instructions which apply to your own instrument. In general, calibration consists of feeding in a signal of known amplitude and adjusting the vertical gain to make the pattern fit the screen as you would like it to. Then feed in the signal to be checked.

For example: If the filament voltage of a television set is 6.3 volts, its peak voltage is known to be (basic a-c theory) approximately 9 volts and its peak-to-peak voltage, 18 volts. If the oscilloscope input is connected to the filament voltage and its gain is adjusted so that the peak-to-peak signal occupies exactly 18 lines on the screen, each line is known to be one volt. If an unknown signal then is checked and it extends vertically across 32 lines, its peak-to-peak amplitude is 32 volts.

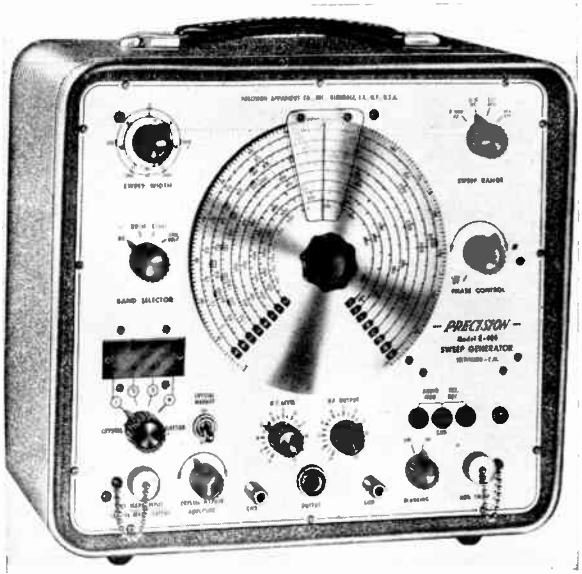


Fig. 6. A sweep generator used for alignment of television and f-m receivers. (Precision Apparatus Co. photo)

You should not be too concerned with reasonable amplitude differences when making checks against service-manual information. If a set calls for 120 volts amplitude for a given waveform and you measure it as 100 or 140, the chances are that things are O.K. A normal variation of 20 to 25 per cent is to be expected. Not until the amplitude approaches half what it should be, or twice, can you begin to be certain that you have a problem.

Sweep-signal Generator. The oscilloscope, by itself, cannot be used for making checks of the r-f or i-f circuits in a television set. The principal reason for this is that, during normal receiver operation, the basic r-f and i-f signals are not *recurring* waveforms of the type which is useful to oscilloscope analysis.

The sweep-signal generator (see Fig. 6) is a television service instrument whose basic purpose is to generate a recurring r-f or i-f signal which produces a result that can be seen on an oscilloscope. With this aid, the performance of r-f and i-f stages can be checked and aligned to meet the desired specifications of the manufacturer.

The recurring sweep signal results in a recurring waveform at the video detector. It is this waveform which is viewed on the oscilloscope. The repetition rate of the sweep signal is synchronized, within the sweep-signal generator, to the power line. This means that the oscilloscope can be synchronized with it simply by employing line sync and using a 30- or 60-cycle scanning speed.

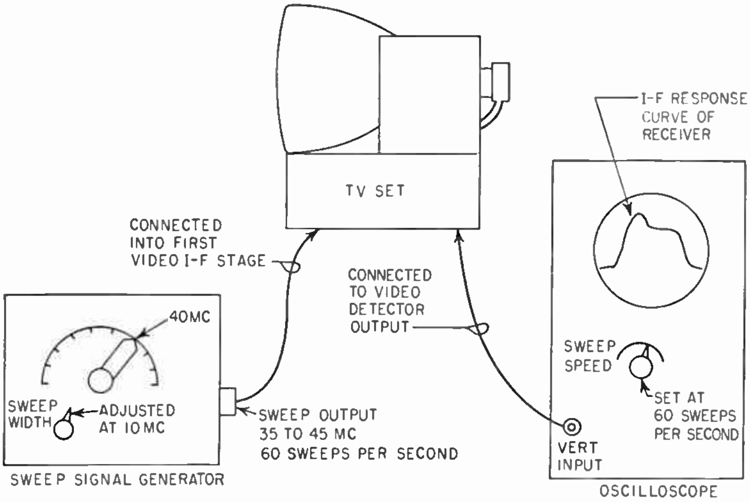


Fig. 7. Block diagram showing the hookup of a sweep generator, oscilloscope, and television set

The sweep-signal generator is an r-f and i-f signal generator, having wide-band frequency modulation instead of tone modulation. Within one sweep cycle, it starts at a given frequency and shifts smoothly in frequency until the cycle is completed. It then returns to the original frequency and starts over. The process is repeated 60 times per second.

Panel controls are provided to control the sweep width (how much frequency it will cover in one sweep) as well as the center frequency of the signal. The generator may be adjusted, for example, for a sweep width of 10 mc and tuned to a center frequency of 40 mc. Each individual sweep will then start at 35 mc and sweep through to 45 mc; this will take place 60 times per second.

When such a signal is fed into the video i-f amplifier of a television set having an i-f passband in the same general frequency range, the sweep signal passes through the set and is detected at the video detector as indicated in Fig. 7. If the set has zero response from, say, 35 to 37 mc, no signal will get through to the detector while the sweep signal passes through this range. As the signal sweeps beyond 37 mc into the range at which the i-f does respond, the signal will get through, in direct proportion to its response. If, for example, it has exceptionally high response at 42 mc, an exceptionally high signal gets through to the detector when the sweep signal passes through 42 mc. The detected signal, in other words, is a faithful indication of how the i-f amplifier is working.

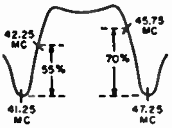
Adjust
L201 (top) for 41.25 MC trap. L201 (bottom) for 47.25 MC trap. Z201 (bottom) for 42.25 MC marker. Mixer plate coil (T101) and Z201 (top) for 45.75 MC marker. Note: Repeat adjustments until markers are positioned as specified. 
Z204 for maximum negative reading. Set signal generator output to maintain reading on lowest range of VTVM.

Fig. 8. An example of how alignment curves are included in manufacturers' alignment instructions

The oscilloscope is connected to view the waveform at the detector. It sees that waveform as a stationary curve. The curve may then be interpreted directly as the response curve of the i-f. If it is not correct, the i-f coils can be readjusted and the results observed simultaneously by the manner in which the response curve changes.

Basic Use. The basic purpose of a sweep-signal generator is to assist in the alignment of r-f coils in the tuner, video i-f coils, and sound i-f coils as well as to permit checks to be made of the performance of these circuits. It is always used together with an oscilloscope on which the response pattern is observed. Fig. 8 shows a typical response curve as it appears in a manufacturer's alignment table.

The operating instructions provided with the sweep-signal generator, as well as the controls on its panel, are all directed toward the basic job of aligning r-f and i-f amplifiers. This is what the instructions describe in detail. They will not tell the whole story, however, because each television set has its own procedure for alignment. The sweep-signal generator manufacturer consequently tells you what you should know about his instrument and how it can be used and he depends upon the television set manufacturer to tell you the exact steps to follow in aligning *his* set.

The set manufacturer, on the other hand, tells you only about his specific alignment procedure and assumes that you know how to use your sweep-signal generator. Between these two sets of instructions you get the whole story. Useful instructions which apply to all sweep-signal generators cannot be given, any more than useful instructions can be provided for the alignment of all television sets.

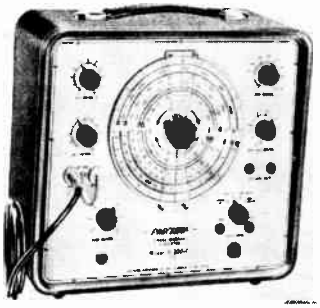


Fig. 9. A signal generator useful as a marker generator. (Precision Apparatus Co. photo)

Almost any oscilloscope can be used for sweep-alignment work, although some provide extra conveniences to make the job easier with a given sweep-signal generator (usually one of the same brand).

Marker Generator. The marker generator is really nothing more than an accurately calibrated signal generator. A typical marker generator is shown in Fig. 9. It is used in conjunction with a sweep-signal generator when alignment work is done. Its purpose is to permit specific frequencies to be accurately located along the response curve which is seen on the oscilloscope. It is a highly necessary piece of equipment because it is important to know where specific frequencies appear on the response curve in order to be able to do an accurate alignment job.

The signal from the marker generator is fed into the television set along with the sweep signal, as shown in Fig. 10. The marker signal remains fixed at the desired frequency. As the sweep signal passes through the marker frequency, a beat is produced which is seen as a wiggle on the response curve. It marks the point on the curve which corresponds with the frequency to which the marker generator is tuned.

The marker generator can be used either to find the frequency of a certain point on the response curve or, conversely, to locate certain desired frequencies along the curve.

Finding the Frequency of a Point on a Curve. Suppose you are viewing a response curve in which there is a pronounced peak or a valley and you want to find the frequency of this particular spot. To do this you tune the marker generator through the frequency range of the sweep generator. You will observe that, as you tune it through the range, a wiggle travels along the curve. You adjust the marker generator dial to place the wiggle right on the spot which you are trying to identify, as shown in Fig. 11A. Then you simply read the frequency of this point on the marker-generator dial.

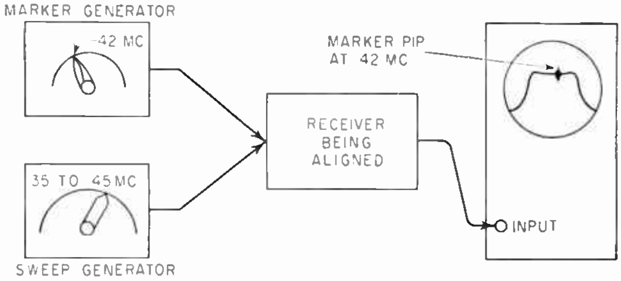


Fig. 10. Block diagram showing the hookup of a sweep generatar, marker generator, oscilloscope, and television set

Setting up Specific Frequency Markers. An important step in the alignment procedure of a receiver is to set up points along the trace on the oscilloscope screen which correspond with two or more known frequencies. These points then act as guides against which alignment is done. The alignment instructions of the receiver will tell you what frequencies are needed.

The general procedure is to place the sweep-signal generator and oscilloscope in operation so that a response curve is seen. Then the marker generator is turned to each of the significant frequencies and its location is marked (or remembered) as to its position on the screen. This may require some adjustment of the sweep-signal generator or oscilloscope, or both, to make the significant frequencies come out in convenient locations on the screen.

To illustrate the point, you may be interested in spotting only two frequencies, one for each side of the response curve. You can set up the marker and then adjust the horizontal position of the oscilloscope pattern to make this marker fall right on one of the heavy vertical calibration lines on the screen as shown in Fig. 11*B*. You may then wish to set up the other marker so it falls right on the next heavy vertical calibration line as shown in Fig. 11C. This will permit you to use the two heavy vertical lines as your guides when you start aligning the coils.

When you adjust the marker to the second significant frequency, the marker may fall short of, or may be beyond, the next calibration line. This can be corrected by either increasing or decreasing the horizontal amplitude of the oscilloscope. You will have to repeat each marker setup several times before they both come out where you want them. When you are through, the two markers will fall right on the two vertical lines which you would like to use as guides. You can then go ahead with the alignment using these lines for reference.

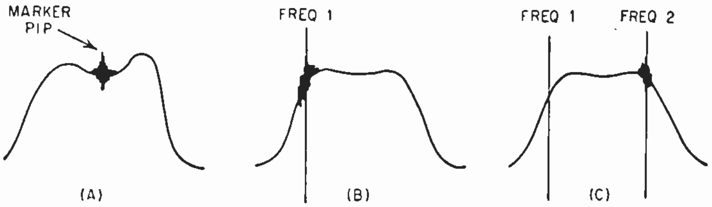


Fig. 11. Examples of how a marker pip appears on response curves. *B* and C represent steps in identifying a desired frequency span on the oscilloscope

If you prefer, the marker frequencies may be simply spotted on the screen with a grease pencil after which these marks are used as alignment guides.

Sweep-alignment Procedure. As explained earlier, the sweep-alignment procedure for a television set consists of following the instructions which are provided for your equipment and for the receiver itself.

The receiver-alignment procedure will give specific instructions as to where to connect the oscilloscope, where to connect the sweep generator, and the response curve that you should obtain in each step of the procedure. They will tell you what sweep frequency range to use and what marker frequencies to set up. They will not tell you how to adjust the oscilloscope, the sweep-signal generator, or the marker-signal generator unless some particular setting is especially important. Ordinarily, you will have to follow the test equipment instructions when setting up the equipment.

The alignment instructions will not only tell how to connect the equipment for each step of the procedure but will also tell what alignment adjusters must be turned to make the response curve shape up to correspond with sketches which are printed in the service manual. This includes the adjustment of traps as well as the alignment of the regular coils.

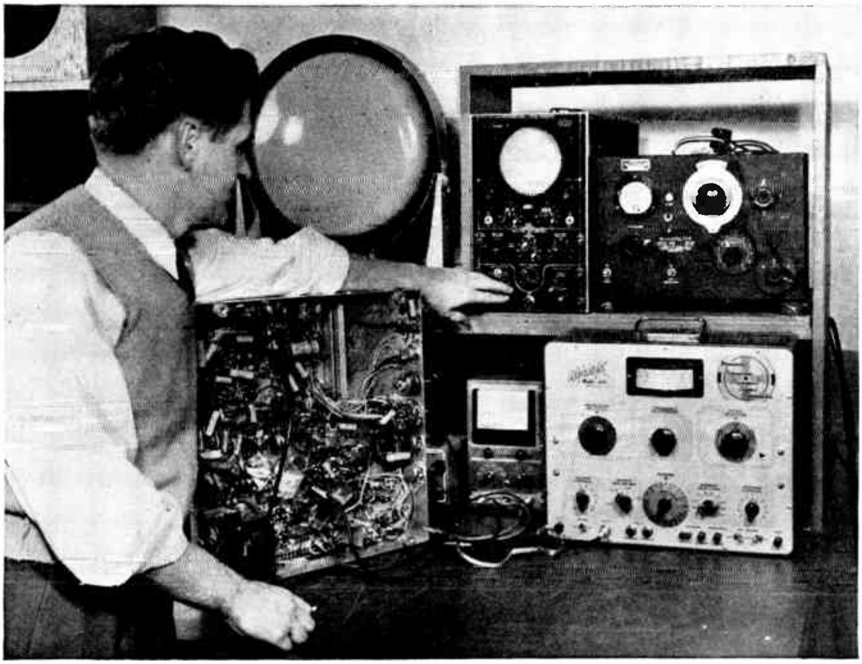


Fig. 12. A sweep alignment setup on the repair bench. The oscilloscope and marker generator share the upper shelf. The sweep generator is directly below them

Video I-F Alignment. The video i-f alignment of most television sets holds up quite well over extended periods of time and thus need not be done at frequent intervals. If you happen to have the set in your shop and have the time and equipment, it's a good idea to check the alignment and touch it up. Figure 12 shows a typical bench setup. The upper shelf contains the oscilloscope and marker; the lower contains the sweep generator.

The chances are that if a set is several years old, and especially if any of the i-f amplifier tubes have been replaced, it will need alignment and will be greatly improved by it. In some cases you may suspect that alignment is needed if the receiver seems to lack the sharp, crisp detail that you know from experience it should have.

If the receiver performs well, provides good picture detail, and generally looks good, there is no need to do an alignment job.

Video i-f alignment can be done only by the sweep method described above. The usual procedure is a stage-by-stage job.

The last i-f transformer is aligned first by feeding the sweep signal into the stage immediately before it and adjusting the coils identified in this step in the service manual. This may involve the adjustment of one or more traps which are associated with the last i-f stage. A curve which applies to this particular step will be shown in the manual.

The next step involves moving the sweep signal down one more stage and then adjusting the next-to-the-last i-f transformer, using the appropriate curve in the manual as a guide.

This procedure is repeated with each additional stage until finally the entire i-f system is properly aligned. The oscilloscope remains connected to the video detector through the whole job.

Video i-f alignment is not especially difficult with the majority of television sets. Your biggest problem, at first, will be to gain familiarity with your test equipment. Once you know how to use it and how it acts, you will find that video i-f alignment is really quite easy to do.

Sound I-F Alignment. Sound i-f alignment is appreciably simpler to do than video i-f alignment. Most television sets, in fact, do not call for the use of sweep-alignment equipment. Ordinary signal generators and voltmeters are used instead, following a procedure similar to that used in radio sets. Many manufacturers recommend alignment with an actual television station because this assures an exact sound i-f frequency.

The alignment indicator is usually a voltmeter connected to the limiter or to a point in the radio detector, as instructed in the service manual. The sound i-f coils are tuned up simply for maximum meter reading. The f-m detector is then tuned up by ear (usually) for minimum buzz or for best audio quality. The alignment instructions will tell you what to use as a guide. If a meter is to be used, the instructions will tell you how to connect it and what to watch for as you make the adjustments.

If the manufacturer calls for *sweep* alignment of the sound i-f (a rarity) the procedure will be described in much the same manner as the video i-f alignment. The oscilloscope is not connected to the video detector for this job. The service manual will tell you where to connect it.

In most sets, sound i-f alignment is so easy to do that there is little need to ponder very long as to whether it is necessary or not. So long as the chassis is out of the cabinet, the job need not take more than 5 or 10 minutes, even in the customer's home.

You may suspect that sound i-f alignment is needed if the sound is weak, noisy, or accompanied by a hiss, and especially if the audio is distorted. The presence of buzz in the sound is almost a certain sign that the f-m detector is in need of adjustment. This latter adjustment is most often needed in television sets and is frequently the only sound adjuster that needs to be touched.

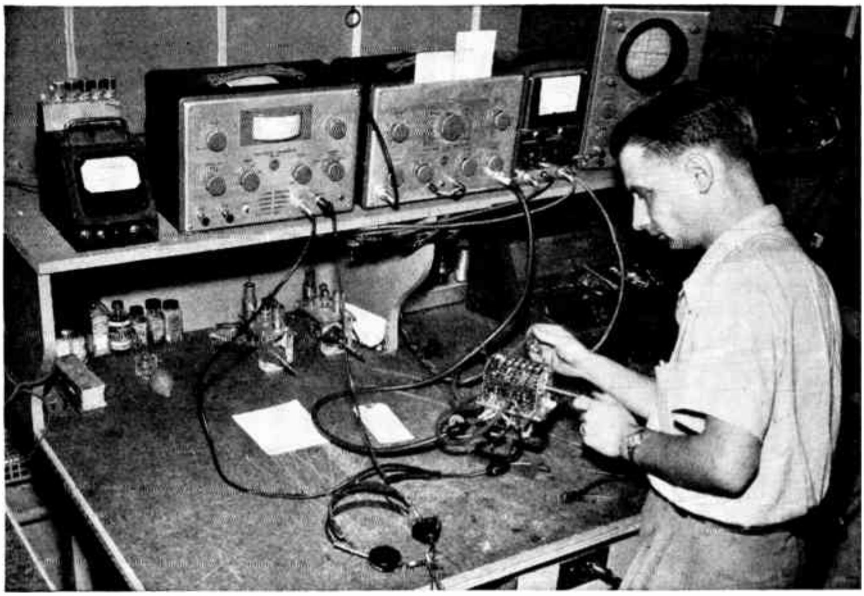


Fig. 13. Aligning a tuner unit. The sweep generator, marker generator, and oscilloscope are used for this purpose. (RCA photo)

R-F (Tuner) Alignment. This is by far the most difficult alignment work in a television set. It should not be attempted until after you are completely familiar with your equipment and have a fair amount of i-f alignment experience. You should also make certain that your equipment is satisfactory for this work, otherwise you will be unable to do the job.

The service manual should be followed most carefully. It will tell you where and how to connect the oscilloscope. Usually this is done to a test point on the tuner unit itself, which is removed from the chassis to do the job, as shown in Fig. 13.

The coils are tuned up channel by channel. This sometimes requires that the coils be spread or compressed, or adjusted by other less orthodox methods. The procedure may not appear to follow a nice, logical pattern as in the case of i-f alignment, but it should nevertheless be followed precisely.

QUESTIONS

1. What unique characteristic must an electrical signal possess in order for it to be displayed usefully on an oscilloscope?
2. What is the purpose of the grid pattern on the face of the oscilloscope screen?
3. What signal is handled by the vertical section of an oscilloscope, and where is this signal obtained?
4. What signal is handled by the horizontal section of an oscilloscope, and what is the source(s)?
5. What are the three sources of sync for an oscilloscope? Briefly, what is the purpose of each?
6. What sweep speeds are most commonly used on the oscilloscope for television service work?
7. What kind of a signal does a sweep generator deliver?
8. Explain the function of a sweep generator within the framework of your answer to question 1.
9. What are the two basic jobs performed by a marker generator?

16

Television Interference Problems

General Problem. The general problem of television interference is one of the most challenging that a serviceman is called upon to face. The work is basically different from the work of *repairing* sets, because usually the set is in good working order but reception *conditions* are poor.

Many interference problems are not easily solved. You may come across some which will stump you, but this should not discourage you. You cannot hope to solve them all. The best you can hope for is to solve many of the problems.

Often an interference problem will call for many hours of hard work before you find the answer. Before you undertake such a job, make certain that your customer is really willing to pay for it. He may have no idea of the amount of work involved, because he may assume that the problem is simple.

Estimating Your Charge. Some interference jobs are difficult to estimate in terms of labor and may not even offer a reasonable guarantee of success. This means that the work may really be a gamble; either you or your customer should be ready to face the gamble. Fundamentally, the gamble should be his, but it will take some selling and explaining to make him understand this. Your approach must be diplomatic, otherwise you may sound too tough. Your explanation should be reasonable and honest so that a workable understanding can be established.

You may want to assume the gamble yourself by setting a maximum price for the job, perhaps even making it payable only if satisfactory results are obtained. This decision is yours to make and it is often a wise one, but it is foolish to commit yourself unless you have a fair idea of what you are up against.

The information which follows should help you get a better idea of what must be done to solve a variety of interference problems.

Attacking the Problem. The typical problem is attacked in two parts. The first part is to *identify* the interference so that you can classify it correctly. This will establish the cause and will reveal, in turn, what you can do to clear it up.

The second part is to do whatever is necessary to *correct* the problem. This may be easy to do or it may call for a lot of work.

Typical interference problems are presented for the principal types of interference. Each problem includes information which shows how to classify the interference. Sometimes the matter of classification is difficult and involved, but it must be done as carefully as you can to save you the trouble of following up blind alleys.

Fig. 1. A bad ghost condition. The dark band is the ghost of the horizontal blanking and sync. (Allen B. Du Mont photo)

Study this information before you actually try to solve interference problems. Don't wait until you face one before you learn the basic methods of attack; that may be too late.

What Ghosts Are. Ghosts are really picture echoes which appear on the screen as additional images, displaced to the right of the original picture. Typical ghost conditions are illustrated in Figs. 1 through 3.

Ghosts most frequently appear weaker than the original picture, but often they may be as strong or stronger. There may be only one ghost or a series of up to five or even more. Some of the ghosts may be negative, that is, the ghost picture may reverse the blacks and whites as shown in Fig. 2.

Neighborhood Ghosts. The ghost condition is usually a characteristic of the neighborhood in which the set is located. It is caused by the fact that the transmitted signal travels to the receiving antenna over two or more different paths. The original signal arrives *directly* from the transmitting antenna to the receiving antenna. The ghost signals reach the receiving antenna over *reflected* paths. The transmitted signal may be reflected by a hill, a building, a water tank, a metal billboard, or other large, prominent object somewhere between the transmitter and the receiver. Because the reflected signal travels over a longer path than the direct signal, it arrives later at the set, and *appears* later (to the right on the screen) than the original picture. Where several reflected paths exist, each with a different length, several ghosts are seen.

The ghost signals enter the receiving antenna and there is nothing that can be done in the receiver to eliminate them. All of the work must be done at the antenna. The ghosts are eliminated only when the antenna is permitted to pick up *one* signal.

Fig. 2. A negative ghost. Note that blacks and whites are reversed in the ghost. Now the ghost of the horizontal blanking and sync appears as a white band. (Allen B. Du Mont photo)

Transient Ghosts. There is a condition in the set which can produce a repeat image on the screen but which is not really a ghost in the usual sense. This is to say that the repeat image is not the result of two signals entering the antenna. Instead, a transient condition in the set causes the picture to be repeated and you see what looks something like a genuine ghost.

It is important to know about this transient ghost, because when it occurs you could easily spend hours in antenna work to no avail. In the subsequent text, the term ghost is meant to cover ordinary multipath ghosts; the term transient ghost is used to refer to the special case just mentioned.

Identifying Ghosts. Ghost problems can be identified by the fact that the ghost changes in strength or position when a different antenna is used, or when the original antenna is rotated. A quick test can be made by substituting an indoor antenna for the regular antenna, and observing the change. If the ghost condition changes with the change in antennas and if further changes are observed as the indoor antenna is rotated and moved about, the condition is definitely identified as a true ghost problem caused by multipath reflected signals.

The ghost problem may be more severe in one channel than another, but this is to be expected for two reasons. First, the transmitting stations may be located in different directions. Second, the receiving antenna may not look in exactly the same direction in each channel. Either of these situations can influence the degree to which reflected signals will enter the antenna.

Troublesome Neighborhoods. Some neighborhoods will be known to you as ghostly neighborhoods because of the experiences of servicemen and customers. You won't have to make any special tests in these neighborhoods to verify the fact that the ghosts you see are caused by multipath reflections.

Some neighborhoods, and especially business areas where there are many large buildings, may be very bad ghost areas. Such areas will have multiple ghost problems, that is, a series of ghosts may be caused by the many reflection paths which exist.

Simple and Complex Ghosts. Because the methods for curing ghosts are very different in the cases of simple ghosts and complex ghosts, they are covered separately below.

Simple ghost problems are defined as those occurring in relatively open areas, free of congested tall buildings, and where only one or perhaps two ghosts are seen. These problems are not especially hard to cure.

Complex ghost problems are defined as those occurring in areas closed in by either many tall buildings or a series of mountains or hills. The ghost patterns are complex, usually revealing many ghosts across the screen. These problems are more difficult to solve and sometimes cannot be solved at all.

Elimination of Simple Ghosts. The only way to eliminate ghosts is to prevent the unwanted reflected signals from entering the antenna. Usually these signals arrive at the antenna from a direction different than that of the direct signal. It is this characteristic which permits you to eliminate the ghost. The difficulty increases, however, when the reflected signal arrives more nearly from the same direction, because it is then harder to eliminate it. It is fairly easy to eliminate unwanted signals when they arrive more nearly at right angles to the direct signal.

Ordinarily you will not worry about the directions of the ghost signals. You will simply try to eliminate the reflected signals without regard to where they come from, but you will observe, as you go along, that some ghosts are harder to eliminate than others.

The easier cases are eliminated simply by orienting the antenna in such a way that the ghost drops out. This may result in a weaker direct signal, but it will be clean.

Try Changing Antennas. Tougher cases may require that you use a different antenna, generally one which is more directional. This type of antenna is capable of much sharper pickup and thus discriminates more against signals arriving at different angles.

Fig. 3. A common ghost condition. (Allen B. DuMont photo)

Generally, you can simply try another type of antenna rather than pick out one which is known to be more directional. The antenna should be geometrically different. (Substitute a conical antenna for an ordinary dipole, or a double V for a conical, for example.) Each type of antenna is different in terms of its directional characteristics, and one type may be better than another in a given case.

With some antennas you will find that you will not have to sacrifice as much of the direct signal in order to eliminate the ghost as you will with other types. In especially tough cases, you may have to use an antenna which is especially designed for high directivity. The Yagi antenna is such an antenna.

The disadvantage of most highly directive antennas is that they are usually one-channel antennas. This is fine when only one channel is in use or when only one channel is a problem channel, but it may not work out when there is a problem in ghost elimination on a number of channels. The only answer may be to use separate antennas for each problem channel, each with its own transmission line. The proper antenna is then selected by means of a switch which you install near the television set.

Use of Antenna Rotator. Some cases may be solved nicely simply by installing an antenna rotator so that the user can change orientation for each station.

The actual work of antenna orientation requires that you know what is happening to the picture while you turn the antenna. Although this can be done by two men in communication with each other by a telephone set, it becomes a little tough when the problem is critical.

A much better plan is to install a temporary rotator, so that you can rotate the antenna and watch the picture at the same time.

Elimination of Complex Ghosts. The elimination of complex ghosts is done exactly as explained above except that different antenna locations must also be tried. It is normal for ghost conditions to change radically from one antenna location to another, or from one height to another.

Part of the test work may require two men, even though you have a rotator to turn the antenna. One man may hold the antenna upright while walking around from one location to another to see if a better spot can be found.

In congested city areas, the only answer often is separate antennas for each channel because it is so difficult to find one spot which is good for all. One spot may be fine for one, bad for another.

If a long, unshielded type of transmission line is used, it may be impossible to eliminate ghosts because some of the ghost signals may be coming in on the line itself. Under these conditions, a coaxial type of transmission line must be used to keep the line free of any signals except those which are picked up by the antenna.

Identifying Transient Ghosts. Transient ghosts can be produced by almost anything which puts a sharp peak or sharp slot in the frequency response of the television set. It produces what is sometimes called ringing. The condition is a transient condition and produces a picture like that shown in Fig. 4. The ghost is a self-generated ghost and is not the result of multipath echoes.

The most common cause for the transient is poor i-f alignment or a defect in the i-f coil system which reacts upon the alignment.

Another cause can be a badly adjusted trap which has been added externally to the set. There are other possible causes but they all deal with the over-all frequency response of the set.

One fairly certain test which can help you to identify the ghost as a transient is to try another antenna. If the ghost remains unchanged with a different antenna and with rotation of the antenna, it is almost certainly a self-generated ghost.

If the ghost is due to an i-f response problem (the usual cause) there is one test which will serve as a clincher. Tune the set through the full range of a panel tuner and watch the ghost. A true multipath ghost will remain stationary but a transient ghost will very definitely slide sideways *as the set is tuned* or it will change very noticeably in appearance.

Eliminating Transient Ghosts. If the transient is caused by a trap in the antenna system, you can locate the troublemaker if you have no reason to avoid tuning the trap. It may have been adjusted earlier by someone else, so mark its original setting carefully. Then tune it through its range. If it causes the ghost to slide in either direction, it is the cause for that ghost. Unless there is some compelling reason to leave it in, the trap may be removed, or detuned slightly to get rid of the transient condition.

Fig. 4. Transient ghosts, or "ringing." This condition is caused by a defect in the set. (Allen B. Du Mont photo)

If it is suspected that the transient is developed within the set, alignment will have to be checked and corrected if it is at fault. This must be done with a sweep generator and oscilloscope. Unless you have this equipment and can do the job yourself, have an expert do it for you.

You can make one further check before you remove the receiver for alignment, to make certain that you are not on a wild-goose chase. Place the receiver in operation outside of the cabinet so that you can get at the i-f coils. Then, while the set is running and you are watching the picture, place your fingers near each of the coils and especially the traps. This should detune the coils enough for you to see the ghost slide sideways or disappear as you do this. This will be a clincher test.

Be careful not to put your fingers right on coils which are carrying voltage. You can avoid shock by placing a strip of paper between your finger and the coil.

Diathermy-type Interference. Diathermy-type interference (hereafter called simply diathermy interference) was once much more common than it is today. It was then caused by diathermy equipment in hospitals and in the private offices of neighborhood doctors. Regulations of the Federal Communications Commission have since placed restrictions on the frequencies and radiation of diathermy equipment and this has greatly reduced the number of offending equipments.

Offending equipment is nevertheless still in use by some doctors who may be unaware of the regulations or who mistakenly believe that their equipment is causing no difficulty.

In addition, certain kinds of industrial electronic heating equipment which may cause identical forms of interference are coming into more popular use. The equipment includes certain kinds of induction heating equipment and electronic sewing machines which sew plastic materials together by heating them. These are classed with diathermy-type units because of the kind of interference they cause. They all generate strong radio-frequency energy which is modulated by the local power line.

Identifying Diathermy Interference. The *modulation* is one of the significant characteristics of diathermy interference. It is present because the equipment is supplied with raw a-c plate power instead of pure d-c. This is permissible because a clean signal is not required; only the heating effect of the signal is used. Raw a-c can be supplied with much simpler equipment because rectifiers, power chokes, and filter condensers are not required in the power supply.

The diathermy signal frequency or its harmonics can fall on one of the television channels or on the i-f frequency of the television set.

A typical diathermy interference pattern is shown in Fig. 5. The interference is in the form of a dark band, horizontally across the picture. Within the band of interference you will see a fine geometric pattern, sometimes called a herringbone pattern.

Effect of Power-line Frequency. The band may remain still or it may drift upward or downward, depending upon the city from which the *television broadcast* is coming. When the broadcast is local, the pictures are synchronized with the local power line which also supplies power to the local diathermy equipment. The band then remains stationary.

When the broadcast originates in a distant city having a separate power system, the *picture* is synchronized with *that* power line. The local power frequency may be nominally the same but it will sometimes be a little higher and sometimes a little lower. The interference, being local in origin, consequently drifts upward or downward through the picture.

If you see a drift of this nature you can be fairly certain that the cause is something outside of the set; if there is a herringbone pattern within the dark band, you then know that the interference is a *radio* signal and not simply a hum problem in the set.

Fig. 5. An example of diathermy interference. Note that the picture has turned negative within the interference band. (Allen B. Du Mont photo)

Two Types of Diathermy Interference. If the interference is present in all channel positions you can be reasonably certain that the interfering equipment is operating at the i-f frequency of the television receiver, or that one of its harmonics falls on that frequency.

If the interference is present on only one or two channels, you can be reasonably certain that the interference is at a television *channel frequency* or that its harmonics fall there. This is called *r-f* interference.

These two conditions are attacked in entirely different ways so you should make careful observations to determine which of the two conditions exists.

Recognizing Hum Band. As is true in so many cases, there is a condition which may be mistakenly assumed to be what you are looking for. You may see a dark band across the picture which you may assume is diathermy interference but which, in fact, is caused by a *hum* condition in the set. The band, however, will not have a herringbone pattern, but rather, will be perfectly smooth. In addition, the band may be seen even when the antenna is removed (although not necessarily). The hum band is cleared up by repairing the set. A common cause is a heater-to-cathode short in one of the tubes.

When diathermy interference is very strong, the interference band grows darker and gets wider. It may become so wide as to obscure most of the picture. When the interference is weak, the band narrows down and becomes lighter until, finally, only a faint band of herringbone interference is seen.

Eliminating Diathermy-type I-F Interference. When you have identified the diathermy interference as i-f interference as described above, there are three basic methods of attack: (1) trap out the signal with an i-f frequency trap; (2) improve the antenna system to favor the desired signals; and (3) locate the source of interference and have the responsible individual eliminate the interference at its source.

Trapping the Interference. When the interference is of moderate strength, an i-f trap may eliminate it completely. Suitable traps are available from radio and television parts suppliers.

Two forms of traps are available; one is a tuned trap while the other is not really a trap but rather a high-pass filter. It rejects all signals coming in through the antenna which are below channel 2 in frequency. The i-f frequency of television sets is always below channel 2.

The trap or high-pass filter is connected in series with the transmission line as closely as possible to the antenna terminals of the television set. The instructions furnished with the trap should be observed.

The tunable trap should be adjusted carefully while the interference is on. It should be adjusted for minimum interference.

The tunable trap will usually be more effective than the high-pass filter, especially if the set uses an i-f frequency in the 40-mc range.

Some television sets include an i-f trap in the tuner unit. Although these are ordinarily pretuned at the factory, it is usually possible to tune them more accurately for the interference signal.

Locate the trap in the manufacturer's service manual and adjust it for maximum rejection of the unwanted signal. It may solve the problem if the interference is not too strong.

In most practical cases, an external trap will have to be added if the interference is very strong.

Improving the Antenna. If the antenna system is poor (indoor type or any system in bad condition), improvement or repair will often correct the i-f interference problem.

To illustrate the point, when one side of the transmission line is broken or shorted to something, the chances of i-f pickup are much greater. This is also true if one of the antenna terminals is badly corroded.

If an indoor antenna is used, a great improvement may be observed by installing a good outdoor antenna.

If unshielded line is used, coaxial line may improve reception greatly.

More careful antenna orientation may help because this will increase the level of the television signal in proportion to the interference.

In short, the better the antenna system as a whole, the better are the chances of keeping i-f interference at a minimum.

Eliminating Diathermy-type R-F Interference. Eliminating r-f diathermy interference is generally much more difficult than eliminating i-f interference because the unwanted signal enters the set at the same frequency as the television signal. Thus it cannot be trapped out without also trapping out the desired signal. This is reason enough to try an i-f trap in the antenna lead-in, just to make sure that the interfering signal is *really* at the r-f rather than at the i-f frequencies. If the trap has a favorable effect on the interference, it may be assumed to be at the i-f frequency.

If the interference is at the r-f frequencies, the problem is handled somewhat like a ghost problem but with some special additional possibilities. Essentially the problem boils down to getting the antenna to favor one signal over the other by making the fairly safe assumption that they are coming from different directions.

Careful antenna orientation may make it possible to eliminate pickup of the diathermy signal. More directional antennas will also help. This much of the work is like ghost elimination.

Diathermy signals, however, are unlike ghosts in that they usually originate close by. This suggests some other possibilities in elimination. The signal may be picked up by the transmission line, for example, because it may be vertically polarized or because the signal may be very strong near ground level.

Often it can be reduced greatly by moving the transmission line to another side of the house. It may also be reduced by using a coaxial transmission line.

If you have tried all of the methods which are practical in an individual case, there is little more that you can do at the *receiving* location. The best attack then is to locate the offending equipment and have the interference eliminated at its source.

Locating the Source of Diathermy Interference. This work can be both time-consuming and fruitless but often it is the only thing you can do.

It is the best thing to do if you have reason to believe that you have a good chance of locating the offending equipment, because this will lead to correction at the source.

The owners of offending equipment are required by law to do all that they can to reduce or eliminate undesirable radiation. It is within your province to seek the equipment and then to call the problem to the attention of the owner, once you have found him.

The fact that interference exists at certain television receivers does not necessarily mean that the offending diathermy equipment is at fault in a purely technical sense, but the owner will usually help determine where the trouble lies. There are certain peculiar things that can happen right in a television set which will encourage interference. These you should not try to solve since they are basic design problems, but you ought to know that they sometimes exist. More information on receiver interference is given later in this chapter.

In most cases, the owner of the offending equipment will find that he has no choice but to eliminate the interference at its source because it is really at fault.

Doctor's Diathermy Equipment. There are certain symptoms which may lead you to believe that a doctor's equipment is causing the interference. These involve the hours and days of usage.

Although the hours may vary in different areas, the pattern of medical usage is similar. Ordinarily the interference is observed only on certain afternoons and evenings, and may appear for periods of approximately 5 to 15 minutes. As you can see, the pattern follows a fixed schedule which suggests regular, repeated treatments.

You may also be led to suspect that medical equipment is involved if an immediate neighbor is a doctor or if there is a medical institution nearby.

If you know of no neighboring doctor, your customer may. You can also thumb through the local telephone directory if you are in a small community with a small telephone book. A local druggist is a good bet for this kind of information; he will undoubtedly know the locations of all local doctors.

You will probably have to try several doctors before you find the one whose equipment is at fault (if you ever do). Perhaps the best approach is to telephone him outside of his regular office hours, and ask him if he owns diathermy equipment.

If he does, try as diplomatically as you can to get him to turn it on. You should, of course, do this from your customer's home where you can watch the set. Note whether the interference appears. Then ask the doctor if he will turn his equipment on and off once or twice on command, and notice whether this causes the interference to come and go. If it does, you have located the equipment.

Working with the Doctor. Your next step is to apprise the doctor of the problem. See if you can get him to call in a diathermy expert to solve the problem. Let him know who you are and how the diathermy man can get in touch with you if he wants to make some cross checks.

If you find that a little pressure is needed to get the doctor's cooperation, that can be obtained through the nearest offices of the Federal Communications Commission. Before you communicate with them, however, let the doctor know of your intentions. He may not wish to run the risk of having his equipment condemned, as it may be if it fails to meet Federal regulations regarding interference.

Doctors are human beings and this means that your whole approach must be as diplomatic and reasonable as possible; otherwise you run the risk of offending him and losing his cooperation in your tests. There is not much you can do until you have definitely pinned down the offending equipment.

Your customer should witness your tests so that he will be convinced of the reasons for his problems. This will take the pressure off you because he will then understand that there is little you can do until the offending equipment is cleaned up. The identification of the problem, in itself, may satisfy him because he will then see that there is nothing wrong with his set, and he may not wish you to press the problem further.

Commercial Equipment. There are certain symptoms which will lead you to believe that the interference is caused by commercial equipment. These also involve the schedules of operation.

Commercial equipment is generally used day after day, during working hours. Some of the equipment is cycled; that is, it may be on for a few seconds, then off for a short period, then on again, repeating this action in a rhythmic pattern. This type of operation most certainly is reason enough to suspect that it is commercial production equipment.

The usage may be irregular during working hours because not all equipment is used on a production-line basis.

Locating Commercial Suspects. Locating commercial equipment is easy in some respects and hard in others. The first part of the job, that of locating suspects, is fairly easy because the manufacturing plant will generally have to be within practical seeing distance. You can find out which plants are so located without too much trouble.

The second phase, that of finding the equipment and of checking it against the interference, may be more difficult. Your best bet is to speak with the manager of manufacturing if they have such a person, or to the man who has the responsibility that this title suggests. Ask him whether any electronic heating equipment is used in his plant. He may be familiar with the term radio-induction heating or simply induction heating.

Verifying Electronic Heating as a Troublemaker. If a nearby plant has such equipment, find out whether it will be possible to carry on a test, via telephone, which will take only a few minutes. They may be willing to do this immediately or may indicate an exact time when it will fit better into the manufacturing schedule.

The general idea of the test is the same as the one described earlier. The equipment should be turned on and off on command while you observe the interference pattern.

If you cannot arrange for a test, see if you can get the manager to have one of his workmen talk to you and explain how the equipment is used, in terms of time. He may even be able to tell you when it is used and how it cycles. This may be enough to serve as a positive identification.

In any event, you should apprise the owner of the offending equipment of the interference problem once you are reasonably sure that you have pinned it down to his equipment. The best advice to give him is to refer the problem to the manufacturer or seller of the equipment.

Continuous-wave (C-W) Interference. Continuous-wave signals, commonly called c-w signals, are a certain form of radio signal. In the strictest sense, this term refers to a simple, steady unmodulated signal such as is generated by the local oscillator in a superheterodyne set. In the practical sense, amplitude-modulated signals are included in this category because they produce patterns which are almost identical and because the problem is attacked in the same way. Frequency-modulated signals, however, are treated separately later, because they look different and are handled differently, at least in the diagnostic stages.

The c-w interference can originate from many different sources. It can be caused by local-oscillator radiation from a nearby television set, short-wave receiver, or f-m receiver. It can be caused by local a-m broadcast stations (short-wave), amplitude-modulated police or fire communication equipment, commercial communication stations, or amateur stations.

Characteristics of C-W Interference. A pattern similar to the one shown in Fig. 6 is produced by c-w interference. An unusually strong signal may just about blank out the full screen and may even reverse the polarity of the picture, changing whites to black and blacks to white. This is rarely seen, however, because it can be caused only by a very strong nearby signal; then it is usually a community problem and is solved on a community basis.

The c-w interference pattern is defined by the fact that the interference lines are straight or only slightly curved, they are parallel to each other, and they cover the full screen from side to side and from top to bottom. The lines may be broader so that there are fewer in number, or conversely, they may be finer and there may be more of them. The lines may slope at almost any angle above the horizontal, sloping from left to right or from right to left, or they may be vertical.

Fig. 6. An example of c-w interference. The lines could be finer or broader or appear at any angle

The interference can enter the set as *r-f interference* acting *directly* against the incoming television signal. It can enter as *i-f interference*, acting against *all* signals because it does its damage in the i-f system. It can enter the set as *image interference*, which is a special case of r-f interference although the damage is done in the i-f.

There are ways to distinguish these forms of interference from each other, and they are attacked differently. These methods will be described before the matter of possible sources will be taken up. As you will see, some types of c-w interference can be solved only at the source, so you should be able to analyze the symptoms toward this end.

Identifying R-F Interference. R-f interference is unique in that it beats *directly* against the television signal. The beat pattern which you see as the interference pattern, therefore, cannot be altered in geometry, no matter what you do at the set.

The acid test is to tune the fine-tuning control through its range at the panel. If the pattern *does not change* when you do this, the interference is positively identified as r-f interference, at or near the carrier frequency of the incoming video signal.

Except in unusual cases, r-f interference is a one-channel phenomenon. There may be times when the local signal has many harmonics which may interfere with other channels but this need not confuse the issue. *So long as the interference pattern remains steady as you change tuning, it is r-f interference.*

Identifying I-F Interference. I-f c-w interference enters the set, passes through the tuner by brute force, and develops c-w interference in the i-f system. To do this, the frequency of the signal must be at or near the video i-f frequency of the set, whatever that may be.

The interference looks exactly like r-f interference except that the pattern changes drastically as you tune the fine-tuning control at the panel of the set. The reason for this is that as you turn the fine tuner, you change the i-f input frequency value and thus change the frequency difference between the desired signal and the interfering signal. The change in the pattern is a change in the angle of the interference lines as well as in their number.

As you will see later, not all tunable interference patterns denote *i-f interference,* consequently there is more which you should do to pin the problem down to an i-f interference problem.

First, you should make a quick observation as to conditions in other channels. Usually, i-f interference is seen on more than one channel. This observation will strengthen the case in favor of an i-f problem.

Ordinarily, you might expect i-f interference to be present in all channels but this does not always happen. Strong stations tend to override the interference so that you may not see it in the stronger channels. In addition, the tuner in the set does a better job of rejecting i-f signals from channels 7 through 13 than it does from channels 2 through 6. The coils in channel 7 and higher virtually short-circuit the i-f interference out of the set before it can reach the i-f coils.

The clincher is to make a quick test with an i-f wave trap designed to cover the i-f frequency of the set you're working on. Connect the trap as recommended by the trap manufacturer, and tune it through its range. If the interference is i-f interference, it will drop in intensity very noticeably as you tune the trap through the interference frequency. The trap may, in fact, also work well enough to provide the cure, in which case your work is done.

Identifying Image Interference. Image c-w interference generates the same type of beat pattern mentioned above, and it responds to tuning just like i-f interference. This is to say that the pattern changes drastically in geometry as the fine-tuning control is turned. It is *not* i-f interference, however, and requires a different method of attack when you are trying to cure it.

Image interference is caused by a stray signal entering the tuner at a frequency which interferes directly with neither the r-f nor i-f signals. The frequency has to meet certain conditions, however, for the signal to be an interference problem. Specifically, it must be the *image* frequency of the channel to which you are tuned.

There are as many image-frequency possibilities as there are channels but these are not all likely possibilities. Some of the interference frequencies are unlikely to be in use because of the bands in which they fall. A practical possibility will be described, however, to illustrate the nature of the condition.

Example of Image Interference. If the video i-f frequency of a given set is 45.5 mc and it is tuned to channel 2, the local-oscillator frequency is roughly 98.5 mc. This assumes a channel 2 video signal frequency of 53 mc (which has been rounded off to simplify the illustration). Note that the difference between 53 mc and 98.5 mc is 45.5 mc, the i-f frequency of the set. The video signal is therefore (properly) converted to 45.5 mc.

If 45.5 mc is *added* to 98.5 mc, the frequency of 144 mc is obtained. Thus, if a *signal* at 144 mc can powerhouse its way through the tuner to the converter, it will mix with the oscillator signal and it will also produce a 45.5-mc beat. Thus, this signal will also appear in the i-f amplifier and will interfere with the channel 2 signal in the i-f circuits.

The possibility is a likely one because 144 mc happens to be assigned to amateur work. It is in the two-meter band which runs from 144 to 148 mc. Furthermore, 45.5 mc is close to one of the popularly used television i-f frequencies.

There are other possibilities in the other channels and with other i-f frequencies, but this will serve to illustrate the problem.

Use of I-F Trap to Verify Image Interference. Image-frequency interference rarely occurs on more than one channel in a given locality. The acid test, however, is made with traps rather than with further observation of symptoms.

Because the interference acts like i-f interference you will want to try an i-f trap as described above to see whether this produces a decided dip in strength of the interference. If you cannot find any semblance of a dip as you tune through the i-f frequency, the chances are very good that the interference is image.

Use of Trap to Block Image Interference. You should then calculate roughly the image frequency for the channel you are using. This is done by *doubling* the video i-f frequency and adding that to the video frequency of the problem channel. Then obtain a trap from your supplier which is capable of covering that frequency.

Connect the trap as recommended by the manufacturer and tune it through its range. If you find a dip in interference, the offending signal is obviously an image signal. The trap may, in fact, cure the problem so that there is nothing further to do.

Summary of C-W Interference. The factors which enter into the analysis, and thus into the identification of c-w interference as either r-f, i-f, or image, are summarized in Table 1.

Table 1. Identifying Three Types of C-W Interference

Type of Interference	*Symptoms*			
	Effect of Tuning	*Channels Affected*	*Qualifications*	*Effect of Trap*
R-F	No change in geometry of pattern *	Usually one	Rarely more than one channel	Do not try
I-F	Pattern geometry changes with tuning	One or more	Usually seen in some channels between 2 and 6; less often between 7 and 13	* I-F trap helps or cures
IMAGE	Pattern geometry changes with tuning	Usually one	Rarely more than one channel	I-F trap has no effect *Image trap helps or cures

* These symptoms are *positive* indicators as to the classification of the interference type.

Attacking I-F Interference. The simplest way to cure i-f interference is to trap it out in the antenna circuit, as described earlier. A trap will do the job nicely in most cases, but sometimes it won't work because the signal may be too strong. The answer may be a better trap. Often, it is not this simple.

Antenna *orientation* rarely helps to *keep out* the interfering signal because the antenna is a poor receptor for the i-f frequency of the set. Most of the i-f signal is generally picked up by the transmission line.

No matter what kind of line is used, it must be in good condition *to keep out* i-f signals. It should not have shorts or open leads because these conditions beg for interference problems. If the trap does not eliminate the signal entirely, a coaxial line may do the trick. It probably will, if the interference has been reduced to a fairly low level by a trap.

Before you go so far as to run a coaxial line, you may wish to try a better antenna. This will often work because it can add so much desired signal to the set that it may swamp out the interference. By the same token, any improvements which you make in antenna orientation will increase the desired signal without increasing the strength of the interfering signal, and significant improvement may result.

If you cannot solve the problem by these methods there is little more practical work that you can do short of locating the source of interference and eliminating the problem there.

Attacking Image Interference. As in the case of i-f interference, the simplest way of eliminating image interference is by trapping it out in the antenna input circuit. This may not be enough, however, and you may wish to try some additional cures.

Image interference is picked up more by the antenna than by the transmission line, as a rule. The exceptions to this are the signals picked up from local amateur stations (the example given) or from local police or fire signals. These are often transmitted and received with vertical antennas, thus are vertically polarized and may be picked up by the line itself. It is therefore important to make sure that the line is in good condition.

If you have definitely identified the interference as police, fire, or amateur (the methods are described later), it is better to think about working on the line than on the antenna, although the latter will also help.

A coaxial line may reduce the interference to a suitable level. A better antenna may also do the same thing, especially if the signal is picked up on the line.

Antenna orientation may be the best single method of improvement. The problem is handled just as though it were a ghost problem, because the desired and undesired signals come from different directions.

If you have identified the interference as local-oscillator interference, it is necessarily caused by a nearby set, perhaps that of an immediate neighbor. In the case of an apartment house you may be able to move the antenna away from the one which you suspect or raise your antenna above the others. In the case of a private home, it may be easier to check your neighbors to find out where the signal is coming from and then to move your antenna further away from the one which is radiating, to the other end of the house, for example.

Identifying Sources of C-W Interference. It is helpful to be able to identify interfering c-w signals in terms of the possible source, especially when the interference is so strong that it cannot be eliminated at the set.

All c-w signals are not the same, and they can be classified rather accurately if the symptoms are clearly observed.

The signals may be commercial broadcast signals, police or fire communications equipment, amateur signals, or the radiation of a local oscillator in a nearby television set.

In general, the signals are distinguished from each other by the schedules of operation, by the duration of the signal, and by the evidence of modulation. Each form of signal has its individual set of characteristics.

Identifying Broadcast Stations. The predominant characteristic of this type of signal is that it remains on the air for many hours without interruption. The signal may also show signs of a-m modulation which would tend to create faint horizontal bands on the picture along with the characteristic beat pattern. The bands will be random in width and will be constantly changing.

Ordinary broadcast stations rarely cause interference when conditions are normal, but they can when the receiving antenna or other nearby antennas are badly corroded. A poor connection which is corroded can act like a rectifier and cause interfering harmonics to be developed, especially when the local broadcast signal is strong.

The chances of interference from a nearby short-wave broadcast station are greater than with stations operating in the 500- to 1,500-kc range.

If the interference is quite strong and you can see modulation patterns on the screen, you may be able to pin down the source without any question; you can *listen* to the video signal and *hear* the modulation. You can do this with the headphone arrangement previously described. The headphones should be connected into the video amplifier circuit. You will hear the interfering signal along with the video and may be able to make out its call letters when the station is identified.

If broadcast station interference turns out to be the problem, you should inspect and clean all antenna connections of all antennas on the roof, if this is practical.

Identifying Police and Emergency Communications. The predominant characteristic of this type of interference is its on-and-off character. Transmissions are usually short and limited to three or four transmissions, after which there may be a quiet period. If the equipment is mobile, the interference can also vary in strength. Sometimes it may be extremely strong and at other times it may be very weak.

The modulation level used in the police-type of communication equipment is quite high so that you will probably see prominent horizontal modulation bands accompanying the c-w beat pattern.

Like the broadcast signal, this signal can be heard in the video amplifier when the interference is strong enough. The context of the transmissions should give you the necessary clues to pin the problem down to police, fire, or possibly taxicab communications.

The operators of this kind of equipment are easily located and, as a rule, will cooperate willingly in the suppression of interference at the source.

Identifying Amateur Signals. Amateur signals are characterized by the transmitting schedules. Because the work is amateur work, the chances ordinarily are that activity will be highest in the evenings and on weekends. In addition, the typical operation is on-and-off in character like police communications, but the individual transmissions are longer and the operating periods are steadier.

To be more specific, the average amateur transmission will be from 3 or 4 minutes to 10 or even 15 minutes in duration, followed by an off-period of about equal duration. The signal then returns for the next transmission, and so on, possibly for several hours at a stretch.

Amateur transmissions can be either by voice or by code. Amateurs refer to the first as phone and the second as c-w. Both produce the characteristic c-w beat pattern.

Phone signals will also produce modulation bands and the signal can be heard through headphones connected into the video amplifier.

Code signals will blink on and off as the code characters are transmitted. It is easy to identify the particular station by its flashes if you can read code but impossible if you cannot.

To cause interference, an amateur station must be fairly close to the television receiver. This usually simplifies the problem of finding suspects. If you find one local amateur he will probably know the others in the immediate area.

Amateurs should be approached as diplomatically as possible because they are so often the innocent whipping boys in interference situations. In recent years, a large percentage of amateur-blamed interference cases have been traced to the television sets themselves rather than to the amateurs.

Most amateurs will cooperate willingly in helping solve interference cases because few will tolerate interference problems which are the fault of their equipment.

Identifying Local-oscillator Interference. This type of signal is perhaps the most difficult to identify as to specific source because it can be caused by almost any f-m, television, or short-wave receiver in the neighborhood. Generally it will create only r-f interference, rather than i-f or image.

There are many possibilities for local-oscillator interference. To illustrate the point, almost any television receiver using a video i-f frequency in the neighborhood of 24 mc can be a potential source of interference to other local television sets. The frequency is such that when the offending receiver is on channel 2, its local oscillator generates a signal in channel 5; when it is tuned to channel 7, the oscillator is on channel 11; channel 8 would affect channel 12; channel 9 would affect channel 13.

There are other possibilities involving interference from f-m and short-wave receivers. Television sets using an i-f frequency in the 40-mc range, however, will not ordinarily interfere with other television receivers.

Local-oscillator interference is observed at the receiving end without regard to the i-f frequency of the affected receiver because the interference occurs right at the carrier frequency of the desired signal.

As you can appreciate, there is no fixed schedule for local-oscillator interference because that depends upon the habits of the person using the offending receiver. There are some distinct symptoms, however, which should permit you to pin the problem down to a local oscillator.

The predominant characteristic of local oscillators is that the frequency is not especially stable and it is tunable at the offending receiver. This immediately reveals a basic distinction against the almost rock-steady frequencies of bona fide transmitters.

The geometry of the beat pattern produced by most transmitters is usually very steady, whereas the beat pattern produced by local oscillators may exhibit frequent changes; the lines may slope one way for a while, then the other, and may also drift slowly from one position to another. Sometimes the pattern will scramble badly as the offending set is tuned. These symptoms are usually enough to identify the case as one of local-oscillator interference.

Beyond this indication, a local-oscillator signal will *never* produce modulation bars nor will it come on and off repeatedly as a police signal might.

Perhaps the only successful way to locate an offending receiver is by a deliberate check with each and every neighbor who may be close enough to cause the problem. A cooperative neighbor should be asked to tune his receiver slowly through its entire range while you watch the problem channel at the affected receiver. If you locate the offending set, you may be able to persuade the owner to permit you to reorient his antenna along with yours for the relative positions which produce a minimum of interference.

Fig. 7. An example of weak f-m interference. (Allen B. Du Mont photo)

Summary. Identifying the source of interference will be helpful only when you cannot eliminate it at the receiver and you would like to contact the responsible source for assistance at his end of the problem. The symptoms given above should assist you in doing this identification work but you are on your own once you have found the source of interference. Each case will develop more into a problem of human relations rather than a purely technical problem.

Characteristics of F-M Interference. F-m interference is caused by a frequency-modulated signal beating against the r-f or i-f signals in the television set. The signal may be classified as r-f, i-f, or image interference in much the same way as is done with c-w signals.

Characteristic f-m interference patterns are shown in Figs. 7 and 8. Note that there are no distinct crosshatch lines, but rather, the pattern is composed of many short, fine lines. In addition, the lines are in a state of almost constant activity as the signal is modulated.

The pattern will occasionally settle down to a typical c-w beat pattern for a moment or two, as the broadcast audio signal is silent between portions of the program. Then it will resume its all-over motion and will once again break up into fine zigzag lines. When the interference is especially strong, it may invert the blacks and whites of the picture, or simply obscure the picture with an intense grain pattern as shown in Fig. 9.

The f-m signal can be produced by any of the general sources listed above for c-w interference, *except* local oscillators of other receivers. Obviously, local oscillators would not be frequency-modulated; consequently, they can be eliminated as a possible source of f-m interference.

A possible source of f-m interference is an adjacent-channel television station. This condition, however, is described separately later. Make certain that you consider this possibility along with others.

Fig. 8. An example of moderate f-m interference. (Allen B. Du Mont photo)

Police, fire, taxi, broadcast, and amateur equipment is sometimes operated with frequency modulation rather than with amplitude modulation and can be responsible for the interference.

Because all of the possibilities involve bona fide transmitting equipment, you stand a better chance of finding the source of offending f-m signals and of getting some help in elimination.

Handling F-M Interference Problems. F-m interference problems are handled in almost the same way as c-w interference problems.

Observations and tests are first made to determine whether the interference is r-f, i-f, or image. The *shift* in pattern when you tune the set is not as pronounced with f-m signals as with c-w, but it is there. You will have to watch the pattern more closely to see it. The shift looks like streaking while you turn the tuning control. The streaking stops when the control is stopped. When the interference is *r-f,* no change occurs with tuning.

Curing the problems is also done in the same way, that is, by installing traps and by doing the recommended work on the antenna system. Every one of the suggestions applies to f-m interference and there are no new ones applicable to f-m alone.

In *identifying* f-m signals as to their possible sources, you will have to rely more on the time schedules of operation because you will not be able to hear the f-m signal in the video amplifier. The general problem is simpler, however, because the possibility of local-oscillator interference is eliminated.

Interstation Television Interference. Under certain conditions, one television station can interfere with another, sometimes so badly as to destroy the picture. The interfering station can be one channel higher, one channel lower, or can be on the same channel.

The most common condition under which this kind of interference occurs is when the location of the receiver is in an area roughly halfway between the two television stations. Less commonly, interference of any one of the three possible forms can occur during temperature inversion conditions.

Temperature inversion is the natural phenomenon caused by a blanket of warm air above a layer of cooler air at ground level. It can occur from early evening to late at night during spring, summer, and autumn months. Under certain weather conditions, it can occur almost nightly for possibly several weeks.

Temperature inversion tends to bend high-frequency signals earthward, and this can make television signals travel well over the horizon. Thus a station a hundred or more miles away can be picked up strongly enough to ruin local reception in one or more channels.

Interstation Interference Possibilities. Interference can occur only between stations on the same channel or on channels which are next to each other in *frequency* assignment. Interchannel interference cannot occur between channels 4 and 5 because of the additional 4-mc separation between them. It cannot occur between channels 6 and 7 because of the additional 86-mc separation here for f-m stations. Interchannel interference is possible between any other consecutively numbered channels (except, of course, 13 which is vhf and 14 which is uhf).

If channel 3 is taken as an example, interference is possible from either channel 2 or channel 4. Only the sound of channel 2 can interfere, because its sound carrier is just below channel 3. By the same token, only the video of channel 4 can interfere with channel 3, because the channel 4 video carrier is just above channel 3. The video carrier of channel 2 and the sound carrier of channel 4 are both too far away from channel 3 to cause trouble.

Sound and Video Interference. The two forms of interference are adjacent-channel sound interference and adjacent-channel video interference, respectively. Both interfere with the *video* of the channel in use. Adjacent-channel sound interference is always caused by the next *lower* channel, while adjacent-channel video interference is always caused by the next *higher* channel.

Same-channel interference, as the names implies, is caused by a television station operating on the same channel. It produces interference with both picture and sound reception although the former is apt to be the more annoying.

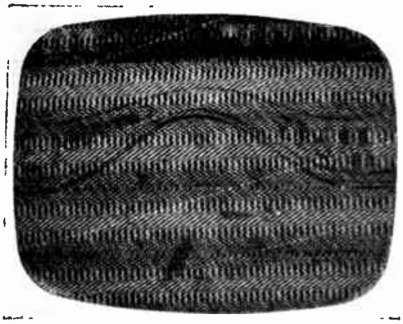


Fig. 9. An example of strong f-m interference. (Allen B. Du Mont photo)

How to Recognize Adjacent-channel Sound Interference. This interference is identical in appearance with the f-m interference described earlier, because it actually is caused by an f-m signal (the adjacent sound). It may be moderate as shown in Fig. 7 or strong as shown in Fig. 9, depending upon the relative strengths of the desired signal and the interfering signal.

The interference is rather easy to identify; all you have to do is to switch to the next lower channel and see if a signal is coming in strongly enough to be seen. The picture may not be recognizable, because now the channel you just left is interfering with the one you are watching, but you can tell that a signal is there. If it is, you have good reason to suspect that it is causing the f-m interference on the channel you were watching.

How to Recognize Adjacent-channel Video Interference. Adjacent-channel video interference is shown in Fig. 10. The dark vertical bar in the picture is the horizontal blanking and sync of the interfering signal. This is seen most prominently because it is the blackest part of the interfering video signal.

The blanking bar will rarely remain stationary. It will usually be in motion, sliding sideways in one direction or the other. This accounts for the common term "windshield wiper" interference which is used to describe it. At times it may stop traveling but will appear to be rubbery in that it will seem to be bouncing slightly from left to right.

Commonly the vertical blanking bar is also seen, although it is not shown in the illustration. It stretches horizontally across the screen and is just as dark as the other bar, but only about one-quarter as wide. The two together form a cross. The vertical bar will generally move slowly upward or downward or may appear to stand still.

Fig. 10. Adjacent channel video interference. The dark band generally sweeps across the picture like a windshield wiper. (Allen B. Du Mont photo)

The interfering picture may also be seen right on top of the desired picture, but only when the interfering station is really strong.

Because the frequency separation of the two video carriers is 6 mc, you will see no beat pattern such as is characteristic of c-w or f-m interference. The frequency of 6 mc is too high to pass through the video amplifier and, even if it could, it would produce an interference grain which is so fine as to be invisible. The only interference you will see will be the two blanking bars and possibly another weak picture on top of the picture you are viewing.

The symptoms are so clear as to make further checks unnecessary but you can verify the source of interference by switching to the next higher channel. You will see the interfering signal in that channel, although it may look like Fig. 7 or 9 because the desired signal will now be developing *sound* interference on *that* channel.

How to Recognize Same-channel Interference. Same-channel interference looks something like adjacent-channel video interference. You will see the blanking bars very prominently. The interference is recognized quickly as same-channel interference, however, by two additional symptoms.

First, you will see a form of horizontal beat pattern all over the screen. It will look like many thin black horizontal lines, perhaps 40 or 50, covering the whole area (venetian blinds on edge). These lines tend to spoil the picture completely.

Second, you will hear a gurgling sound in the background of the audio. It may be very strong or quite weak. It is the sound-upon-sound carrier interference. When you hear it and see an interference pattern with the characteristic black cross, there is no question but that you are experiencing same-channel interference.

How to Correct Adjacent-channel Interference. Either form of adjacent-channel interference can usually be reduced greatly by careful adjustment of the appropriate adjacent-channel traps. All television sets have these traps but they may not have been tuned right on the nose. (In practice, they are often found to be *nearly* right, but not exactly right.)

Locate the trap adjusters carefully by using the manufacturer's service data. Look for the adjacent video or adjacent sound traps, whichever needs to be adjusted. There may be one or more of each type.

If the interference is present you can adjust the traps by eye, at least as well as you could do it with alignment equipment. Usually you can do better. Adjust the appropriate traps for minimum picture interference.

Be careful not to touch the (same-channel) sound traps because these influence video alignment. Make sure you have located *adjacent-channel* traps.

Do not attempt to adjust the traps if the interference is not present. This can then be done accurately only with precision alignment equipment. The manufacturer's instructions should be followed if you intend to make adjustments without using the interfering signal.

When the traps are properly adjusted, no further improvement can be made in the set itself but much can be done at the antenna. Since interfering television signals rarely come from the same point of the compass, antenna orientation can do much to help.

If the receiver is *between* the stations and both can be picked up well enough to be used, separate antennas for these channels can be installed, each adjusted to eliminate the other. An antenna rotator may be even more desirable.

Do not depend upon antenna orientation to do the cleanup job by itself. *Always* make certain that the adjacent-channel traps are adjusted for their maximum effectiveness.

An important warning: On intercarrier sets, make certain that you have the set tuned for best *picture* quality (not necessarily *least* interference) before you adjust adjacent-channel traps, because the traps will be most effective only when you return to that same tuning during normal viewing. On split-carrier sets, make certain that the sound is tuned in perfectly before you adjust the traps.

How to Correct Same-channel Interference. This interference is tougher to eliminate because all the work must be done at the antenna. There are no trap adjustments which can help the situation.

If the condition is an occasional freak condition which occurs only during unusual temperature conditions, it is better to advise your customer to grin and bear it. The freak weather conditions cannot be predicted or even estimated by anyone but experts, so don't try to figure them out. The condition can occur in wet weather or dry, cool weather or warm. The important effect occurs up in the stratosphere.

If the condition occurs often enough to be a problem, accurate antenna orientation should be done.

Quite frequently, the offending station comes from some point in back of the antenna (because you are between the stations). When this is true, you should use one of the special antennas which features exceptionally high front-to-back ratio. It will provide a great deal of improvement. The Telrex Thunderbird is such an antenna since it is claimed to have a front-to-back ratio of better than 22 db. Any antenna with a ratio approaching 20 db would do the job.

Electrical Impulse Noise Interference. Electrical impulse noise can be created by almost any sparking device. Brush-and-commutator motors are a notorious source of such noise, although other kinds of sparking devices are also troublesome.

The following list includes some of the more commonly encountered noise generators:

Electric razors which use brush-type motors or have vibrator contacts.
Electric drills, fans, sewing machines, food mixers, or vacuum cleaners

when they have brush-and-commutator motors. Most of these do, except for fans, which rarely do.

Electric typewriters or calculating machines which may employ brush-and-commutator motors and contact-type speed regulators.

Electric cash registers with brush-and-commutator motors. The contacts also may be troublesome.

Oil-burner ignition systems. These employ a high-voltage spark to ignite the fuel. The spark usually operates for the first 90 seconds when the burner starts operating.

Figure 11 shows typical electrical impulse noise interference. Different motors may create more streaks or they may be longer, but the pattern will be somewhat like the illustrated example. The vertical sync may be affected by the noise, as shown, or it may not, depending upon how severe the noise is.

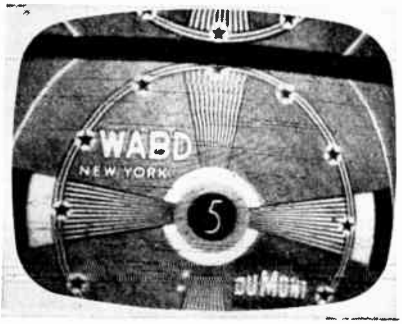


Fig. 11. Electrical impulse noise interference. The noise causes the horizontal streaks and may cause the picture to jump out of vertical sync. (Allen B. Du Mont photo)

When the television signal is moderately strong, the noise may not be heard but will be seen on the picture. If the television signal is weaker or if the noise is exceptionally bad, it may be heard as buzzing in the sound as well as being seen on the picture.

Contrary to general belief, the noise rarely enters the television set through its power line but rather is almost always picked up via the antenna system. This is true even though the power line may be the initial source of the noise. Consequently, the noise can rarely be eliminated by means of a noise filter at the set.

Locating Source of Electrical Interference. The only successful approach in most cases is to eliminate the noise right where it is generated. This means that you have to find the offending device.

You should have little trouble finding the culprit when it is located in your customer's home. Often your customer will know what it is but will feel that the condition should not occur.

If you are trying to locate the device, have your customer turn on *every* electrical device he has, one at a time, while you watch the set. To help him remember all possible devices, go through the above list as a check. If one of these is to blame, you will have little trouble locating it.

The oil burner cannot always be turned on and off to demonstrate its action because of the various interlocking devices which it employs. Generally, the problem will develop only from a cold start and you may have to wait for the burner to cycle normally to see the effect.

When the noise source is outside of the home, you will have more trouble locating it, especially if it is on only occasionally. Before you look for it, however, you should try to get a rough idea of what it might be.

How Time Clues Aid Identification. Your best clues deal with the manner in which the noise comes on and off. Each of the above devices has its own peculiar characteristics of use. Try to think of how each suspected device is actually used and look for a correlation with the noise.

To illustrate the point, an electric razor is usually used steadily for 5 minutes or so, once or twice a day at fairly regular hours. A sewing machine may be used for many hours, but continuously goes on and off as the sewing is done. Moreover, the motor starts slowly (fewer streaks) and speeds up (more streaks) each time it is started. Electric typewriters may also run for hours, but will run steadily without interruption. (The motor runs as long as the machine is turned on, even though the keys are not depressed.)

In many practical cases you will not see the noise but rather will have to make a guess as to what it is through your customer's description. If he has not been especially observant, you should ask him to make further observations which he can report. He should record the time of day, the duration of the noise cycles, and the period over which the device appears to be used.

If the noise is one which occurs only during rainy or wet weather or if it continues day after day and is troublesome over a wide area, the problem may be in the power transmission system of the local electric utility. Report the condition to them. They may be able to clear it up or to locate it along their power-line system.

Curing Electrical Interference. The devices listed above are sometimes difficult to cure of noise. Sometimes the simple cleaning of the commutator of a motor will do the job. More often condensers may have to be connected across the brushes to filter out the noise. Small condensers in the order of 100 to 1,000 mmfd will usually be most effective, but you should try a variety of sizes. The condenser must be placed directly across the brushes with the shortest possible leads, otherwise the filter may not work.

Power-line plug-in filters may work in some cases although this is not to be expected in the general case. The power line from the appliance to the filter will often serve to radiate the noise very effectively. A greater degree of success is obtained when a line filter is installed inside the appliance, if there is room.

Ordinarily it is unwise to do more than to identify the noise-generating device and clean its sparking contacts when these are easy to reach. Most other work will require that the appliance be taken apart and you may not wish to do this. You may prefer to advise your customer to put up with occasional interference or to have the device cleaned and filtered properly by the manufacturer or a competent serviceman for that product.

Special radio filters are made by most manufacturers of electric typewriters, calculating machines, cash registers, and sewing machines. These are quite effective and should be used if available for the specific device. As an alternative, these devices can be interference-serviced by the specialists who handle these products.

Ignition Noise. Gasoline engine ignition interference is similar in general appearance to Fig. 11. There are other characteristics which make it fairly easy to identify.

First, ignition interference normally fades in and out as the vehicle approaches and passes. Second, the sparking rate is directly related to engine speeds which change with acceleration and normal driving in such a way as to suggest almost automatically an automobile engine. If you have ever heard ignition noise in a car radio, you will have little difficulty recognizing it in a television set.

If ignition noise is severe and objectionable it can often be reduced or eliminated by making changes or improvements in the antenna system. It will help you to know that most ignition noise is picked up in the transmission line, although some also may be picked up by the antenna.

The most obvious corrective measure is to run the transmission line down the side of the house at a point farthest removed from the traveled road. This takes advantage of the shielding effect of the building.

In more severe cases, a shielded form of transmission line may be needed and will help appreciably.

Raising the antenna also helps because it increases signal strength, thus overriding the noise to a greater degree, and places the antenna farther away from (above) the source of noise, which is at ground level. A stacked antenna also helps greatly because this form of antenna picks up less signal from below the antenna.

In the typical case, it is usually enough to rerun the line if a better path is possible, to raise the antenna, and to orient it accurately for best signal. If these steps fail to provide sufficient improvement, a better antenna will usually finish the job. Then the additional work of running a shielded line can be tried as a last resort.

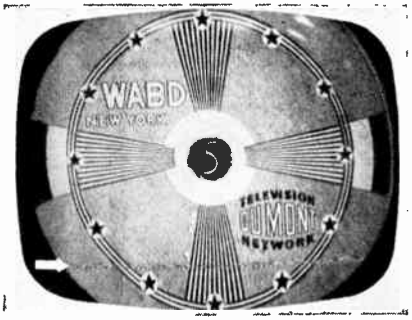


Fig. 12. Electric lamp interference. The interference band is identified by the arrow. (Allen B. Du Mont photo)

Incandescent Lamp Interference. Figure 12 shows a typical example of incandescent lamp interference. It shows up as a thin line which contains a visible beat pattern. The signal is an r-f interference pattern.

The line may remain stationary or it may drift upward or downward depending upon the phasing of the picture with respect to the local power line. The interference pattern is synchronous with the local power line.

Occasionally a double line is formed with about a half-inch spacing between. Each line then looks like the single line shown in Fig. 12.

Lamp interference is a curious phenomenon popularly attributed to lamps using the old type B bulb in which the filament is supported by a central glass stem in a zigzag shape. It has also been observed, however, with several types of modern lamps.

An interfering lamp can cause troubles over a radius of up to about 500 feet. This means that the lamp could be in any one of a number of neighboring homes in built-up suburban areas. The possibilities are greater in congested neighborhoods.

The matter of finding the offending lamp is simply a problem of turning suspected lamps on and off one at a time to see if the bad one can be found. In a suburban community, your customer may inquire of neighbors as to whether they observe the same phenomenon and, if they do, to request that they too search for the offender.

The cure is to discard the bulb.

QUESTIONS

1. What are the two basic steps in dealing with interference problems in general?
2. What causes ghosts? How can a simple case be cured?
3. What two characteristics identify diathermy-type interference?
4. What is the difference in appearance between c-w and f-m interference?
5. What positive test indicates that interference is caused right at the r-f frequency of the television station?
6. How can you tell positively that the interference is at the i-f frequency?
7. Name one symptom which positively rules out a local oscillator of a neighborhood receiver as the cause for interference which has been identified as c-w.
8. In what three ways can one television station interfere with the signals of another?
9. How can you identify each of these?
10. What classes of electrical devices are most responsible for impulse noise interference?

17

Fundamentals of Color Television

Black-and-White Screen. The screen of a monochrome (single-color) picture tube is coated with a phosphor which emits white light when it is struck by electrons. White light, however, is a *mixture* of all colors of the spectrum. The white phosphor is really a blend of *colored* phosphors which add up together to produce white. The colors are carefully selected and mixed in proper proportion by the tube manufacturer.

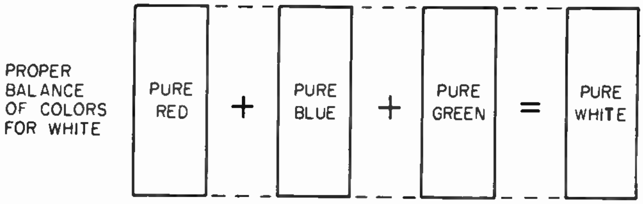


Fig. 1. The sum of three additive primary colors produces white

There are many combinations of individual colors which will produce white light. The mixture of red, green, and blue in *proper proportion* will do this because these constitute a set of additive *primary* colors. The general idea is illustrated in Fig. 1, in which it is assumed for convenience that *equal* amounts of the primary colors are needed for white.

Some television tubes have phosphors which are mixed with a little more blue than is needed to produce pure white. This is done because the blue-white color seems to be more pleasing to the eye than a technically pure white. Often you can see this blue tint without even looking for it, especially if you shift your eyes from something that is pure white to the television picture.

Mixing Phosphor Colors. Pure white, as suggested above, is a careful and exact balance of red, blue, and green. When this balance is upset, deliberately or otherwise, color becomes visible.

To illustrate the point, if the green content is increased or if both the red and blue are reduced, a green color becomes visible. If this unbalance is very slight, the color will be a very pale shade of green. By the same token, a small reduction in red and green will produce a pale blue tint. This is illustrated in Fig. 2.

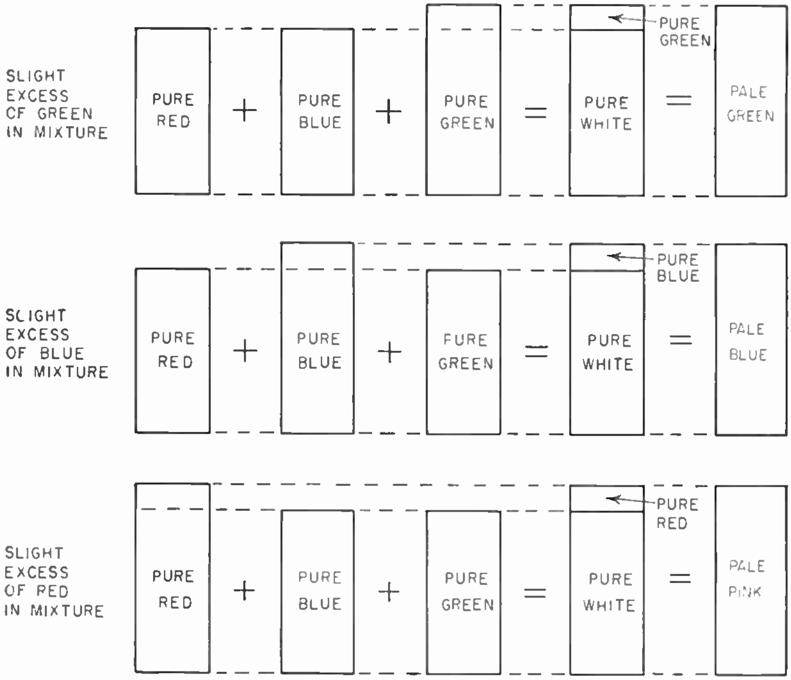


Fig. 2. Examples of how slight excesses of one primary color result in a low saturation, or pastel, color

These colors are said to have *low saturation* because there is only a small amount of color compared with the white. To put it another way, the light is mostly white with a little color added to produce a pastel shade. Pure white light has *zero color saturation* because no specific color can be seen.

A pink color, therefore, is not one which contains *very little red* but rather one which contains just a *little more red* than the amount needed to produce a balanced white light. Most of the red light is "used up" in the mixture with green and blue to produce white.

If the green and blue are reduced further, less red is used in producing white light and more is left over to be seen as red. The color, therefore, becomes a deeper pink. The more the green and blue are reduced, the more the red that is freed and the redder the resultant color. This effect is one of increasing the color saturation. This is shown in Fig. 3.

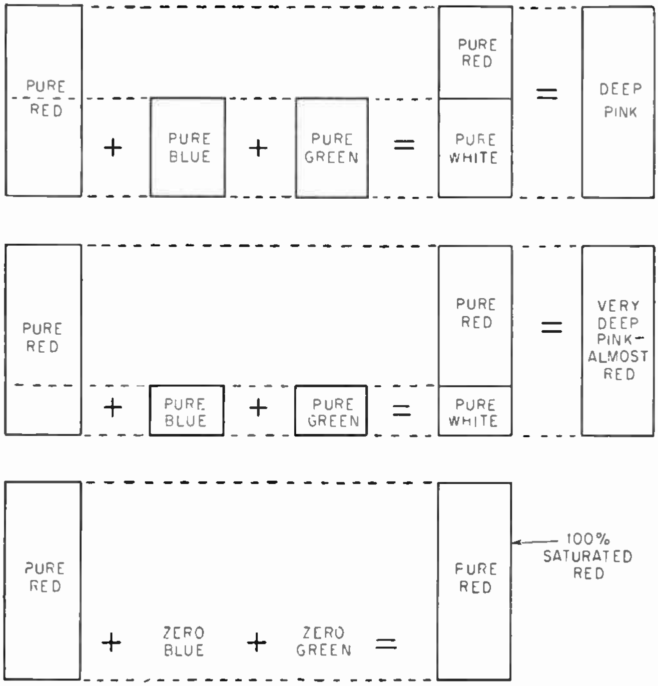


Fig. 3. The method by which primary color saturation is increased by modifying the quantity of the remaining primaries

When all green and blue are removed, only red remains and it is seen as a vivid red without any of its color being used up in a mixture of white. The color is then 100 per cent saturated; the color is as red as it can get.

The same effect can be produced with either of the other two primary colors—with green by removing red and blue; or with blue by removing red and green.

As long as *any* amount of *all three* colors is present, *some white light* will be produced and the remaining color will be the result of the colors which exceed the white balance. Thus colors *other than* pure primaries can be seen when the blend is right.

Examples of Color Blends. To illustrate the point, if *only* the blue is reduced, the white light will be reduced and an excess of *both red and green* will remain, as shown in Fig. 4. These will mix in the eye to produce yellow (red plus green produces yellow). A small reduction in blue leaves little color over-and-above white and the result will be a pale yellow (low-saturation yellow). If all blue is removed, a strong and vivid yellow will be seen. The color is called a secondary color because it is a mixture of two primary colors.

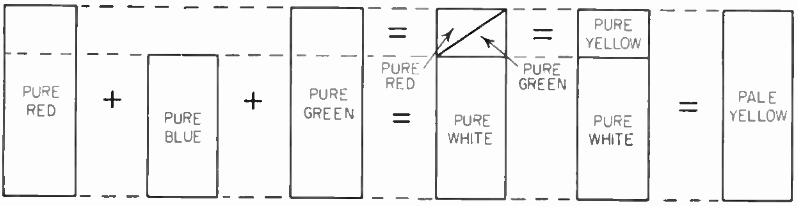


Fig. 4. How a low-saturation secondary color is produced

Variation between these conditions is also possible. The blue alone may be reduced to leave yellow as described, but if the green is then also reduced, but not so much as the blue has been, an orange color will result. This is shown in Fig. 5. This happens because the excess color, above white, consists of red with which some green is added, but not enough to use up all the excess red in making yellow. Some pure red is left over to mix with the yellow, and this produces orange. The resulting color is called a tertiary color because it is a mixture of a secondary color (yellow in this case) with a primary (red in this case).

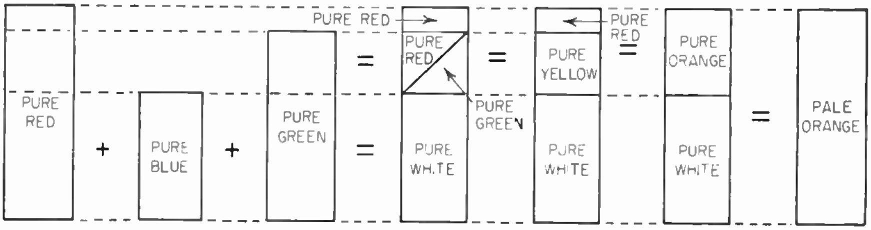


Fig. 5. How a low-saturation tertiary color is produced

The mixture can go the other way, by removing a substantial amount of blue and then some of the red. This will now leave a tertiary color which is between *green* and *yellow*.

Removal of One Color. In all of the above cases, the color saturation will go to 100 per cent when one color is removed entirely, as shown in Fig. 6. The resultant color will depend upon the proportions of the two remaining colors, but it will be vivid.

The removal of red leaves a mixture of the blue and green. Balance between these two is the secondary color called cyan (a greenish-blue color). If the blue is reduced, the color becomes a tertiary color which is more greenish than cyan, and vice versa.

The removal of green leaves a mixture of red and blue which produces the secondary color known as magenta (deep violet). Removal of some of the red shifts this color nearer blue, and vice versa.

The combinations and variations described above permit any color of the spectrum to be produced at will, and, at any level of saturation, to give any hue in any condition from pale pastel to the most vivid form.

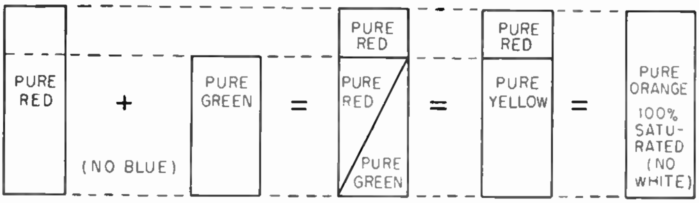


Fig. 6. How a fully saturated tertiary color is produced

The total range of colors in phosphors is not quite as wide as those found in nature, but it is remarkably close. The range, or gamut, as it is called, is much greater in television color tubes than is possible with the best color-printing techniques.

Characteristics of Color. Certain terms are used in color television work to define the characteristics of the colored light which is seen. You should become familiar with these terms because they are frequently used on schematic diagrams of color sets and on the names of certain controls and adjusters.

The term *saturation* has already been discussed. It relates to the proportion of white light to color. Pastel shades have low saturation and are predominantly white light; vivid shades have high saturation and have little or no white light. Some white light is always produced when *all three* primary colors appear.

Chrominance is the term for hue. It relates to the specific portion of the spectrum in which the visible color lies. Pale pink and red both have the same chrominance characteristic, regardless of what the color saturation may be. Changes in saturation merely move the shade from vivid red to pink but do not alter the fundamental nature of the red itself.

Red and orange are different color mixtures, hence differ in chrominance. Red and blue differ radically in chrominance.

Luminance is the brightness of the color, whether it be white or any other. Luminance varies independently of saturation or chrominance. To illustrate the point, pink has a chrominance characteristic of red and a low saturation, being mixed with white; but it may have high luminance (be bright) as would be the case of a pink object in the sunlight, or it may have low luminance (be dim) as would be the case of the same pink object in a dimly lighted room.

It is true that the amount of white light changes with luminance in the example, but this does not affect the *relative* amount of white light mixed with the red to produce pink. At low luminance, the white light may be so low as to be gray, but the red light also drops in proportion and the color remains a pastel. It may appear grayish due to low lighting but its chrominance and saturation have not changed in the process.

In more direct terms:

Luminance is the *brightness* of the light regardless of the hue or whether it is vivid or pastel.

Chrominance is the hue characteristic of the visible color; it may be a pure primary color or the mixture of two primaries.

Saturation is the dilution of the color by the presence of all three primary colors which produce a given amount of white light.

How a Tricolor Picture Tube Works. A color tube, in a sense, is three cathode-ray tubes in a single envelope with a single picture screen. Three separate phosphor colors are used. One is red, one is blue, and one is green. Three electron guns are employed in the neck of the tube, each separately controlled. Each gun operates in conjunction with its respective phosphor color. Thus, there is a red gun, a blue gun, and a green gun.

The three guns are clustered together like a three-barrelled shotgun, if you can imagine such a thing. The three beams are therefore very much like a single beam and are handled as one in scanning. A single deflection yoke with horizontal and vertical windings deflects this three-stranded beam over the surface of the picture screen as in monochrome television. The picture is constructed in the same way.

The major difference is that each gun produces only one color of light at the screen. Since the beam intensity of each gun can be separately controlled, the proportion of each color can be controlled independently of the proportions of the other two. The result is that the scanning spot of light can be changed in luminance, chrominance, and saturation, and thus a full-color picture can be produced (assuming that intelligent color signals are applied to the guns).

All three guns can be tied together within the color set so as to produce a conventional black and white picture when there are no color signals available. In this case, the relative intensity of the guns is set so as to balance the colors to produce white light.

This description of a color tube is simplified to convey only the general idea behind its operation. The construction of the tube is relatively complex and critical. As you will see, it is no simple matter to get the three guns and three phosphors to act this way.

Main Parts of Color Tube. There are three special constructional features which go to make up a workable color tube. One is the *phosphor screen*, the other is the *triple-gun assembly*, and the third is a *shadow mask*, an added item which makes color selection possible.

Each of these features will be described separately because each is unique. It must be understood, however, that none of these features alone would permit color operation; they work in combination. The combined operation will be described after the features are covered separately.

The description which follows relates specifically to the earlier type of tricolor tube. It employs a 15-inch envelope although the useful picture area is smaller than that of a 15-inch monochrome tube. Later tricolor tubes employing 19- and 21-inch screens are referred to as large-screen color tubes. These tubes differ from the earlier type in certain important details. They will be described after the basic color tube is covered.

Color-tube Screen. The three primary phosphors are placed on the screen in the form of tiny dots. There are blue dots, red dots, and green dots. Their color becomes visible in the light which they emit when they glow. When they are unexcited they all look like little white spots. The phosphors, however, are chemically different.

Because any one of the colors may be called for at any point in a picture, the color dots are extremely small and close together. The tiny pin point of light which forms one dot of a picture in a monochrome tube must fall upon at least three color dots on a color tube, one of each color. This permits any color to appear at any point.

Arrangement of Color Dots. A typical 15-inch commercial color tube employs 585,000 *separate color dots*. The dots are arranged in a careful geometric pattern, shown greatly enlarged in Fig. 7. The pattern is composed of color groups or *triads* which consist of a triangular arrangement of three primary colors. Looking from the gun end of the tube, the blue dot is on top, the green dot is the bottom-left, and the red dot is the bottom-right.

The triads are repeated over the full surface of the screen. Thus there are 195,000 triads to take care of the 585,000 individual dots.

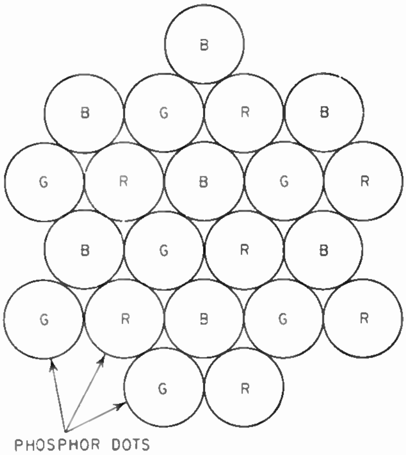


Fig. 7. The arrangement of color dots which make up the phosphor screen of a color tube. This pattern is shown greatly enlarged

The dots are placed on the screen with great care and precision so as to obtain a dimensionally uniform pattern. The screen is aluminized to increase light output and also to prevent ion damage; no ion trap is required.

Triple Gun. The electron guns are located at the base of the tube. They, too, are arranged in a triad, if you view the guns from the end. The arrangement of the triad is similar to the arrangement of the dot pattern.

Each gun has its own heater, cathode, grid, and focusing electrode. They share a common converging electrode through which all of the beams pass, as shown in Fig. 8.

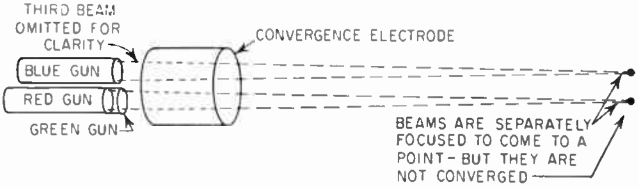


Fig. 8. Each gun of a tricolor tube emits a separate beam

Each electron beam is individually focused to come to a pin point near the screen. The converging electrode permits these three sharp beams to be pulled toward each other so that all three hit the same point near the screen. This is shown in Fig. 9. The three beams, therefore, act essentially as one.

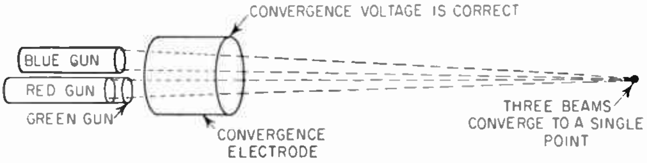


Fig. 9. The convergence electrode brings all three beams to focus at a single point

The beams pass through the neck of the tube around which the deflection yoke is placed, as in monochrome tubes (see Fig. 10). The deflection yoke acts on all three beams in unison.

Purity Coil. A second coil is slipped around the neck of the tricolor tube. It passes around the triple-gun assembly. This coil is called the *purity* coil. Its purpose and adjustment will be described later. In a broad sense, adjustment of the purity coil serves the same purpose as moving the three guns sideways or up and down or along any other transverse direction. This permits the guns to be electrically centered within the neck more accurately than could be done in initial assembly.

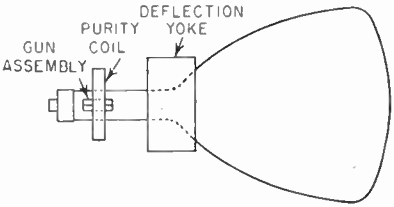


Fig. 10. The arrangement of components on the neck of a color tube

The term purity refers to *color* purity. Only when the purity is set right can the tube reproduce a uniform color all over its screen when a pure color is called for. To put it another way, poor purity adjustment results in color contamination because one or more of the guns will begin to miss its own color spots at some points on the screen and will hit the wrong colors instead.

Shadow Mask. The shadow mask is a thin perforated metal plate which is mounted behind the phosphor screen at a fixed spacing. It has one hole for each *triad* of color phosphors, as shown in Fig. 11. Each hole is centered within its triad. The electron beam passes through a hole before it can strike the screen and excite the phosphor.

The blue gun is the *lowest* gun of the three-gun assembly (rather than as shown in Figs. 8 and 9). Its beam is therefore *rising* as it passes through the aperture in the shadow mask and it strikes the screen at a point directly *above* the hole, as shown in Fig. 12. The blue dot is located at that point, thus only the blue phosphor is excited and only blue light is seen. The *shadow* of the mask, so far as the blue gun is concerned, falls on the red and green dots and these are not hit by the beam.

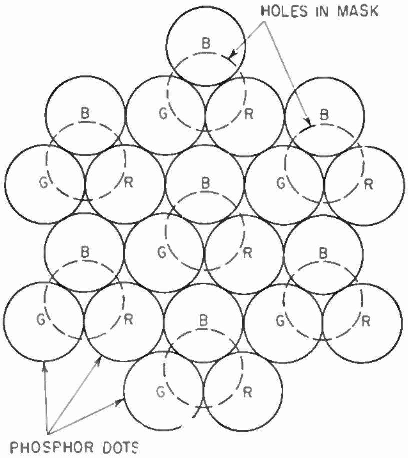


Fig. 11. The location of holes in the shadow mask. Each hole is directly behind a triad of color dots. This pattern is greatly enlarged

The red gun is *above* and to the *left* of center, looking from the base of the tube. Its beam, therefore, crosses *downward* and to the *right* as it passes through the aperture. This is where the red phosphor dots are located and only these are illuminated.

The same idea applies to the green gun which is above and to the right of center. It excites only the green phosphor dots.

As you can see, each gun causes only one color to be seen and each can be separately controlled in intensity. Thus, all combinations of color mixtures are possible.

Large-screen Color Tubes. Large-screen color tubes are very much like the one described above, but employ some valuable improvements. These are described in the following paragraphs.

A typical 19-inch tricolor tube employs 750,000 color dots, or 250,000 color triads. A typical 21-inch tube employs a little more than a *million* color dots; the number of color triads is approximately 357,000. Because of this, the large-screen tubes produce a more pleasing picture. The viewer finds it harder to see the individual specks of light transmitted through the shadow mask at normal picture-viewing distances.

The gun arrangement is improved over that shown in Fig. 8. Instead of being parallel to each other, the guns are all tilted so that they point toward a common axis and accomplish the result shown in Fig. 9 without the need for a common converging electrode; that electrode is omitted.

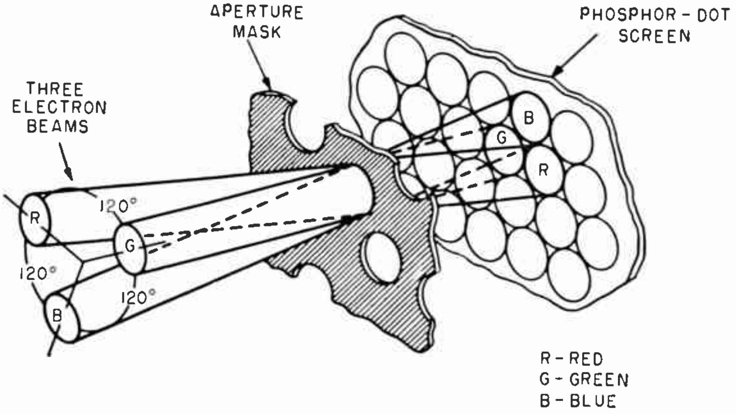


Fig. 12. A perspective drawing which shows how the three beams pass through the shadow mask so that each strikes a separate color

The tilted-gun structure provides a convergence condition which is nearly correct but not perfect. Normal manufacturing tolerances make this difficult, if at all possible. Each individual gun is therefore provided with a pair of its own convergence pole pieces. These are magnetically permeable tabs which extend to the inside surface of the glass tube neck. External, adjustable, convergence magnets placed around the neck and next to each of the internal pole assemblies then permit each beam to be adjusted individually for perfect over-all convergence. This not only simplifies the process of setting up the receiver but simplifies the convergence circuits and provides better all-around performance.

A purity coil or purity magnet is used with the large-screen tricolor tubes to perform the same function described earlier; that is, to permit the electrical centering of the three-gun assembly.

Basic Monochrome Signal. Whether a picture is transmitted in color or in monochrome, the standard monochrome signal is transmitted, with video, sync, and sound. As a result, compatibility is obtained because the standard monochrome signal is available for monochrome sets.

For color work, some additional information is included with the signal. Monochrome sets are blind to this added information but color sets use it to control the color mixture at the color picture tube.

Before the additional signals are discussed, the monochrome signal should be given a little more thought.

The monochrome video information is really *luminance* information because it deals with the brightness of the individual elements of the picture which are being picked up by the camera. The original scene is usually a natural color scene and, consequently the video information is true luminance information *of a color scene*. Monochrome sets reproduce this luminance as the black and white equivalent of the variations in color luminance. Color sets use this luminance information to control the *total brightness* of the *color mixtures*. This will be described in detail a little later.

Color Information. Any specific element in a color scene is fully defined by its luminance, chrominance, and saturation. If the color mixture is known for a given luminance, the chrominance and saturation are automatically established. Thus, the only information which must be added to the luminance signal in order to construct true color pictures is the information which tells how much green, blue, and red are contained in the video signal.

Offhand, it might seem that *three* signals, in addition to the luminance signal, are needed—one to define the amount of blue, one to define the amount of red, and one to define the amount of green. These three signals would be needed to control the three color guns in the color picture tube, and would serve to control the color mixture during the scanning of the picture.

A little study reveals that all three color signals are not needed. It is enough to transmit only *two* of them. The reason for this is that the *luminance* signal is really the *sum of the three colors*. If you know how much red and how much blue are contained in the signal and you know the sum from the luminance signal, you can find out how much green there is because the remainder can only be green.

To express this another way, if the luminance signal indicates a luminance of, say, 100 units at a particular spot on the picture, the blue signal indicates 25 units of blue, and the red signal indicates 40 units of red, the blue-plus-red content is then 65 units and the remainder of 35 *must be* the amount of green.

In view of this, only two color signals are transmitted along with the luminance signal. The color receiver is expected to unscramble these signals and to use them to control the red, blue, and green guns of the picture tube.

Color Breakdown in Transmission. Because the television set must do a job of color unscrambling in any event, it really makes no difference how the color spectrum is broken up for transmission. Any set of primary colors can be used, just so long as the receiver unscrambles these signals and translates them properly into red, blue, and green.

If the primary combination of red, blue, and green were actually used in transmission, there would be no point in making the above observation. These colors, however, are not the best ones to use in terms of color transmission. The reasons are quite complex and involve appreciable theory. In any event, another set of colors is used, but these colors are difficult to identify by name. They are identified simply by the letters I and Q. The reason for the choice of these particular letters will become obvious a little later.

Although only two colors are identified, the I and Q colors really represent *four* colors because each one can be transmitted electrically as a positive or a negative signal. The negative signal represents the color in the spectrum which is opposite to the color represented by the positive signal. The I signal is an orange color; the negative I signal is cyan (a greenish blue). The Q signal is a yellowish-green color; the negative Q signal is a magenta (deep violet) color. When the color receiver unscrambles these colors, it interprets the mixture as so-much-blue, so-much-red, and so-much-green.

The I and Q colors are never actually used except during the radio transmission and reception. The situation is somewhat like the use of an i-f frequency in a radio receiver; it matters little what i-f frequency is used because it is only an *intermediate* condition. The detected signal is always a reproduction of the original audio signal regardless of the specific i-f frequency. Similarly, the I and Q colors are only an intermediate color step. When these colors are unscrambled, pure blue, red, and green are obtained.

Color Signal. The color signal is called the chrominance signal or more simply the *chroma* signal. It is really a dual signal. One of the signals is the I signal and the other the Q signal.

These signals could each be transmitted at its own carrier frequency but that is not practical because there is little enough opportunity to squeeze even one new frequency into the existing monochrome signal channel.

The two signals are therefore transmitted at exactly the same frequency but at different *phase.* One signal is in phase (the I signal) while the other is 90 degrees away, or in quadrature phase (the Q signal). This relationship accounts for the choice of the letters I and Q for the two signals. The combined chroma signals look and act very much like a single signal, but it is possible to separate them from each other with *phase detectors* at the receiver.

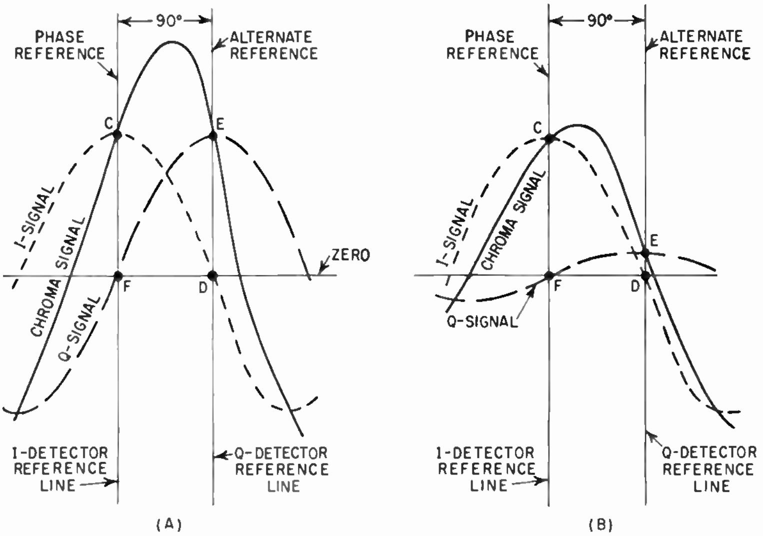


Fig. 13. The I and Q signals are added together to form the chroma signal. A shows the addition when the two are equal. B shows the addition when the two signals are unequal. The two signals are always 90 degrees apart as shown

Combining Equal I and Q Signals. The condition which prevails when the I and Q signals are equal in strength is shown in Fig. 13A. The I signal is in phase with the *phase reference* line, thus is maximum at point C. The same signal drops to zero at point D which is 90 degrees away.

The Q signal is phased 90 degrees away from the I signal, on the *alternate reference* line. Thus it reaches maximum at point E on its reference line and is at zero at point F on the original reference line.

Note that when the I signal is maximum (C), the Q signal is zero (F); when the Q signal is maximum (E), the I signal is zero (D).

The transmitted chroma signal is the sum of these two signals and takes on the character of a single signal which follows the solid line. It is phased neither with the I signal nor the Q signal. It is halfway between because the I and Q signals are equally strong. (The colors are equal.)

Combining Unequal I and Q Signals. The conditions which prevail when the signals are unequal are shown in Fig 13*B*. The Q signal is quite low and the resultant chroma signal is different. It is still a single signal but it is more nearly in phase with the I signal. The I and Q signals still maintain the maximum–zero relationship described above, as indicated by the corresponding letters on the diagram.

The signals can be separated in the receiver by two separate detectors, one of which looks at the chroma signal along the *phase reference* line and one of which looks at it along the *alternate reference* line. The former will see only the equivalent of the I signal because the Q signal is always zero along the reference line; the latter will see only the equivalent of the Q signal because the I signal is always zero at its respective reference line.

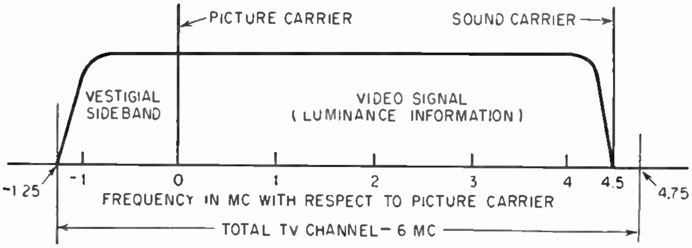


Fig. 14. Standard channel for a monochrome video signal

The situation is clearer in Fig. 13*B*. The I detector, in looking at the chroma signal, will see a voltage equal to value C, whereas the Q detector, looking at this same signal, will see a voltage equal to value E. The I signal *is* equal to C and the Q signal *is* equal to E, and thus the two different signals are correctly extracted from the chroma signal.

If the Q signal should drop to zero, only the I signal will remain and the chroma signal will then be the same as the I signal. The Q detector will see zero voltage in this case, as it should.

Adding Chroma Signal to Video Signal. The standard monochrome channel is shown in detail in Fig. 14. In order to maintain compatibility between color and monochrome transmission, the chroma signal must be transmitted *within this same channel.*

There is no free space in the channel, hence the signal must be added somewhere within the video signal range. As a consequence, the chroma signal must be considered in terms of an *interfering* signal and it must be added in such a way as to prevent creating any visible interference pattern on the screen. Ordinarily, a signal which rides in with the video will create such a pattern and destroy the picture. Two distinct methods are used to attack this problem.

Chroma-carrier Suppression. First, the carrier of the chroma signal is suppressed at the transmitter to keep this carrier from appearing in the signal. Only the modulation (the sidebands) is transmitted. This complicates receiver design but eliminates a prime source of interference trouble. The receiver is complicated by this approach because it must develop an artificial carrier to replace the one which was suppressed. This is done with a crystal oscillator. The carrier is generated in the receiver and added to the chroma signal *after* the point at which it could cause interference with the video.

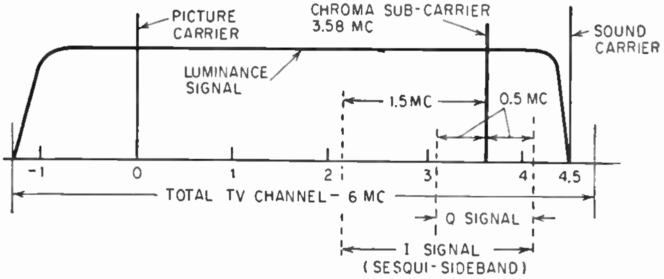


Fig. 15. Standard channel for a color video signal. The chroma subcarrier is 3.58 mc away from the video carrier

Carrier suppression alone is not enough because the chroma sidebands are transmitted and these could cause visible interference patterns if additional precautions were not taken. This possibility is virtually eliminated, however, by the careful selection of the carrier frequency for the chroma signal.

Chroma-carrier Frequency. The carrier frequency is established at 3.579545 mc (usually referred to as 3.58 mc). It appears at a point in the channel which is this much *higher than the video-carrier frequency*. This is shown in Fig. 15. Because the chroma carrier is suppressed, it is identified on the illustration as the chroma *subcarrier*.

The idea behind this particular chroma-signal frequency is a principle called *interlace cancellation*. The color signal appears as fine specks of interference on each line of the picture but these specks alternate in each line and they also alternate in each successive frame. This makes them drop almost completely out of sight. Each dark speck will appear next to a light speck on the adjacent horizontal line. This relationship is due entirely to the choice of the chroma frequency. If some other frequency were used, the specks would not cancel but rather would form a visible interference pattern.

Color Synchronization. The color television receiver must perform two critical functions in order to get the correct information out of the chroma signal. First, it must generate a chroma carrier at the correct frequency. Second, it must develop accurate reference signals for the I and Q phase detectors so as to enable them to split the two signals apart properly.

The reference signals for the phase detectors consist of steady oscillations at the chroma-carrier frequency, but the signals must be accurate in terms of phase so as to keep in perfect step with the transmitter.

Color Burst. Both of these requirements are met by means of a single color-synchronizing signal which is added to the video at the transmitter.

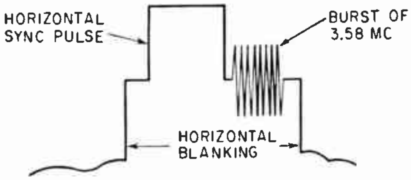


Fig. 16. The color burst is located right after each horizontal sync pulse. The burst serves as a color synchronizing signal

Fig. 16 illustrates this signal. It consists of a burst of 8 cycles of the 3.58-mc chroma-carrier frequency immediately following *each* horizontal scanning sync pulse. Because this *color burst* (as it is called) occurs during horizontal blanking, it does not appear on the picture; it lies partly in the blacker-than-black region, like the sync pulse, and is confined to the extreme left-hand edge of the picture where it creates no viewing problems.

The color burst is used in the color television receiver to lock (synchronize) a crystal oscillator, not only in frequency but also in phase. The oscillator output is therefore capable of serving as the *re-created carrier* for the chroma signal and also fixes the reference signals for the I and Q phase detectors. More specifically, the color burst locks the crystal oscillator so that it places the I and Q phase detectors on the reference lines shown in Fig. 13.

Color Tube Summary. Any element in an illuminated color picture can be defined by its luminance (brightness), chrominance (hue), and saturation (color richness).

White light is the sum of three primary colors, mixed in proper proportion. There are many possible sets of primary colors, but red, green, and blue are the set used in the color cathode-ray tube.

The color tube uses a tricolor screen and three guns, one for each color. Each gun produces its own primary color of light. The control signals on the guns can be proportioned so as to produce any practical luminance, chrominance, and saturation. The color range is greater than that of the best color-printing inks.

Color Signal Summary. The color television signal is a standard monochrome signal *plus* a chroma signal and a color burst for color synchronization.

The video signal is the luminance signal. The chroma signal provides information as to the mixture of the separate colors which make up the picture.

The chroma signal conveys information about the color content of the picture in terms of I and Q colors. Red, blue, and green are obtained by unscrambling the color signals at the receiver.

Chroma Signal Summary. The chroma signal frequency is 3.58 mc nominally. This frequency is chosen to cancel out interference patterns.

The chroma carrier is suppressed to reduce interference. The receiver must therefore generate a substitute carrier to serve in its place.

The chroma signal is phase-modulated by two separate signals, 90 degrees out of phase with each other. This is done to maintain a single chroma frequency while permitting the two signals to be separately detected by suitable phase detectors.

Color Sync Summary. A color burst of 8 cycles of the 3.58-mc chroma frequency is transmitted directly after each horizontal sync pulse.

The color burst locks a 3.58-mc crystal oscillator in the receiver into both phase and frequency. This generated signal serves as the chroma carrier and as the phase reference for the I and Q phase detectors, permitting them to detect the two signals individually.

QUESTIONS

1. Describe a low-saturation primary color in terms of the color mixture which produces it.
2. What is a secondary color and how is it produced?
3. Define luminance, chrominance, and saturation.
4. How is the pattern of a color-phosphor screen related to the holes in the shadow mask?

5. What information, useful to a color set, is contained in the basic monochrome signal?
6. What information is contained in the chroma signal?
7. Why is the term "subcarrier" used with respect to the chroma signal?
8. Why is the 3.58-mc oscillator a necessity in a color set?
9. What is the function of the color burst?

18

How Color Television Sets Work

Color Block Diagram. The functional block diagram of a color television set is built up in this chapter in much the same way as was done with the monochrome diagram, starting with the block diagram of an intercarrier monochrome receiver. A color set performs all of the functions represented on that diagram plus some added ones. The additional functions will be covered here.

There are enough added circuits to make it unwise to look at them all in detail right from the start. The diagram is therefore started with only a few added blocks and the function of these blocks is explained. Then the blocks are broken down into smaller pieces and the functions are explained in more detail. Finally, the full block diagram of a classic set is given, using standard color television nomenclature. This will permit you to identify and locate each individual circuit in a practical color set.

The set to be described is the classic color receiver designed for use with the original 15-inch tricolor tube. It is typical of the first commercial color receivers built by the major television manufacturers. The value in examining the classic set is that it represents the approach used in color television sets before major circuit simplification was practiced. The set therefore performs *all* of the basic color functions in individual steps and its study provides a better understanding of what goes on in color sets. After it is understood, the more modern simplified receiver can be studied with a better foundation of knowledge.

Numbering System. A logical numbering system is used in the block diagrams given in this chapter to permit you to check backward and forward as you study. The numbers show how the blocks grow out of the simpler diagrams.

The numbering system is illustrated best by an example. In Fig. 2, a block is identified by the number 3. This same block is broken into smaller pieces in Fig. 3; they are numbered 31, 32, and 33. Block 31 is broken down further in Fig. 4 where its component parts are numbered 311, 312, and 313. Block 312 is again broken up into further detail in Fig. 5 where numbers such as 3121, 3122, etc., are used.

Working backwards, block 3132 is known to be a part of block 313 wherever that number appears. Block 313, in turn, is part of block 31; finally, block 31 is part of block 3.

You will notice that in Fig. 7, numbers from 41 through 49 are used. These blocks are an expansion of block 4 which appears on all diagrams from Fig. 2 to Fig. 6.

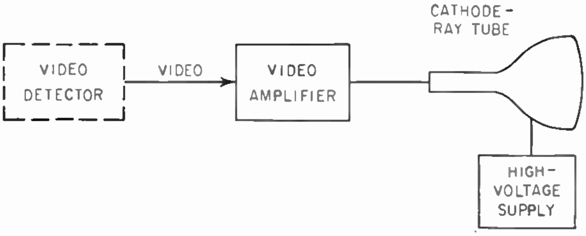


Fig. 1. The solid lines in this diagram show the only part of a monochrome television set which is altered to produce a color set

The information given in this chapter will help in installation, adjustment, and troubleshooting work on color television sets. It will also help you understand the service manuals of color television manufacturers. As a rule, these manuals will fill in detailed circuit descriptions which you will be able to follow by using the information given in this chapter as a guide.

Basic Additions for Color. The only portion of a monochrome set which is affected by the addition of color is that part shown in solid lines in Fig. 1. It involves the video amplifier, the cathode-ray tube, and the high-voltage supply. All other monochrome circuits work in an identical manner in color sets.

The additional functions of a color set are shown in Fig. 2. The cathode-ray tube of the monochrome set is replaced by a tricolor tube, 5, employing separate green, blue, and red guns, as shown. The high-voltage supply for the tube provides both the focus and the illuminating voltage. The supply will be described at the end of this chapter, because its functions are secondary in nature.

The heart of the color television receiver circuits is represented by blocks 2, 3, and 4. Block 1 is a conventional video amplifier stage which amplifies the incoming video signal whether it be monochrome or color. As you will see, a color set will work with either signal, providing a black and white picture if the signal is monochrome and a color picture if the signal has color information.

Color information consists of the chroma signal and the color-burst information.

Luminance Amplifier. Block 2 is nothing more than a second video amplifier stage. It amplifies the complete video signal, exactly as it is detected, but passes it on to a matrix, block 4, instead of directly to the cathode-ray tube, as is done in monochrome sets. The amplifier, however, is not always called a video amplifier in color sets. It is often called a *luminance* amplifier because it is used to supply information relative to the luminance of the signal. This is only part of the information needed for color although it is *all* of the information needed for black and white.

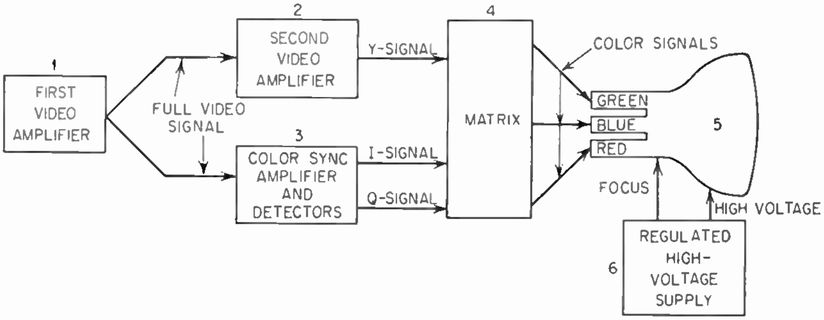


Fig. 2. The basic sections of a color set

Color Unscrambler. The matrix is the color decoder or color unscrambler. It is in the matrix that the signals are separated into three appropriate signals, one for the green gun, one for the blue, and one for the red.

Color Signal Circuits. Block 3 represents the color signal circuits. The video signal is fed to this block through coils which are tuned to respond to 3.58 mc. Only the color burst and chroma signals appear at this frequency, hence only these signals get through. The color burst is used to synchronize the chroma circuit; this will be explained later.

The most important function performed by block 3 is the detection of the chroma signal which consists of two separate color signals, the I signal and the Q signal.

The I and Q signals represent the intermediate colors which are used to transmit the color signal by radio. The luminance of the colors is contained in the luminance signal. In order to decode these signals in terms of green, blue, and red, the I and Q signals are fed into the matrix along with the luminance signal. The latter is called the Y signal to permit reference to all three signals by means of single letters. The Y, I, and Q signals are combined in the matrix, block 4, where they are decoded and converted into green, blue, and red signals.

I and Q Signal Detectors. The diagram of Fig. 2 is expanded somewhat in Fig. 3 to show more clearly the idea behind the separation of the I and Q signals. The color circuit is now broken into three parts; block 31 represents the color circuitry up to the separate I and Q phase detectors, blocks 32 and 33. The chroma signal is a mixture of both I and Q signals. They differ from each other only in phase. The combined chroma signal is fed to block 32, where only the I signal is detected and passed on to the matrix. The same thing happens in block 33, which detects only the Q signal.

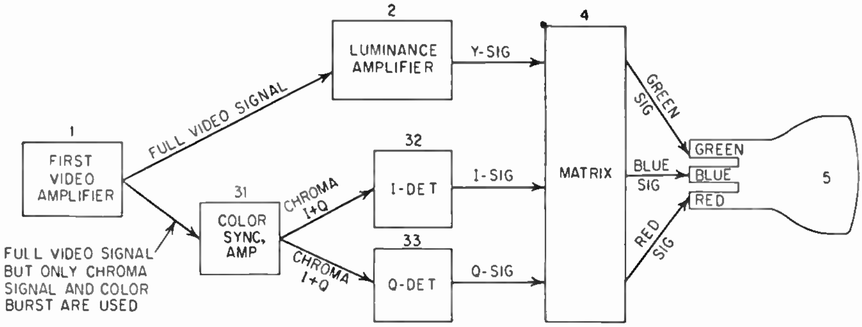


Fig. 3. This diagram shows how block 3 breaks down into basic circuits

Re-creating the Chroma Carrier. The block diagram of Fig. 3 is broken down further in Fig. 4. Block 31 is broken into the chroma amplifier, block 311; the color sync circuit, block 312; and the 3.58-mc signal generator, block 313.

The chroma amplifier, block 311, is commonly referred to as the bandpass amplifier in color sets because it is tuned to pass a band of frequencies on each side of the chroma carrier position of 3.58 mc. The band extends downward 1.5 mc and upward 0.5 mc. This represents the limits of the chroma signal. A bandpass tuned coil system is used to keep out everything but the chroma signal, and especially the video and sound signals.

The chroma signal is transmitted without its carrier, which is suppressed at the transmitter. The carrier must therefore be re-created and added to the chroma signal before detection can take place.

The function of block 313 is to generate a 3.58-mc carrier which can be used as the chroma carrier. Because the frequency and phase of this signal must be exactly the same as the one which was suppressed at the transmitter, a color sync circuit, block 312, is used.

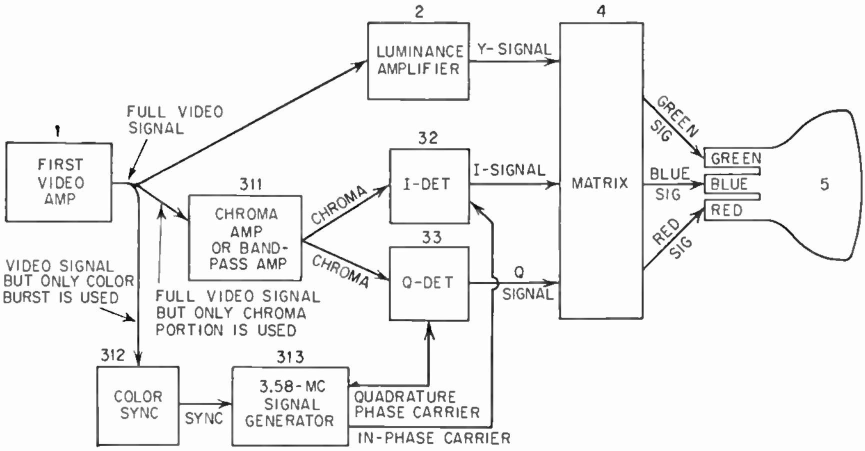


Fig. 4. Block 31 is broken down into its basic parts in this diagram

Color Sync Circuit. By means of a keying system, which is described in more detail a little later, the sync circuit, block 312, selects only the color-burst signal out of the video signal. The color burst is a small but accurate sample of the chroma carrier at the transmitter. This sample is used to lock a 3.58-mc oscillator into perfect sync with it. The oscillator is a part of block 313. The color burst pulls the oscillator into step at the end of each horizontal sweep (during retrace) when there is nothing visible on the screen. The chroma carrier is transmitted at this time because it is the only time when it will not interfere with the picture.

The 3.58-mc oscillator coasts freely during the horizontal sweep while picture information is being transmitted and delivers its oscillation to the two chroma detectors where it provides the two carriers needed for detection.

Chroma-carrier Signal Generator. Block 313 contains more than a simple oscillator; it also contains a means for extracting two phases of the oscillation. One phase is exactly the same as the color burst; it is called the in-phase oscillation and is supplied as the carrier for the I detector. The other phase is 90 degrees away from the color-burst signal; it is called the quadrature phase and is supplied as the carrier for the Q detector.

This difference in carrier phasing is what causes each of the detectors to respond only to its corresponding part of the chroma signal and which, therefore, results in separate I and Q output signals from each detector.

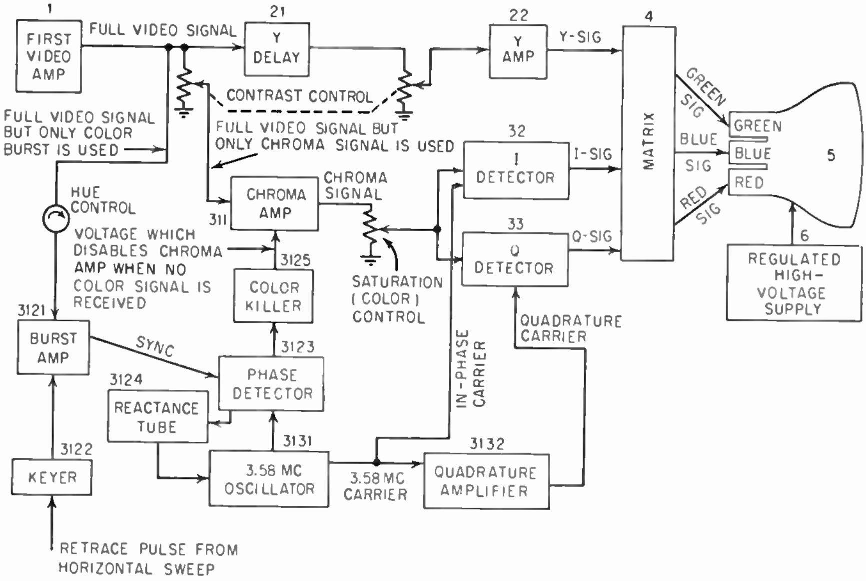


Fig. 5. Final breakdown of the color synchronizing circuits in a complete color receiver

Color Synchronizing Circuits. The block diagram shown in Fig. 4 is expanded into its detailed steps in Fig. 5. This diagram shows all of the color synchronizing functions performed in a color receiver.

The color sync circuit represented by block 312 in Fig. 4 is composed of five functional steps shown in blocks 3121 through 3125 in Fig. 5.

Keying. Block 3121 is the burst amplifier. Its function is to amplify only the color burst and to keep the rest of the video from getting through to block 3123. This is done by the simple principle of electronic switching. Because the switching takes place at high speed and in a carefully timed pattern, it is called *keying*.

The switching action of the burst amplifier is controlled by the *keyer*, block 3122. The keyer is driven by the horizontal scanning retrace pulse which is obtained from the horizontal sweep amplifier stage. This pulse happens to coincide with the time during which the color burst appears.

The scanning retrace pulse is amplified by the keyer which is so connected to the burst amplifier that the latter can work only during the retrace pulse. The burst amplifier is completely disabled at all other times.

As long as the horizontal scanning of the set is properly synchronized, only the color burst gets through the burst amplifier. This is true because the color burst follows immediately after the horizontal sync pulse, during the time when the horizontal deflection circuit is retracing across the screen. The sync pulse would also get through except that the burst amplifier is tuned to pass only the 3.58-mc frequency of the color burst.

Keying Action. As a consequence of the above actions, the signal fed from block 3121 to block 3123 (the phase detector) consists of a series of samples of the 3.58-mc chroma carrier. The samples consist of bunches of 8 cycles of the signal; the bunches appear 15,750 times each second (at the end of each horizontal sweep).

Reactance Tube. In the meantime, an oscillator (block 3131) generates a steady 3.58-mc signal. A portion of this signal is fed to the phase detector, block 3123, to which the color burst is also fed. The phase detector compares the oscillator signal with the color-burst samples and develops a d-c output voltage which is proportional to the difference in phase of the two signals. This d-c voltage is fed to block 3124, a reactance tube which controls the frequency of the oscillator.

Blocks 3131, 3123, and 3124 form a loop into which the color-burst signal is fed. The color burst acts to alter the frequency of the oscillator so that it remains in perfect phase with it. As a result, the oscillation is an exact substitute for the chroma carrier which had been suppressed at the transmitter.

Quadrature Amplifier. Because the oscillator signal is in phase with the color burst, it is correctly phased to serve as the carrier for the I detector. The Q detector, however, calls for a carrier which is 90 degrees away from that carrier. In order to get this quadrature phase, a quadrature amplifier, block 3132, is used after the oscillator. It shifts the phase of the 3.58-mc signal by 90 degrees and supplies this as the carrier for the Q detector.

I and Q Detectors. The I and Q detectors are both provided with the chroma signal which is obtained from the chroma amplifier, block 311.

Color Killer. Color operation can take place only when *color* signals pass through the chroma amplifier and into the I and Q detectors. When a monochrome signal is transmitted, some of the video could get through this amplifier and act upon the color circuits. This would make various forms of color patterns appear on the picture when no color should be seen. In order to avoid this situation, a color killer, block 3125, is incorporated in the circuit.

Basically, the color killer is a disabling switch for the chroma amplifier. The switch is always off (chroma amplifier dead) unless the phase detector sees an in-phase condition between the color burst and the 3.58-mc oscillator.

When monochrome signals are received, there is no color burst, the in-phase condition is obviously impossible, and the chroma amplifier remains dead. Then only the luminance amplifier delivers a signal into the matrix and it is automatically decoded into that balance of green, blue, and red which add up to white.

When a color signal is received and the 3.58-mc oscillator falls into step with the color burst, the color killer enables the chroma amplifier to operate, and the color circuits then operate.

Hue Control. A review of the color sync circuit will reveal that the accuracy with which the I and Q carriers are split apart depends upon how accurately the phase of the color burst is duplicated in the 3.58-mc oscillator. Any errors in the circuit result in an improperly split chroma carrier.

To overcome the difficulties which grow out of errors and of drift between different stations, a phase shifter is provided in series with the input to the burst amplifier. The phase shifter is provided as a front-panel control; it is called the HUE CONTROL.

The user adjusts this control by eye to obtain a balance between redness and blueness, usually by watching familiar flesh tones for natural color. By this means, errors in phasing within the set are compensated for by the user.

Color Channels. The luminance amplifier (block 2 in Fig. 4) is broken into two parts in Fig. 5. The first part is the Y *delay* (block 21) and the second is the amplifier. The purpose of the Y-delay circuit is better understood when the I and Q circuits are investigated more closely.

The I and Q circuits are broken down into their final functional detail in Fig. 6. Block 32 is broken down into four parts while block 33 is broken down into three parts.

Q Detector. Block 331 is the Q detector. It uses the quadrature carrier as the reference carrier against which the chroma signal is detected. The quadrature carrier is phased so that the chroma signal is viewed at the *Q-detector reference line,* consequently the detector is blind to the I signal and responds to the Q signal as though it were alone.

The Q signal has a bandwidth of 0.5 mc. In order to make sure that only this signal gets past the detector with a minimum of interference, the detector output is passed through a low-pass filter, block 332. This filter passes all frequencies from 0 to 0.5 mc.

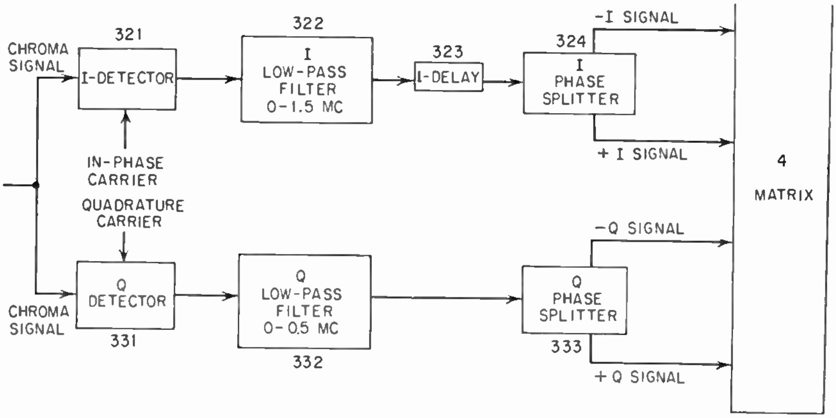


Fig. 6. This diagram shows the breakdown of blocks 32 and 33 into their basic parts

The I detector, block 321, is supplied with an *in-phase* carrier against which it looks at the chroma signal. This carrier corresponds with the *I-detector reference line,* and thus it sees only the I signal, which it detects.

The I signal has a greater bandwidth than the Q signal. It is 1.5 mc wide. This difference has been established through the careful tests, observations, and calculations which formed the basis of present-day color television standards. It is closely related to the quality of color definition of which the system is capable. The standards call for 0.5-mc bandwidth for the Q signal and 1.5 mc for the I signal; the luminance signal (Y-signal) bandwidth is almost 4 mc.

To accommodate only the I signal, the I detector is followed by a 1.5-mc low-pass filter. This filter passes all frequencies from 0 to 1.5 mc.

Phase Splitters. The function of block 323 may be ignored for the moment—it may be considered to be absent. This makes the I and Q channels appear the same. Each provides its respective signal to a phase-splitting stage.

The purpose of these phase splitters is to provide both negative-going and positive-going signals to the color decoding matrix. This is essential to the operation of the matrix because it performs the function of decoding by adding signals in some cases and subtracting them in others. The work is done in *adder circuits* which *add,* when positive signals are fed to them, and which *subtract,* when negative signals are fed to them. Thus, both positive and negative signals are needed.

The phase splitters are roughly similar to conventional phase-inverter stages in audio amplifiers, used to drive push-pull power amplifiers. The outputs of the splitters are push-pull outputs; one is a plus signal and the other a minus, as indicated on the block diagram.

Bandpass Circuit Action. As mentioned above, the I and Q channels differ as to their bandwidths; the former is 1.5 mc wide while the latter is 0.5 mc wide. This difference is important because of a phenomenon which occurs when signals are passed through bandpass circuits. This phenomenon is *signal delay.* The narrower the bandwidth, the greater the delay.

Because the Q channel is narrower, its delay is greater than that which takes place in the I channel. Thus the Q signal would normally be expected to arrive at the matrix a little later than the I signal. If it did, the decoding process would be ruined, because decoding must be done by means of signals which correspond perfectly with each other.

I-delay Circuit. Compensation for the greater delay of the Q channel is made by adding an artificial delay to the I channel. The work is done by a delay circuit represented by block 323. It uses no tubes but rather is composed of a network which includes (usually) one or two coils, a condenser, and two or more resistors. The I delay required is less than 1 microsecond. The use of the I-delay circuit ensures the simultaneous arrival of I and Q signals to the matrix.

Y-delay Circuit. The luminance signal is also fed into the matrix for color decoding purposes (see Fig. 5). This signal has a bandwidth of almost 4 mc, and therefore experiences less delay than either the I or Q signals. For this reason, the Y-delay circuit, block 21, is inserted into the Y circuit. It provides a delay of about 1 microsecond which delays the luminance signal the proper amount to have it arrive simultaneously with the Q signal to which the I signal has already been matched. Thus, *all* signals fed into the matrix are matched and arrive simultaneously.

The Y-delay circuit is usually made in a form which looks like a long tube or cable. In any case, it has at least several inches of length. This type of construction is employed because simpler circuits tend to destroy definition in that they tend to limit the bandwidth of the signal passing through. In the case of the I-delay filter, this is not a problem, because not much definition is conveyed in the color signal; its bandwidth is fairly narrow. The real source of picture definition is the Y signal and it must be preserved as carefully as possible.

Decoding Y, I, and Q into Green, Red and Blue. The Y signal contains luminance information representative of *total* color luminance whether it be of individual colors or of any combination of colors. The I and Q signals tell how the total luminance is divided up among red, blue, and green. Thus all three of these signals must necessarily be fed to the matrix to be decoded properly.

The luminance signal is fed to three separate video amplifier circuits, one for each of the color guns. The I and Q signals are also fed to these amplifiers, in such a way as to reduce the output of one color amplifier and increase the output of another, to correspond with intelligence contained in the chroma signal.

Because each of the red, blue, and green primary colors is a discrete mixture of I and Q, both the I and Q signals must be fed to each of the color amplifiers so as to select the correct portion of the luminance signal for each of the three primary colors.

How the Matrix Works. The signals are fed to the separate color amplifiers through a resistor network which composes the matrix. As a rough illustration of how the matrix works, a luminance signal of 100 units may be divided among the three amplifiers as follows: 20 units of blue, 10 units of red, and 70 units of green, for a particular desired color.

To understand better how the matrix works, you should have at least a rough idea of how the I and Q colors act together to produce red, blue, and green.

Red lies somewhere between the colors I and Q. To be more specific, pure red is obtained by adding (roughly) three parts of the color I (orange) to one part of the color Q (yellowish green).

Blue lies about halfway between the color Q (yellowish green) and the *complement* of color I. The complement of color I is cyan (bluish green) or *minus I*. Pure blue can thus be obtained by *subtracting* from each part of the color Q an equal amount of the color I.

Green lies somewhere between the complements of Q and I or between the colors minus I (cyan—bluish green) and minus Q (magenta). Pure green can be obtained by *adding* together roughly three parts of minus I to five parts of minus Q.

The three preceding paragraphs deal with the *relative* amounts of color mixtures which make up red, blue, and green. In other words, they deal with the *chrominance* of the signal.

Luminance. Chrominance, however, tells only part of the story; the rest is conveyed by the luminance.

To illustrate the point, again in rather rough terms, 30 units of the color I and 10 units of the color Q represent pure red, *but only when the total luminance is 40,* because only under these conditions is the luminance completely used up in making red. If the luminance were 50, there would be 10 units of brightness left over. This means the addition of either blue or green or both, as something other than pure red is involved.

The same kind of examples can be given for the other two primary colors to illustrate the same point. The examples are exceedingly rough because exact figures call for the laborious use of mathematics which must take into account not only the mixing principles just stated, but also mathematical corrections for the difference in the efficiencies of the three different color phosphors, as well as other factors.

Servicing Matrix Circuits. Exact mathematical computations are not needed for service work; only an understanding of the general principles is needed. It should be recognized that exact information as to how much blue, green, and red is contained in a given picture element can be obtained through the simple process of adding or subtracting suitable proportions of the I and Q signals to or from the Y signal. The *exact* proportions are designed into the color receiver and are manifest in the resistor values used in the matrix circuitry. If you are careful to avoid the use of anything but the exact values specified on the manufacturer's schematic diagrams when you make replacements, you will get into no trouble.

Adders. The matrix and primary color channel circuitry is shown in Fig. 7. Each of the three color channels is identical in that each uses an adder, an amplifier, and a d-c restorer.

The adder is simply an amplifier stage with good signal-handling ability (low distortion). Three signals are applied to the grid of each adder through the resistors shown. The resistor values are selected to provide correct decoding proportions, as explained above. This is to say that the resistors are selected to provide so-much-Y, plus so-much-Q, plus so-much-I to get the equivalent red, green, or blue, depending upon which adder is considered.

The green adder, block 41, is supplied with a fixed amount of the Y signal together with fixed proportions of minus I and minus Q. This agrees with the statement made earlier that green lies between minus I and minus Q.

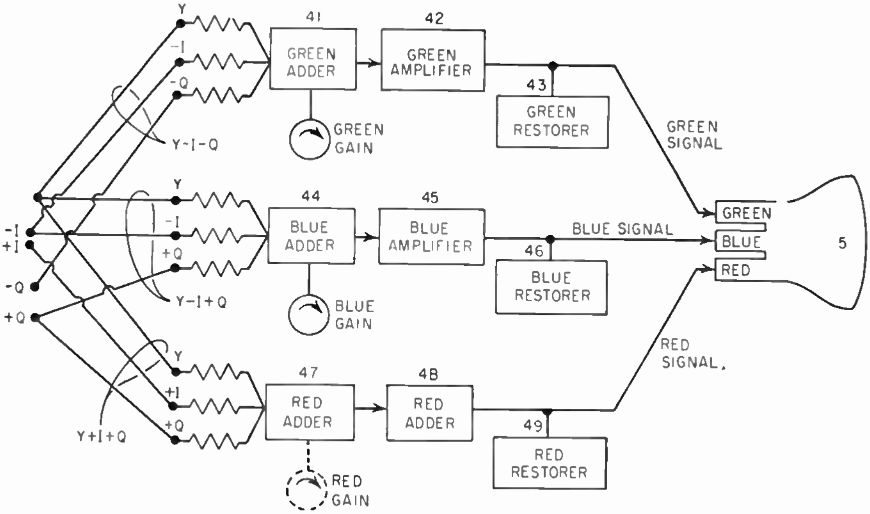


Fig. 7. Breakdown of block 4 into its basic parts. It includes the matrix (the resistor network), color adders, amplifiers, and restorers

The blue adder, block 44, is supplied with fixed proportions of Y, minus I, and plus Q. This agrees with the fact that blue lies between Q and minus I.

The red adder, block 47, is supplied with fixed proportions of Y, plus Q, and plus I which agrees with the fact that red lies between Q and I.

The color amplifiers, blocks 42, 45, and 48, are used as output amplifiers which provide enough signal voltage to drive their respective guns in the cathode-ray tube. The d-c restorers, blocks 43, 46 and 49, are used to stabilize the bias on the grids of the guns.

Color Gain Controls. Each adder is shown with its own gain control although only two are needed; usually the red is omitted. The controls permit the three color channels to be balanced with respect to each other so that white is produced (for example) when white is called for. The balance actually provides for correct chrominance in all colors but only white can be used as a setup guide because it can be readily identified by an untrained eye. The adjusters are set up at the time of installation.

Division of Y Signal for White. When no color information is received, only the Y amplifier works. The signal, in other words, is a monochrome signal. The only signal which enters the matrix is the Y signal. The dividing resistors automatically divide this signal among the three adders to provide the proportions of green, blue, and red which together produce white.

This division of the Y signal into proper balance to produce white is no accident. The Y signal contains no color, consequently the resistor networks divide the Y signal into each of the color channels as a neutral luminance signal. The neutral character is evident as the dividing up of the signal into a white balance of green, blue, and red. It is only when color signals are present that this white balance is modified by the I and Q signals, and colors are seen on the screen.

User Controls for Color. The controls shown in Fig. 5 are panel controls which are operated by the user of the set.

The CONTRAST control performs the same function as the contrast control in monochrome sets, and works in exactly the same way when monochrome signals are received. The control is a two-gang unit. It adjusts the level of the Y signal along with the level of the chroma signal, keeping them in fixed proportion to each other.

The SATURATION control permits adjustment of the chroma signal alone, independently of the Y signal. This permits the intensity of the *color* to be adjusted by the user. At very low settings, all colors appear as pastels; at high settings, all colors are exaggerated in vividness. The control is usually identified simply as the COLOR CONTROL for the user.

The HUE CONTROL permits adjustment of the phase of the burst signal, hence the accuracy with which the I and Q colors are split apart. The control is adjusted by eye to obtain a balance between redness and blueness. The most familiar color to the eye of the user is flesh color and this is usually used as a guide to correct adjustment.

High-voltage Circuits. The last special color circuit is the one shown in Fig. 2 as block 6, the high-voltage supply. It is broken down into five separate blocks in Fig. 8.

The blocks represented by numbers 61 and 62 constitute the main high-voltage supply. It includes a rectifier, block 61, which supplies about 20,000 volts for the second anode of the cathode-ray tube.

High-voltage Regulator. The regulator, block 62, is found only in color television receivers. Its function is to regulate the high voltage, usually to a value of 19,500 volts. As will be explained later, it is extremely important to provide the color tube with stable voltages, otherwise correct color register will not be possible. The regulator uses a special tube designed for this purpose. It holds the high voltage at a constant level even with appreciable changes in line voltage or other conditions which normally act to alter the voltage. In monochrome receivers, high-voltage regulation is unnecessary because voltage changes act only to alter the picture brightness, and this only to a slight degree.

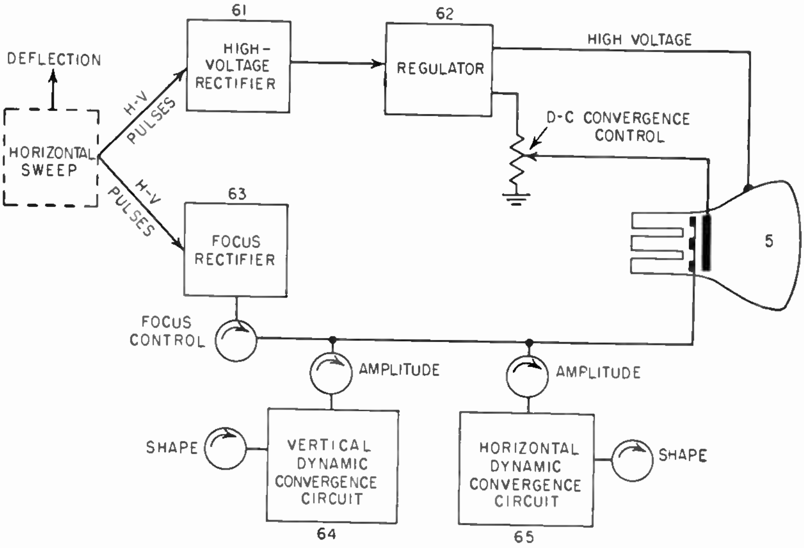


Fig. 8. Block diagram of the high-voltage and convergence circuits. (block 6 in Fig. 5)

Accelerator Voltage. The high-voltage supply is also used to supply the accelerator voltage for the color tube (about 10,000 volts). This voltage is also critical not only in so far as stability is concerned, but also as to exact level. Stability is taken care of by the regulation of the supply. Exact voltage adjustment is provided by means of a potentiometer, identified as the D-C CONVERGENCE CONTROL. It is one of the setup adjusters for the set. Its adjustment will be described below.

Focus Voltage. Block 63 represents a second high-voltage rectifier which supplies about 4,500 volts for the focus electrodes of the three color guns. The focus is adjustable by means of a single control as shown.

Blocks 64 and 65 represent the vertical and horizontal *dynamic convergence* circuits. These serve to modulate the focus voltage (for the 15-inch tricolor tube which has a common convergence-focus electrode) so as to obtain perfect focus all over the screen. Perfect focus is essential at all points of the surface, otherwise correct beam crossover will not take place properly through the tiny holes in the shadow mask.

Focus in Monochrome Sets. Perhaps you have noticed in monochrome sets that it is sometimes impossible to get perfect focus all over, all at once. You may have noticed further that, at some settings of the focus adjuster, you can get good focus in one corner, at the sides, or in the center. In other words, perfect focus appears to be possible anywhere on the screen, but not at the same time; the focus control has to be adjusted differently for different areas.

The reason for this is that the cathode-ray beam travels a different distance to the screen to strike different areas. The center of the screen is nearest the gun; the corners are farthest from it. The greatest focus force is needed for the center—least in the corners.

To express this problem more accurately, the amount of focus voltage needed for *perfect* focus depends upon how far the beam is deflected away from a straight center line. As the horizontal sweep scans the beam sideways, correction is needed. The same is true of the vertical sweep. The most correction is needed at the ends of the sweep, less as the sweep approaches screen center. The greatest amount of correction is needed when both the horizontal and vertical sweeps are at their extremes, because this places the beam in a corner of the picture.

Dynamic Convergence Circuits. These relationships are used in color sets to bring about automatic full-screen focusing. The two scanning circuits are made to excite tuned circuits, one for each scanning circuit. These are called dynamic convergence circuits. The term convergence is almost synonymous with focus in color sets although it means more—it means color focus in a sense. The term dynamic is used to indicate that the focus is continuously under the influence of the scanning circuits so as to compensate in focus voltage for the deflection of the beam.

The convergence circuits are tuned to suit their respective sweep speeds. The horizontal is tuned to operate at 15,750 cps while the vertical is tuned to operate at 60 cps. Each circuit develops a parabolic waveshape, centered within the sweep. The horizontal convergence voltage is maximum at the beginning of the sweep, drops smoothly to its minimum at the center of the sweep, and rises again to maximum at the end of the sweep. The vertical convergence voltage acts the same way in the vertical direction.

Shape Controls. The shape of the parabolic waveshape is adjustable by means of two shape controls, shown in Fig. 8. The amplitude of each is also adjustable by means of the amplitude controls. The controls are usually identified as vertical (or horizontal) convergence shape and vertical (or horizontal) convergence amplitude. The term dynamic convergence adjusters is used only when all of these adjusters are referred to as a group.

The procedure for adjusting convergence is always described in detail in the service manuals of color television manufacturers, as are all other special color adjusters, for that matter.

D-C Convergence Control. D-c convergence is adjustable by means of the *d-c convergence control* associated with block 62. The purpose of this control is to adjust the color tube for perfect convergence only at the center of the screen, before dynamic convergence is attempted. Ordinarily this adjustment is done in conjunction with three beam-position magnets, not previously mentioned. These magnets are placed around the neck of the tube, one near each gun. They may be in the form of magnetized metal devices which can be moved toward or away from the neck of the tube.

Color Register. Although convergence has been spoken of as a kind of focusing up to this point, it must be understood to be more than that. Convergence is really *color register*. It relates to the manner in which the three color beams sit on top of each other when they hit the screen.

When convergence is proper, white dots on the picture will appear as white dots; when convergence is poor, the white dots will break up into three colors, perhaps around the edges. When convergence is very bad, the single white dot will be seen as three separate dots, one red, one blue, and one green.

Dot Generator. Convergence is usually set up using a dot generator which delivers a test signal into the color set such that a polka dot pattern of white dots is generated.

D-c convergence is adjusted so as to obtain pure white dots at the center of the screen. Dynamic convergence is adjusted so as to get pure white dots out to the edges and into the corners of the screen.

QUESTIONS

1. What signals are handled by the bandpass amplifier in color sets?
2. What kind of output signals are extracted from the 3.58-mc oscillator?
3. Why is a keyer used in the color sync circuit?
4. What is the basic function of the killer circuit?
5. What is the purpose of the Y-delay circuit?
6. Express, in general terms, the signals fed into the matrix and the signals which come out.
7. What is meant by dynamic convergence in a color set?
8. How does the high-voltage supply of a color set differ from that of a monochrome set?

19

Large-screen Color Receivers

Block Diagram. This chapter deals with a popular form of simplified color television circuitry, such as is employed with large-screen tricolor tubes. A block diagram of the color circuits is covered, together with circuit diagrams of typical color stages, to show how they actually operate.

The block diagram of the color circuits is shown in Fig. 1. It is similar in general form to the block diagram of a classic color set and represents

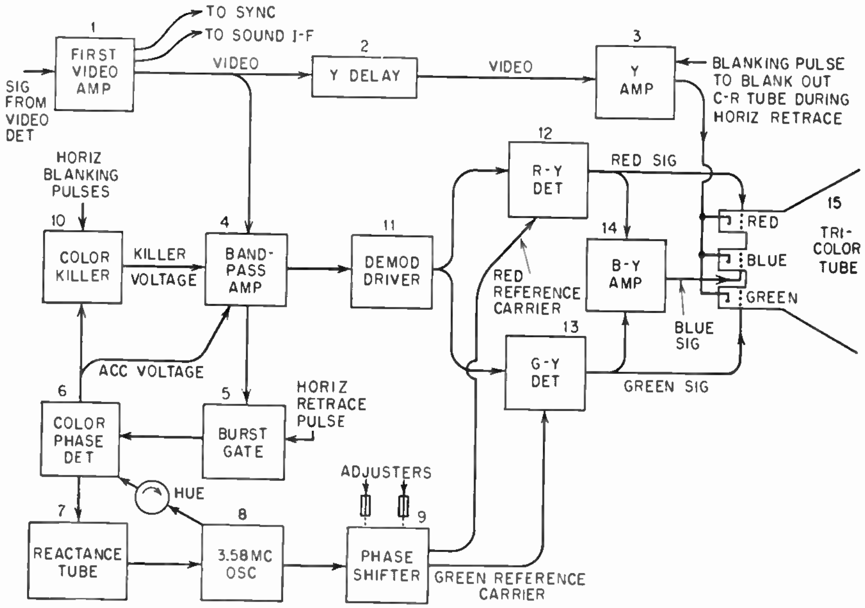


Fig. 1. Block diagram of a large-screen color receiver

the same general circuits. The major difference is found in the color detectors, or demodulators, as they are called, and in the fact that there is no matrix in the simplified receiver.

First Video Amplifier. The first video amplifier, block 1, amplifies the detected video signal and supplies a signal to the second video amplifier, block 3, through a Y-delay circuit, block 2. It also supplies the video signal to conventional sweep sync circuits and the intercarrier beat to the sound i-f amplifier. In addition it supplies the color-signal portion of the video signal to the bandpass amplifier, block 4. The color signal includes the color sync burst and the chroma signal.

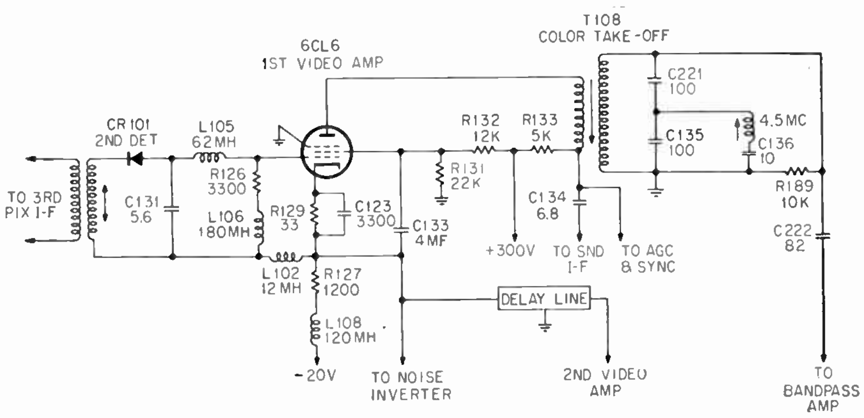


Fig. 2. Circuit of the detector and first video amplifier. The major part of this circuit composes block 1, Fig. 1

The circuit of a first video amplifier stage is shown in Fig. 2. The video signal is fed from crystal detector CR101 to the grid of the amplifier tube. The input signal actually appears between the grid and the junction of R129 and L102.

The amplified video signal appears across R127 and L108. It is coupled through a delay line (the Y delay) to the second video amplifier. Video from this same point is taken for the noise inverter in a conventional noise-cancelling sync pulse clipper circuit.

The video signal also appears in the plate circuit of the first video amplifier. It passes through the primary of color take-off transformer T108. A portion of the signal appears at the bottom end of the primary. It is fed from that point to the agc and conventional sync circuit where the horizontal and vertical sync pulses are extracted. It is also fed through

C134 to the sound i-f transformer, where the intercarrier beat is extracted and used to provide sound.

The color take-off transformer is tuned to 3.58 mc. Resistor R189 is used to broaden its response so as to permit the full chroma signal to get through. Output is fed through C222 to the bandpass amplifier. A trap circuit is connected into the secondary to trap the intercarrier beat so as to keep it from passing through to the color circuits.

Second Video Amplifier. The circuit of a second video amplifier stage (block 3) is shown in Fig. 3. The video signal passes through the delay line and is impressed on the grid. The grid circuit contains suitable compensating coils and resistors to maintain faithful video response.

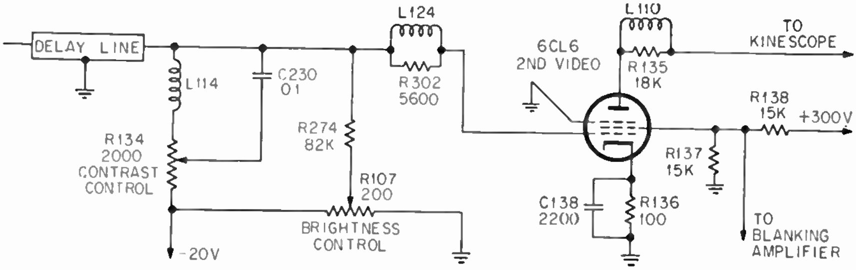


Fig. 3. Circuit of the Y amplifier. This circuit corresponds with block 3, Fig. 1

A contrast control, R134, is included in the grid circuit to permit the signal level to be controlled by the user. Amplified output (the Y signal) is fed through video compensating coil L110 to the cathodes of *all three* color guns in the cathode-ray tube, as shown in the block diagram. The signal is coupled directly to the cathodes, consequently the d-c plate voltage appears on the cathodes. This not only makes a d-c restorer unnecessary but also permits brightness to be controlled by varying the bias of the amplifier tube. This is done by means of R107 which is the brightness control at the panel of the set.

Blanking voltage is fed to the screen grid to blank out the video amplifier during horizontal retrace.

Bandpass Amplifier. The circuit of a bandpass amplifier (block 4) is shown in Fig. 4. Bandpass transformer T113 is tuned to pass only the color signals. Virtually no video or sound get through this transformer. Signal is delivered to the burst gate (block 5) and to the demodulator driver (block 11).

Bias is supplied to the amplifier tube through the grid return resistor

R298. This voltage is identified on the block diagram as the automatic-color-control (acc) voltage. It serves to establish an automatically correct gain during the reception of color signals and to provide a blocking (signal-killing) voltage when monochrome signals are received. This will be explained later when the operation of the color killer is described.

Burst Gate. The circuit of a burst gate or burst keyer stage (block 5) is shown in the upper left-hand corner of Fig. 5. The color signal is fed into the cathode of the burst keyer from the output of the bandpass amplifier. The keyer stage is hooked up as a grounded-grid amplifier. Normally, the grid of the keyer is cut off (note that the diagram indicates —43 volts on the grid). This prevents the color signal from being amplified by the tube.

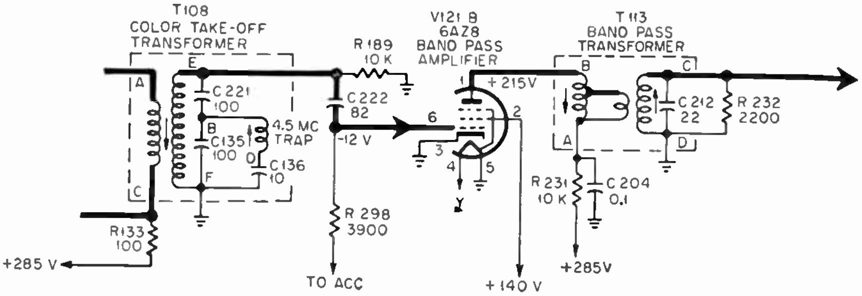


Fig. 4. Circuit of the bandpass amplifier, block 4, Fig. 1. The heavy arrow at the right supplies signal to the demodulator and to the burst gate. Killer voltage and ACC voltage are fed in through R298

The grid is coupled through C192 to a tap on the horizontal sweep output transformer. The retrace voltage at this tap appears as a highly positive pulse of voltage, high enough to overcome the bias voltage on the keyer. As a consequence, the tube operates only during the retrace pulse. During this interval, the color-burst signal is amplified and coupled into keyer output transformer T112.

The keyer stage is commonly referred to as a gate circuit because it is a normally dead circuit which is enabled by an applied pulse. The pulse action on the circuit can be described as an opening of a gate. The width of the gate is equal to the width of the pulse.

Color AFC. The color sync signal appears across the secondary of T112 and is applied to phase detector V120 (block 6). A continuous signal from the 3.58-mc oscillator (block 8) is also applied to the phase detector through R247. The detector develops a d-c voltage at the arm of afc balance control R228. The voltage is proportional to the phase difference between the incoming color sync signal and the oscillator signal. It acts as a control signal for the reactance tube (block 7). It is applied to the grid of that tube through R272-L126 and R242.

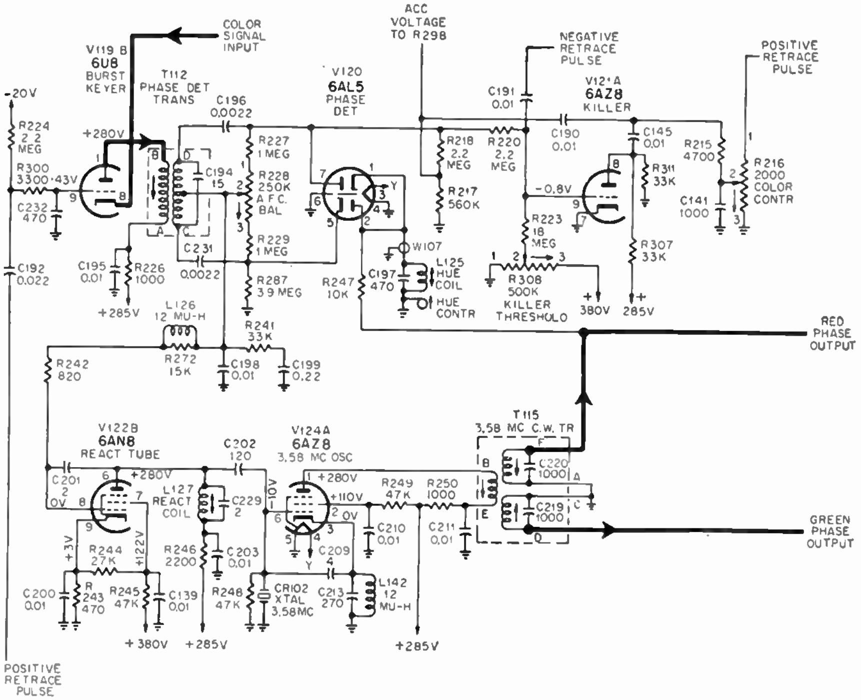


Fig. 5. Color circuits which correspond with blocks 5 through 10 inclusive in Fig. 1. Input to the keyer (burst gate) is obtained from T113 in Fig. 4. The two retrace pulse references at the upper right correspond with the *horizontal blanking pulse* shown feeding into block 10. The *positive retrace pulse* at the lower left corresponds with the *horizontal retrace pulse* shown feeding into block 5

The reactance tube is connected across coil L127 in the grid of 3.58-mc oscillator V124A. Although the frequency of the oscillator is primarily controlled by 3.58-mc crystal CR102, the effect of changes in reactance coil current is to shift the frequency of the oscillator just enough to get it into perfect step with the color sync signal.

Phase detector V120, reactance tube V122B, and 3.58-mc oscillator V124A form a loop circuit into which burst keyer V119B feeds a signal. The loop acts in such a way that it homes on this sync signal.

Automatic Color Control. The voltage at pin 7 of the phase detector is negative and proportional to the amplitude of the color burst. The stronger the color burst, the more negative this signal becomes. The voltage is used as an automatic-color-control voltage. It is reduced to a suitable level by a voltage divider composed of R217 and R218 and fed to the bottom of R298 (see Fig. 4), the grid return resistor of the bandpass amplifier. It serves to hold the level of the chroma signal constant from station to station and also with changes in fine tuning, antenna response, etc.

Should the color-burst signal be subnormal in strength, the acc voltage drops and the gain rises in the bandpass amplifier and this increases the signal to a normal level. The reverse happens when the color burst signal is initially too strong.

Color Killer. The color-killer circuit (block 10) is in the upper right-hand corner of Fig. 5. Note that the acc voltage is fed to the killer circuit through R220. When a color signal is being received, and consequently when an acc voltage appears at the top of R218, the color-killer tube is heavily biased and thus is virtually inoperative. Its killing action is neutralized and the bandpass amplifier works normally, passing color signals through to the rest of the color circuits (blocks 11 through 14).

When the color sync signal is absent, as with monochrome signals, the acc voltage drops off and this enables the killer circuit to work. It acts to block out the bandpass amplifier, and no signals can then pass on to the color circuits.

The killer circuit is shown in simplified form in Fig. 6. It works as described in the following paragraphs.

When a color signal is being received, the phase detector supplies a bias voltage through R220 to the grid of the killer. This may be assumed, for the time being, to be a cutoff voltage which blocks out the killer tube. As a consequence, the input signal to the killer through C191 may be disregarded during normal color reception.

The acc voltage is impressed through R218 and R298 to the grid of the bandpass amplifier, where it acts as described earlier. Blanking voltage pulses (low-level horizontal sweep retrace pulses) may be added to the acc voltage by means of the color saturation control. When the saturation control is fully retarded, however, its arm is grounded. No blanking pulses are applied and the bandpass amplifier gain is determined entirely by the acc voltage coming through R218.

When the color control is advanced, positive blanking pulses are coupled through R215 and C190 into the grid circuit of the bandpass amplifier. These pulses coincide with retrace and thus serve to increase gain, but only during the retrace interval when the color sync burst is being amplified. This causes more color-burst signal to get through the keyer and into the discriminator. This, in turn, results in higher acc bias

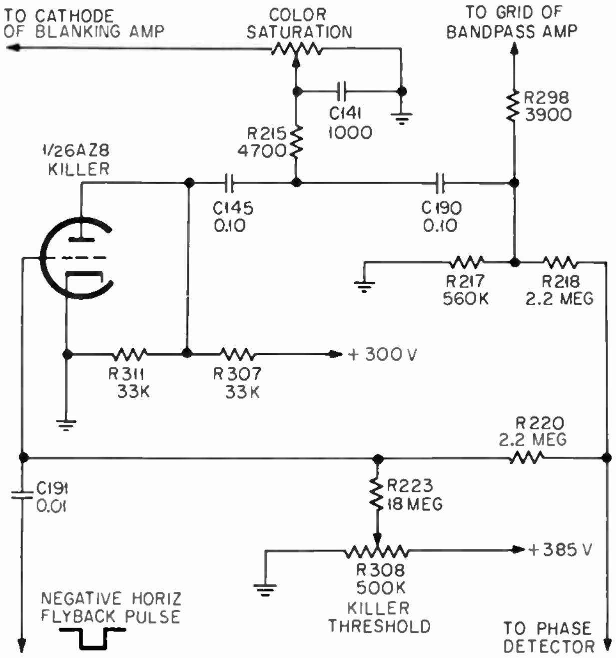


Fig. 6. Circuit of the killer, block 10, Fig. 1. Killer and acc voltage feeds through R289 to block 4. The arrow at the lower left corresponds with the *horizontal blanking input* to block 10. The arrow at the lower right corresponds with the line from block 6

which reduces the gain in the bandpass amplifier during *trace* when the chroma signal is being amplified. The net result is that the level of the chroma signal can be altered with respect to the level of the color-sync-burst signal. It permits the intensity of color to be set up initially, after which it is automatically maintained.

When the color signal disappears (set tuned to a monochrome signal) the bias from the phase detector falls off. This enables the killer tube to operate. The signal at its grid then goes to work.

Negative horizontal blanking pulses are applied to the grid. These pulses cut off the tube during retrace but permit it to carry heavy current during the horizontal trace period. The output of the tube is thus composed of rectangular pulses, *positive during retrace* and *negative during trace.*

The trace period coincides with the time when the scanning beam is visible. The negative plate pulse at the killer is coupled through C145 and C190 to R289 and serves to blank out the bandpass amplifier during this time. As a result, the color circuits are dead during the time when they might otherwise affect the picture. The color circuits are killed for all practical purposes.

During retrace, the killer plate pulse is positive. This enables the bandpass amplifier to operate during that interval, although no effect is seen in the picture since the cathode-ray beam is retracing and is blanked out. The bandpass amplifier, however, is in a position to see a color sync burst should the transmitter switch over to color. When this happens, the receiver goes back into the color condition which was described above.

During monochrome operation, some noise and random video may get through the bandpass amplifier (only during retrace) but because this contains little if any energy at 3.58 mc, very little voltage is developed across T112. The phase detector, in turn, develops little voltage and does not interfere with the color-killed condition of the killer circuit.

In actual operation, the killer is never entirely disabled. During the reception of color signals, the phase-detector voltage reduces the gain of the killer tube. The killer continues to develop rectangular pulses in its plate circuit, but at low amplitude. These pulses do not blank out the bandpass amplifier but simply serve to kick the gain up higher during the sync burst than it is during reception of the chroma signal. This serves to cancel out the effect of the acc voltage on the color *sync* signal when weak signals are received, and ensures enough sync signal to lock the 3.58-mc oscillator solidly.

Color Demodulation. The demodulator circuit, represented by blocks 11 through 14, is shown in Fig. 7. The input signals are three: the chroma signal through R313, one phase of the 3.58-mc signal (red phase) through R254, and another phase of the signal (green phase) through R260. The output signal is likewise composed of three parts: the red signal, the blue signal, and the green signal. These are each fed directly to their respective control grids in the tricolor gun assembly, as indicated on the block diagram.

The demodulator driver (block 11) is used to build the chroma signal up to a level high enough to drive the cathode-ray tube. As you will see, the demodulators are not amplifiers; consequently the driver must supply the full energy needed to drive the cathode-ray tube.

The demodulator driver signal is fed to the demodulators through driver transformer T114. This transformer is at the left-hand side of Fig. 8 which represents a simplified circuit of the demodulators. The upper 12BH7 tube represents block 12 on Fig. 1, while the lower one represents block 13. The 6AZ8 represents block 14.

Colors Detected Directly. The simplified receiver design approach involves the detection of colors directly in terms of red, blue, and green rather than in terms of I and Q colors which must be decoded later in a matrix. This is a matter of utilizing appropriate reference phases for the carrier signals in the detectors.

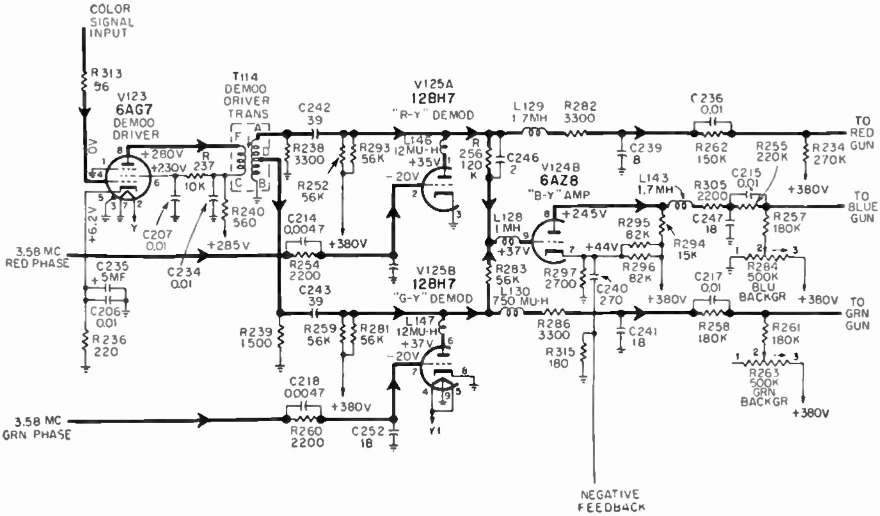


Fig. 7. Circuits which correspond with blocks 11 through 14 inclusive in Fig. 1. The input and output connections are easily compared with the signal circuits shown in the block diagram

Since the chroma signal contains color information relative to *all* colors, any color can be sensed from it so long as a suitable carrier reference angle is used in the detector.

Red Detector. The pure red color lies between the colors I and Q. More specifically, it lies at an angle of about 75 degrees with reference to the color sync signal. In order to make the red detector respond to red, the reference carrier fed into the detector through R254-C214 is phased 75 degrees away from the color sync signal. (The figures are approximate.)

The 75 degree phase angle is obtained in transformer T115, shown in the lower right-hand corner of Fig. 5. The upper secondary, which is tuned by C220, feeds the 3.58-mc carrier to the red detector. The coil is adjustable with an iron slug (one of the two shown over block 9 in Fig. 1). In practice, it is tuned so that the red detector provides maximum output on a pure red signal.

The detector (like all detectors) is a mixer; it mixes the chroma signal and the carrier and delivers an output which is representative of the red color in the transmitted picture. The chroma signal (see Fig. 8) is fed to the plate of the detector through C242; its basic frequency is 3.58 mc.

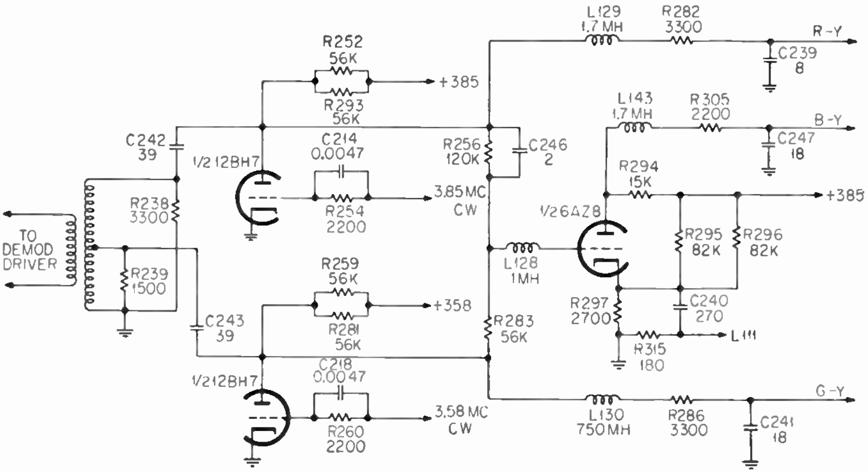


Fig. 8. Circuit diagram of the red and green color detectors and the blue color amplifier (blocks 12, 13, and 14)

The red reference carrier (also at 3.58 mc) is fed into its grid through R254-C214. The resulting signal is fed through L129 and R282 to the grid of the red gun in the cathode-ray tube. The signal consists of the two 3.58-mc signals as well as the beat between them. The *beat* is the red signal. The two 3.58-mc signals are filtered off by means of L129 and C239.

The red signal is called the R — Y signal because it contains only chrominance information and has no luminance information. The latter is contained fully in the video or Y signal, hence the red detector signal represents color *without* luminance, or more specifically, red minus Y.

Green Detector. The pure green color lies between the colors minus I and minus Q. More specifically, it lies at an angle of approximately 300 degrees with respect to the color sync burst. In order to have the green or G — Y detector respond to green, its reference carrier must be phased about 300 degrees away from the color sync signal.

The green reference carrier is also obtained from transformer T115 in Fig. 5. The correct phase is obtained first by reversing the direction of the lower coil which provides an initial 180-degree shift, and then by tuning it to produce maximum green output on a pure green signal.

The 3.58-mc green reference carrier is coupled into the grid of the G — Y detector through R260-C218 as shown in Fig. 8. The chroma signal is coupled into its plate through C243. The resultant green signal, or G — Y signal, is coupled through L130 and R286 directly into the grid of the green gun.

The driver transformer is tapped down so as to deliver a smaller signal to the green detector than to the red detector. The principal reason for this is that the green phosphor is more efficient than the red, and less signal is required to give equivalent light output. The position of the tap is carefully chosen to take care of this difference in phosphor efficiency.

Getting the Blue Signal. Blue lies halfway between the *complements* of red and green. This is another way of saying that it is the *reverse* of the color which lies directly between red and green.

The network composed of R256 and R283 is used to obtain a color voltage which lies between red and green. It is fed to the grid of the B — Y tube through L128. The tube acts as an amplifier although its principal function is to invert the signal. This takes care of the requirement of getting the reverse of the color between red and blue. The reversed signal appears at the plate and is coupled through L143 and R305 to the grid of the blue gun.

Resistor network R256-R283 is unevenly balanced because the red and green signals are unbalanced; the green signal is lower in amplitude because of the tap on the driver transformer. The resistor network is unbalanced in such a way as to favor the green. The net result is a suitable over-all split of red and green which represents the complement of blue. The polarity-reversing effect of the B — Y tube converts that color into blue, as mentioned above.

Y Delay. The color circuits introduce a certain amount of signal delay, yet all signals (color and Y signals) must reach the cathode-ray tube simultaneously.

The Y amplifier introduces less delay than the color circuits (because its bandwidth is greatest), and thus it tends to arrive at the cathode-ray tube ahead of the other signals. The Y-delay line (block 2 in Fig. 1) delays this signal to prevent that.

Matrixing. A significant simplification over a classic television receiver is the elimination of the complex color decoding circuits or matrix. In the simplified receiver, the cathode-ray tube itself performs this function. The signals are fed into the cathode-ray tube in the manner shown in Fig. 9. The Y signal is fed to all three cathodes while the color signals are fed to their respective grids.

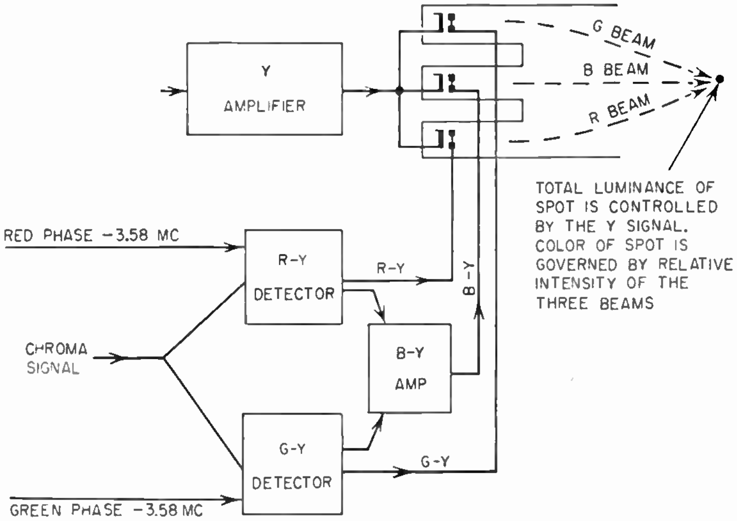


Fig. 9. Simplified block diagram of the driving circuits for the color tube

The Y signal contains luminance information which relates to the total amount of light in the televised picture, regardless of color. It is the same signal which is used in a monochrome set to produce a black-and-white signal. This luminance signal controls all three guns, and consequently serves to control the light output of all colors simultaneously. This satisfies the basic purpose of the information contained in the luminance signal.

The chroma signal before demodulation is fixed in amplitude and represents the *total* color spectrum. It may be thought of as having an amplitude value of 100. The separate color detectors together with the B — Y amplifier break up this total into three separate parts. To illustrate the point roughly, the combined circuit may sense 40 units of red, 15 units of green, and 45 units of blue at a given moment; or they may sense no red at all, 90 units of green, and 10 units of blue at some other moment. In short, the color circuits serve to break the total spectrum into three component parts, each one representing its proportion of its particular color which is contained in the whole.

The three color signals appear at their respective control grids and serve to alter the otherwise equal effect of all three beams (the Y signal drives all cathodes equally). If the incoming signal is all red, the red grid is driven most positive while the other two are cut off by the blue and green signals. The luminance signal then serves to control the amount of red light at the screen; it has no effect in the blue and green guns because no beam current flows in these.

When a mixed color is to be reproduced, the color signals drive their respective grids to appropriate levels and this color is observed at the screen due to the action of the individual guns. The luminance signal, however, continues to control the total brightness of the resultant color because of its common drive on all three guns.

When no chroma signal is received, the color detectors deliver no output signal to their respective grids; the grid voltages settle down to appropriate d-c levels which, together, are balanced out to produce white. This d-c balance is actually set up by means of potentiometers when the receiver is initially installed.

Three Convergence Systems. Large-screen tricolor tubes employ three separate convergence systems, one for each gun. Each system includes a pair of pole pieces within the neck of the tube, an external convergence magnet which acts on the pole pieces, and an electrical circuit which feeds a modulated current through the coils of the convergence magnet to take care of the convergence correction needed during the beam-scanning process.

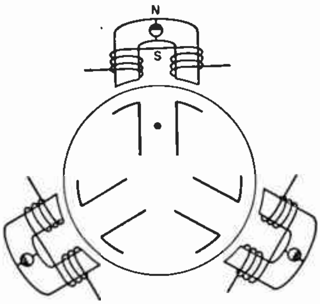
Figure 10 shows how the three pairs of internal pole pieces are oriented with respect to each of the convergence magnets.

Convergence Magnet. Figure 11 shows how the static convergence magnet works. (Disregard the coils for the time being.) The static magnet is the small round element, half black and half white, in the drawing. It represents a magnetized shaft with the shaft end showing. The shaft is magnetized laterally; that is, the black side is the north pole and the white side is the south pole. The rest of the frame is nonmagnetized iron. The magnetized shaft can be rotated for setup purposes.

When the shaft is tuned to the position shown in Fig. 10, no magnetic field appears at the pole pieces because each pole shares north and south equally. The corresponding cathode-ray beam, represented by the single dot in the uppermost (the blue) gun assembly, is thus unaffected and it assumes the central position shown.

When the shaft is turned to the position shown in Fig. 11*A*, the right-hand pole piece is strongly north and the other is strongly south. The magnetic flux is transmitted through the glass, into the pole pieces, and across the gap through which the beam travels (the beam is coming toward you, out of the page). This causes the beam to shift position as shown, and it stays there so long as the magnet position is not changed.

Figure 11*B* shows an intermediate setting of the magnet. This produces a weaker field and shifts the beam less. If the magnet is turned so that the left-hand side becomes north, the beam position is moved *upward*.



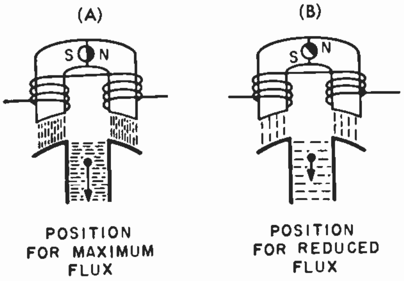


Fig. 10. (Left) Simplified sketch showing how the convergence magnets are arranged around the neck of the color tube

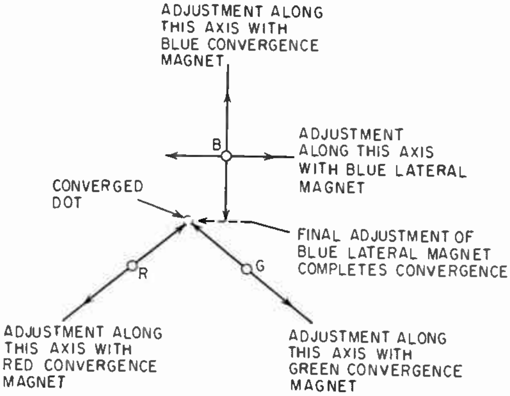
Fig. 11. Rotation of the little round magnet alters the flux at the pole pieces and moves the beam to a new position. This is the static convergence adjustment

Each of the three beams can be individually adjusted in this manner. The adjustment is called the static convergence adjustment because, once made, it remains fixed. Its purpose is to correct for initial misalignment of the three-gun assembly.

How Static Convergence Works. The effect of all three static convergence adjusters is shown in Fig. 12. The three beams can be moved toward or away from a common center. The object of the adjustment is to make all three beams hit the same spot on the screen.

If you think about it a little, you can see that there is no guarantee that all three beams can be made to hit the same spot by means of radial adjustment alone. (The convergence adjusters described above move the beam *radially*, i.e., toward or away from center.) This condition is possible only if all three guns are spaced exactly 120 degrees apart in a perfect circle—a hardly likely condition in an actual tube. A little further thought, however, reveals that if any *one* beam can be moved laterally in addition to radially, perfect coincidence is then possible to obtain. This is illustrated in Fig. 12.

Blue Lateral Adjustment. Lateral beam adjustment is provided for in the blue gun, in addition to the radial adjustment. Two additional pole pieces, at right angles to the first, are added to this gun as shown in Fig. 13. These pole pieces are located farther back on the neck of the tube, nearer the base. A blue lateral adjustment magnet is clipped onto the neck of the tube, like an ion trap. It is adjustable like the radial magnets, and permits the lateral beam position to be set up accurately.



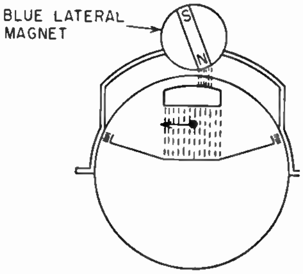


Fig. 12. (Left) The blue beam has an extra adjustment to provide lateral positioning

Fig. 13. (Right) Sketch of the blue lateral adjuster. It resembles an ion trap

The lateral adjustment is purely a static adjustment, intended to correct for mechanical error in gun position.

Dynamic Convergence. The static convergence adjusters can be set up only to produce perfect convergence at the center of the screen. As the beam is scanned about, correcting influences are needed to maintain convergence at all other portions of the screen. The process of doing this is called dynamic convergence. In effect, it calls for the high-speed readjustment of the static magnets as the beam is scanned about. The speed is obviously too high to be practical by mechanical means. It would call for rocking the adjuster screw back and forth slightly at a speed of 15,750 times per second in time with the horizontal sweep, along with an additional rocking action of 60 times per second in time with the vertical speed. Instead, this rocking action is developed electrically.

Each of the convergence magnets has a winding as indicated in Figs. 10 and 11. When a small current is passed through this winding, the strength of the magnetic field is modified. If the current is high-frequency a-c, the effect is similar to high-speed rocking of the static adjuster.

Each of the dynamic convergence magnet circuits is the same, thus only one need be looked at to understand how they work. Figure 14 is a simplified schematic of one of these circuits. The coil is supplied with adjustable current waveforms from both the horizontal and vertical sweep circuits.

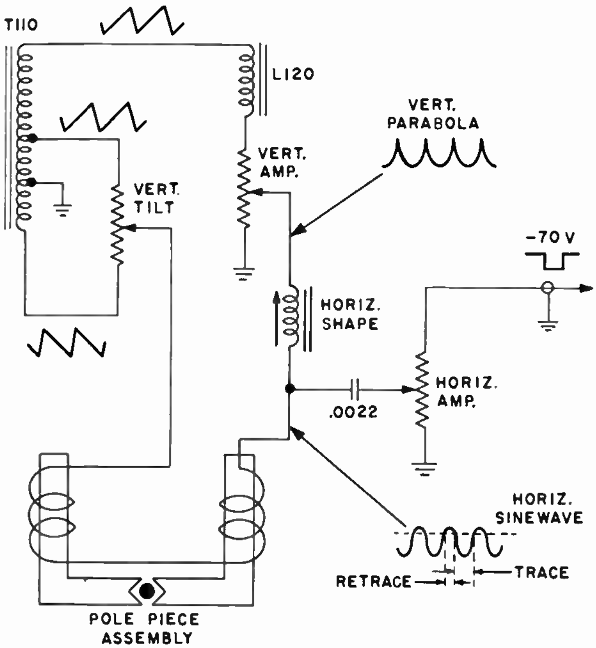


Fig. 14. Simplified circuit of the dynamic convergence circuit

If the horizontal amplitude control is turned to zero, no horizontal sweep current flows through the convergence coil. This condition will be assumed as the initial condition in the following explanation.

Transformer T110 is the vertical sweep output transformer. Only one winding is shown. It is the special winding added to a conventional sweep transformer for convergence purposes. When the vertical amplitude control is turned up, sweep current flows through the convergence coil. The current flows through L120 which serves to smooth the sawtooth out to a parabola as shown. This shape is more suitable for convergence purposes. The horizontal shape coil has no effect on the vertical convergence current. The higher the setting of the vertical amplitude control, the higher the vertical current flowing through the convergence coil.

The vertical tilt control changes the effective point of return to the output transformer. As it is turned, its effect on the parabolic current is as illustrated in Fig. 15. Its effect on a color picture is quickly apparent when you turn it.

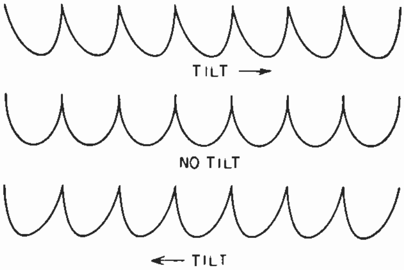


Fig. 15. Waveform of the vertical convergence current with different values of tilt

When the horizontal amplitude adjuster is advanced, horizonal scanning current also flows through the convergence coil. The higher the setting, the greater the component of horizontal sweep current. The horizontal shape inductor is tunable with an iron slug. Its effect on the horizontal current is similar to that which the vertical tilt adjuster has on the vertical current, although the horizontal current is more nearly a sine wave rather than a parabola.

When both horizontal and vertical currents flow through the convergence coil, the total waveform looks something like that shown in Fig. 16.

Fig. 16. This sketch suggests the waveform of the combination of horizontal and vertical convergence currents

The complete dynamic convergence circuit includes one of each of the adjusters shown for each of the guns. The three vertical tilt adjusters are called blue vertical tilt, green vertical tilt, and red vertical tilt. Each of the other adjusters is identified in a similar manner; that is, each is identified with its own color to correspond with the convergence coil of a given gun.

The convergence setup procedure is described fully with the installation instructions of each color receiver.

High-voltage Supply. The horizontal deflection and high-voltage circuit of a typical large-screen color set is shown in Fig. 17. The horizontal damper and output tubes are shown primarily to reveal the relationship of the high-voltage circuit to the normal sweep circuits.

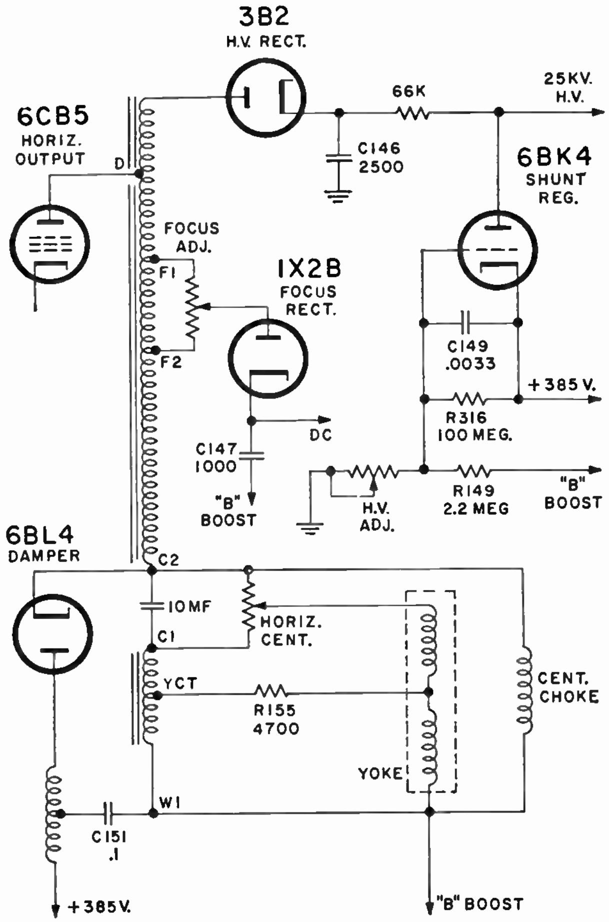


Fig. 17. Circuit of the high-voltage power supply

The coil winding between terminals C1 and W1 is the yoke winding which feeds sweep energy to the horizontal winding of the deflection yoke. The circuitry below terminal C2 is, therefore, the standard yoke-driving circuit, similar to that used in monochrome sets.

The winding from point D to the 3B2 rectifier is a high-voltage extension winding. It elevates the sweep retrace pulse to above 25,000 volts. The 3B2 is a special high-voltage rectifier made for color sets to handle the extremely high voltages needed for the color tube.

The high voltage is regulated to a level of 25,000 or 26,000 volts (depending on the type of tricolor tube used and on the manufacturer's design criteria). This is accomplished by means of a 6BK4 regulator tube, also designed especially for color sets. The regulator bleeds current from the supply through a series resistor (66,000 ohms in this case). The amount of bleed current is automatically adjusted to hold the voltage at the desired level. The voltage level is adjustable by means of a control in the grid circuit of the regulator tube.

Voltage regulation is essential to provide stability for the conditions under which the tricolor tube operates. Without it, convergence could not be maintained accurately.

Lower voltage is obtained from a tap on the sweep output transformer for the focus voltage supply. A conventional high-voltage rectifier is used to rectify this voltage. It is adjustable as to level in some manner to permit focus to be controlled accurately. The voltage is supplied to pin 9 on the tricolor tube. This connects to a common focus electrode which acts on all three beams at the same time.

QUESTIONS

1. What are the two input signals of the color phase detector?
2. What is the nature of the output from the phase detector? What is its principal use?
3. What function is performed by the automatic color control (acc) circuit?
4. What is the advantage of detecting red and green directly rather than I and Q?
5. How is the blue color signal related to the red and green signals?
6. How is the luminance signal used in a simplified color receiver?
7. Why is a blue lateral adjuster provided on large-screen color tubes?
8. From what circuits are the dynamic convergence signals initially obtained?

20

Installing, Adjusting, and Servicing Color Sets

Antenna Requirements. In general, the antenna requirements for color television are the same as those for good monochrome television. Thus, a monochrome receiver can be replaced with a color set simply by disconnecting the antenna from one and connecting it to the other. In a practical situation, however, the antenna should be replaced if it has been in use for two or more years, because it probably is in need of service anyway at this time. When the cost of a color set is considered, it seems hardly worthwhile to economize by using an old antenna and transmission line when these represent a potential source of trouble.

Antenna accessories such as boosters, rotators, cross-over networks, special transmission line, standoff insulators, and the like, are also identical for monochrome and color.

Special Color Requirements. Although there are some requirements which are more important to color than to monochrome, it should be understood that there is no justification for identifying antennas, boosters or other antenna accessories as special color devices. If the device is good for high-quality monochrome, it is good for color; it is difficult to imagine how these devices could be made so as to warrant special recommendation for color. In short, don't pay premium prices for accessories which are claimed to be especially designed for color.

The special requirements described in the following paragraphs involve certain compromise conditions which may be tolerable in monochrome but which may be more objectionable in color.

Matching Line to Set. It is important with any set to match the characteristics of the transmission line to the input of the television set, but it is even more important that this be done in color sets. A poor match may produce smear in monochrome, but it can cause loss of color or degradation of color in color receivers.

There is really nothing complicated about matching; it requires that a 300-ohm line be used with a set that calls for 300-ohm input (the standard input) or that a matching transformer be used when the two are different. For example, if a 73-ohm line is to be connected to a 300-ohm antenna input, a 73-to-300-ohm matching transformer must be employed. Matching transformers are available from radio parts suppliers to match any practical combination which could occur in practice.

The reason for considering match more important in color is that a poor match can cause holes in the antenna-circuit response under certain conditions. If there is such a hole or dip, and if it happens to fall in that part of the bandpass where the chroma signal is located, the color signal may be badly distorted or lost completely. In either case, color response will suffer.

Sharply Tuned Antennas. Special one-channel Yagi antennas are apt to be poor for color reception, especially if the channel happens to be between 2 and 6. This form of antenna in the range of channels 7 through 13 will generally be satisfactory for color.

The reason that this type may be troublesome in the channel 2 through 6 range is that the antenna is so sharply tuned to the specific channel that it may not provide uniform response over the full bandwidth of the channel. If the response should fall off excessively in the 3.5-mc region, low chroma information may result.

Around channel 2, the antenna is called upon to cover a range of 6 mc which is about 10 per cent of the carrier frequency. This kind of coverage is difficult for a *one-channel* Yagi. At channel 7, the 6-mc bandwidth is roughly about 4 per cent of the carrier frequency which is easily covered even by a sharply tuned Yagi.

Broad-band Antennas. If a sharply tuned Yagi has been used for monochrome reception in the lower channels, the antenna should be replaced with a broad-band type. The Yagi may have been used to get better reception of a weak signal. In this case, a *high-gain broad-band* antenna can be used as a replacement.

In rough terms, a broad-band antenna is one designed for use in several channels. An antenna designed to cover the range from channel 2 through 6, for example, is considered a broad-band antenna.

Interference Problems. Interference problems and especially ghost problems are apt to be more noticeable and annoying in color than in monochrome. Ghosts may destroy color balance; interference can do the same thing, or it may appear in the form of color patterns. Because of this, antenna installation work must be done more carefully for color if the area is a problem area.

User Controls. Table 1 lists all standard controls and installation adjusters which are used on a color television set. The user controls include all of those normally employed on a monochrome set plus the following:

Hue Control. This control may be described to the user as the balance control between redness and blueness. It is most easily adjusted by watching flesh tones because these tones are commonly recognized. The hue control will set the color but not the saturation. It must be adjusted for each channel when a picture is tuned in. The control is dead when monochrome signals are received.

Technically, the hue control alters the phase of the color sync burst which alters, in turn, the color detector reference carriers. It permits the user to split the color signals apart properly by using the familiar flesh tone as a guide.

Any other known critical color could also be used as a tuning guide, but it is difficult to think of one which can be remembered accurately or which is actually known. Even sky and grass colors, although generally familiar, exhibit enough variation to be almost useless as a guide.

Saturation Control. This control permits the user to adjust the *depth* or *vividness* of color from pastels to deep colors. Again flesh tones may be used as a guide, although correct adjustment is easier than with hue. The control is dead when monochrome signals are received.

Technically, the satuation (color) control adjusts the amplitude of the signal fed into the chroma channel. This establishes the saturation of color.

Convergence Control. (Not used with large-screen tricolor tubes.) This control may be described to the user as the *color register* control. Most people are familiar with the idea of color register through their observations of printed color matter. Cheap color-printed matter (color comics) often shows signs of poor register when the colors fail to fall properly within their respective areas.

When the convergence control is in need of adjustment, color fringes are seen on white areas, even when monochrome pictures are received.

The convergence control is really the *d-c convergence control.* It controls the voltage applied to the convergence electrode in the cathode-ray tube. The control is provided for the user in order to permit him to compensate for the many small factors which could influence convergence as the set ages. Poor convergence is objectionable to the viewer because of the color fringes which appear around objects.

Table 1. Basic Controls and Adjusters on Color Sets

<table>
<tr><th colspan="2">1. Components in Common with Monochrome Sets</th></tr>
<tr><td colspan="2"><i>Adjusters</i>
Horizontal—Hold, Width, Linearity, Drive, Centering
Vertical—Hold, Height, Linearity, Centering
<i>User Controls</i>
Channel Selector, Fine Tuning
Contrast, Brightness, Focus
Volume, Tone</td></tr>
<tr><th colspan="2">2. <i>Additional</i> Components for Color</th></tr>
<tr><th><i>Classic Receiver with 15-inch Tube</i></th><th><i>Simplified Large-screen Sets</i></th></tr>
<tr><td colspan="2"><i>User Controls</i></td></tr>
<tr><td>Hue (Chromaticity)
Color (Saturation)
Convergence</td><td>Hue (Chromaticity)
Color (Saturation)</td></tr>
<tr><td colspan="2"><i>Adjusters</i></td></tr>
<tr><td>High-voltage Level (approx 19,500 v)
Screen Adjusters—Red, Blue, Green
Background Adjusters—Red, Blue, Green (any 2 or all 3)
Color Gain Adjusters—Red, Blue, Green (any 2 or all 3)</td><td>High-voltage Level (approx 25,000 v)
Screen Adjusters—Red, Blue, Green
Background Adjusters—Red, Blue, Green (any 2 or all 3)</td></tr>
<tr><td colspan="2">Convergence <i>Adjusters</i></td></tr>
<tr><td>Horizontal Shape
Horizontal Amplitude
Vertical Shape
Vertical Amplitude</td><td>Green-V Tilt, V Amplitude, H Shape, H Amplitude
Red-V Tilt, V Amplitude, H Shape, H Amplitude
Blue-V Tilt, V Amplitude, H Shape, H Amplitude
Blue-lateral Adjuster
Blue-static Convergence
Red-static Convergence
Green-static Convergence</td></tr>
<tr><td colspan="2"><i>Miscellaneous Adjustments on C-R Tube Assembly</i></td></tr>
<tr><td>Yoke Position—Longitudinal
Field Neutralizer Coil or Magnets
Purity Coil or Magnet</td><td>Yoke Position—Longitudinal
Field Neutralizer Coil or Magnets
Purity Magnet</td></tr>
</table>

Standard Controls. The balance of the user controls are operated in the same way for both color and monochrome reception, except that a little more care should be used in adjusting the fine-tuning control. When color signals are received, poor tuning adjustment may permit a c-w interference pattern to be seen. The control should be adjusted to make this pattern drop out. The same is true of the tuning of standard monochrome receivers when they are tuned to a color signal.

Adjustment Procedure. The adjustment procedures given in this chapter are not intended to be used in preference to the manufacturer's standard instructions which are provided for each set. His instructions should be followed exactly as they are given in his service manual. The purpose of the procedure and description which follows is primarily to illustrate what is involved in the setup and adjustment of a color receiver. This work must be done on a set in which a new color tube is installed or in which the color-tube adjustment is disturbed in the course of service work.

Each step includes an explanation of what is accomplished within the set as the adjustment is made. This kind of information may not be given in service manuals. It will provide you with a broader knowledge of the why and wherefore of adjustment which should contribute materially to your speed and ability in this work.

PROCEDURE FOR SETS USING 15-INCH COLOR TUBE

Step 1—Installing a New Color Tube. Each brand of set will be different physically and this requires that the manufacturer's service data be followed carefully when adjustments are to be made.

In the course of installing a new color tube, the yoke, a purity coil, a metal shield, and a set of three beam-positioning magnets are installed with the tube. The assembly is shown schematically in Fig. 1.

The yoke is generally larger than monochrome yokes but it is otherwise similar. It includes provision for rotation to permit the picture to be squared up with the mask. The yoke is not pushed forward against the tube as in monochrome sets, but is usually left a little farther back. The reason for this is that the position is critical and will require adjustment forward and back (described in Step 4) to obtain good color purity.

The purity coil (or magnet) is similar to the magnetic focus assembly used on many monochrome tubes. The coil is adjustable by rotating it around the neck of the tube. Its adjustment is described in Step 4.

The metal shield is made of Mumetal or similar magnetic-shielding material. It is used to keep stray magnetic fields out of the color tube because even weak outside fields can influence the path of the three beams and thus destroy color purity, convergence, or both. The beams will operate properly only when they meet a number of critical conditions which outside fields can upset.

The beam-positioning magnets may be supported physically on the metal shield. Three are provided; the top one is for the blue gun, the lower left (looking from behind) is for the green gun, and the lower right is for the red gun. The magnets can be moved toward or away from the neck of the tube to alter the effective position of their respective guns. The adjustment is described in Step 6. The magnets are usually moved away from the tube and kept there until Step 6 (d-c convergence) is performed.

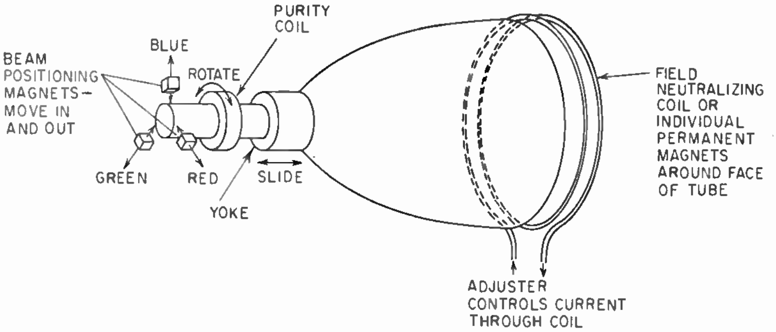


Fig. 1. Adjusters associated with the 15-inch color tube

Field Neutralizing. You may notice either before or during the installation of the tube that a large coil with only a few turns of wire is located in the cabinet so as to pass around the face of the tube. This coil is called the *field neutralizing coil* and is used to compensate for any stray magnetic fields which may be present in the general area of the screen. Its adjustment is described in Step 4 and affects color purity.

Step 2—General Preparations. The set is placed in operation with a monochrome signal and set up in much the same way as a monochrome set. The convergence may be poor but it can be improved by adjusting the convergence control. Any remaining convergence error should be ignored until Steps 6 and 7.

The general setup includes the adjustment of horizontal and vertical size, linearity, centering, and synchronization. Size and linearity must be set up accurately, otherwise Steps 6 and 7 will have to be repeated later when these adjusters are reset. If there is an internal adjuster for the horizontal hold circuit, this must also be adjusted accurately now because it, too, will influence convergence. Make certain that the horizontal sync circuit is acting properly before you proceed further.

Step 3—High-voltage Adjustment. The high-voltage regulator should be adjusted to provide the exact voltage recommended by the manufacturer. You will have to use a high-voltage meter to do this.

When the adjustment is made, check the effect of the brightness control when you turn it through its full range. You may find that it causes variation in the voltage, in which case the regulator will have to be adjusted more carefully. The final adjustment should reveal a minimum of variation, if any at all.

The object of the high-voltage adjustment is to establish the first and most critical requirement for proper operation of the color tube. Once the high-voltage level is fixed, the stiffness of the electron beams is also fixed, and this provides the foundation for the rest of the adjustments which govern the geometry of the three beams. If the high voltage were to drift about, the stiffness would change and all other beam adjustments would also go off. These beam adjustments involve color purity and beam convergence.

Step 4—Color-purity Adjustment. This adjustment is made with a raster only, thus the contrast control must be turned to its minimum position and the brightness to maximum. The adjustment is made by using the red screen as a guide. Before adjustment is started, the beam-positioning magnets are moved as far away from the neck of the tube as possible.

The red screen control is turned to maximum and both the *blue screen* and *green screen* controls are turned to minimum. This will provide a red raster.

If the color purity is perfect, the screen will appear to have a uniformly smooth deep rich-red color all over the surface. If the purity is in error, color contamination will be seen. The corners of the picture, for example, may blend into an orange or yellowish tinge.

The object of the purity adjustments is to establish the effective point at which the beam bends away from a straight line on its way toward the screen. When this point is accurately centered, the beams will pass properly through the shadow mask and will then hit only the proper color phosphor.

Purity is adjusted by rotating the purity coil for maximum red over the greatest area. The field neutralizing control is also adjusted. Its effect will be most pronounced around the outer edges of the screen.

The yoke position (forward or back) will also affect purity. It should be adjusted for best purity (being careful not to rotate the raster out of squareness with the mask).

The adjustments of the purity coil, field neutralization, and yoke position all interact to some degree. The adjustments will have to be repeated as long as improvement can be obtained. The final adjustment should provide a high degree of color purity and uniformity.

Correct red purity should automatically provide best purity for the other two colors, but this should be checked to make certain that this is the case. Reduce the *red screen* control to minimum, advance the *green screen* control to maximum, and check the green purity. Then reduce the green to zero and advance the *blue screen* control to maximum and check the blue purity. If either of these shows evidence of contamination, a compromise purity adjustment may be required to get the best all-around results with each primary color.

Step 5—Temporary White Setup. The next major adjustment to be performed is that of convergence, but convergence is checked by observing the manner in which *white* spots break up into three colors. Thus, the screen must be adjusted to produce a white raster.

This is done by having both the contrast and color controls at minimum and the brightness control at maximum, and then adjusting the *red, green,* and *blue screen* controls for the balance which produces white. The white need not be a brilliant white but may be equivalent to a low-brightness white of a monochrome set.

Step 6—D-C Convergence. Convergence is best accomplished by using a *dot generator* to feed a test signal into the receiver. This generator will cause white polka dots to appear all over the screen. The contrast control will have to be adjusted so that the dots will appear strongly on the screen.

Before d-c convergence adjustment is attempted, all dynamic convergence controls must be turned to their minimum positions to eliminate the effects of interaction.

D-c convergence is adjusted with regard only to the dots *at the center of the screen*; the dots away from center are disregarded. Poor convergence shows up as the break-up of the white dot into distinct primary colors. Perfect convergence is obtained when the dot is all white without any evidence of color fringing or color break-up.

First, the convergence control is adjusted for best convergence, then each of the beam-positioning magnets is adjusted to bring about *perfect* convergence. These adjustments will interact to some degree but it will not be difficult to get good convergence at the center of the screen.

The object of the d-c convergence adjustment is to position the three color beams so that they all hit the same point on the screen. Only when convergence is correct will all beams act as one.

Step 7—Dynamic Convergence. The adjustment of dynamic convergence is an extension of d-c convergence in that it deals with the dots located *away* from the center of the screen. Dynamic convergence is done first in the vertical direction, then in the horizontal.

Before the controls are touched, look at a vertical row of dots which pass through the center of the screen (the "north-south" picture axis). Ignore all others.

These dots will appear to be out of convergence in varying degrees, with the center one properly converged. (That was just done in Step 6.) Adjust the *vertical shape* and the *vertical convergence amplitude* controls to get all dots in the row to *look the same.* The center dot will go out of convergence but this should be expected. The amplitude control will govern the degree of color separation while the shape control will govern the distribution of the error.

For example, if the extreme upper dot is more off-convergence than the extreme lower dot, the *shape* control will balance that out. If the end dots are about the same but not the same as the center, the *amplitude* control will balance that out.

The object is to get a kind of parallelism in the "north-south" axis. Once this is obtained, readjustment of the d-c convergence control will bring the entire row into perfect convergence.

The same thing is then done in the horizontal direction, looking at dots along the "east-west" axis which passes through the center of the screen. The *horizontal shape* and *horizontal dynamic convergence amplitude* controls act in the same way as their vertical equivalents just described.

When perfect horizontal convergence is obtained across the "east-west" axis by the final adjustment of d-c convergence, the vertical will be observed to go into error. It must then be repeated, followed by horizontal adjustment. With each step the error will diminish until good convergence is obtained in both directions. Then the convergence will also be best, right out into the corners of the screen.

Dynamic convergence adjustment is really the introduction of appropriate corrections which are needed to make the three beams coincide at *all* parts of the screen. The beams normally tend to go into error as they move about the screen because the distance from the guns to the center of the screen is less than the distance to other parts of the screen. Thus, the aiming of the guns must be changed a little as the target (the screen) is further away, as it is when the beams bend away from center. The dynamic convergence voltages are the aim-correcting voltages; they are directly related to the position of the beam because they are derived from the scanning circuits which actually move the beam about.

Step 8—White Highlight Adjustment. The adjustment of white highlight must be preceded by the white background adjustment described in Step 5. It is set up with no signal (contrast at zero) and at maximum brightness.

A monochrome picture, or a dot pattern, is then tuned in and the *contrast control* is advanced. This will cause the white to shift into one of the primary colors to some degree, particularly at the brightest parts of the picture (the highlights).

Adjust the *blue gain* and *green gain* controls to produce *white* on the highlights, or *white* dots, if a dot generator is used.

The object of the highlight adjustment is to equalize the gain of the three color *amplifiers* so that they are in proper balance.

Step 9—Lowlight Adjustment. Reduce the *brightness control* to produce a fairly dim picture. This will cause a change in color. Adjust the *green background* and *blue background* controls to produce white. It will really produce a gray which is a dim white.

The object of the lowlight adjustment is to balance the three color *guns* in the color tube.

Step 10—White Tracking Adjustment. Repeat Step 9, then 10, then 9, as often as necessary to get a white color at any brightness setting. This is necessary because the color gain and color background controls interact, and repeated adjustment is needed to get them correct. Otherwise, the setting of one will be in error to compensate for the error in the other. Unbalance in color *gain* is predominant at high brightness; unbalance in color *background* is predominant at low brightness.

The object of this step is to compensate for nonlinearity in the three color guns. Each rises in brightness along its own particular response curve. As these adjustments are made, the three response curves become more nearly identical.

PROCEDURE FOR LARGE-SCREEN SETS

Step 1—Installing New Color Tube. The large-screen color tube is installed with the components shown in Fig. 2. A magnetic-field-equalizing magnet assembly is clamped in place around the face of the tube. The yoke, converging coil and magnet assembly, purity-magnet assembly, and blue lateral beam-positioning magnets are assembled in the positions shown, following the manufacturer's instructions accurately.

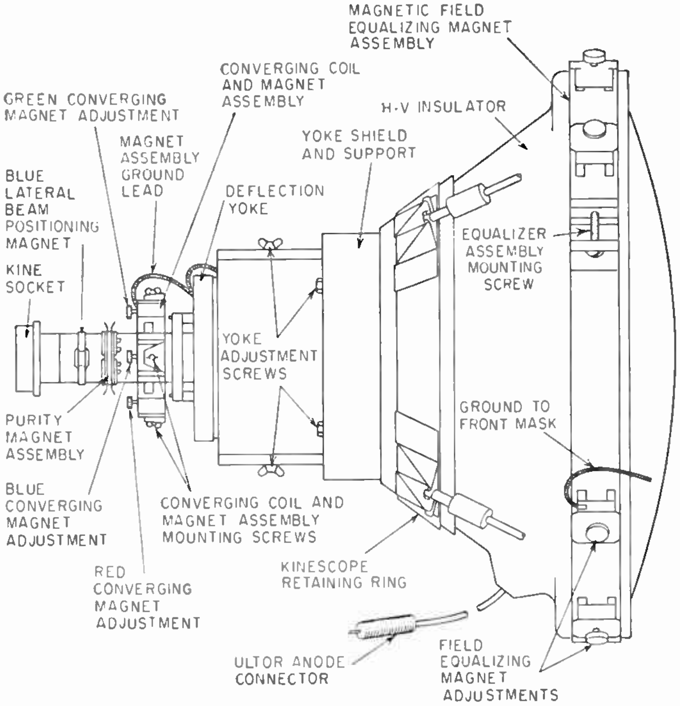


Fig. 2. Adjusters associated with a large-screen color tube. (RCA drawing)

The assembly is similar to that used with the 15-inch color tube except that the three beam-positioning magnets on the latter are not used; a converging assembly, mounted forward of the purity magnet, is used instead. The large-screen tube also uses a small clip-on adjustable magnet for blue-beam positioning.

The field-neutralizing or equalizing assembly is composed of a number of individually adjustable magnets as shown in Fig. 3. A detail of one of the magnet assemblies is also shown. As the magnet is rotated, its field rotates. When the magnet is fully within the cup, its field is virtually shorted out. As the magnet is advanced through the action of the thread, its field becomes stronger, hence it has greater effect on the picture. At the start of the setup procedure, the magnets are retracted into their cups.

Step 2—General Preparations. This step is the same as Step 2 in the earlier procedure except that there is no convergence to be concerned with.

Step 3—High-voltage Adjustment. The high-voltage adjuster is set up to the exact voltage recommended in the service manual. This is around 25,000 volts for large-screen tricolor tubes. This requires the use of a high-voltage test probe.

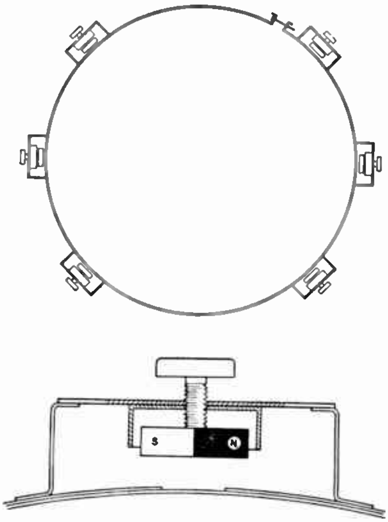


Fig. 3. Sketch of a field neutralizing assembly with a detail of one of the adjusters

The high-voltage adjustment procedure may call for some apparently unrelated adjustments but these should be done as described in the service manual. To illustrate, a horizontal sweep tuning adjustment may be called for prior to setup of the high voltage. This is done because the horizontal sweep amplifier feeds energy to the high-voltage rectifiers and it should be set up for maximum efficiency. A tuning coil may be connected to the sweep output transformer by means of which the resonance frequency of the latter can be adjusted. This is done while reading plate current in the sweep amplifier stage. The service manual will tell you where to connect your meter for this adjustment. It will also tell you where to connect the high-voltage probe for the high-voltage adjustment.

Step 4—Color-purity Adjustment. Prior to the adjustment of purity, the width and height controls are set up for proper picture size (slightly beyond the size of the mask).

Color and contrast are reduced to zero, as are the blue and green screen adjusters. This leaves a red raster.

The purity of the raster is adjusted by means of the purity magnet. The object is to get as uniform a red color as possible. The field-equalizing magnets are left in the retracted (noneffective) position. If necessary, the yoke is moved forward or backward slightly to get the best purity.

Step 5—Temporary White Setup. With the brightness control at mid-position, the screen controls are adjusted to produce a gray raster.

Step 6—D-C or Static Convergence. A monochrome picture is tuned in, after which a dot generator is connected into the receiver. The object is to develop dots on the screen while maintaining synchronization with an incoming signal.

The three convergence magnets and the blue lateral magnet are adjusted for good convergence at the center of the screen.

After this, repeat Step 4 for best over-all purity, then check purity with blue and green screens. Adjust the purity magnet and the yoke for the best compromise, if compromise is necessary. Leave the field-equalizing magnets in the retracted position.

Step 7—Dynamic Convergence. The screen is readjusted for a gray color and the dot pattern is superimposed on a monochrome picture.

The red, blue, and green dynamic convergence controls are adjusted for best registration in the vertical direction. The convergence magnets may need readjustment in the process.

The procedure is then performed with the horizontal convergence controls, this time for best horizontal registration.

When this work is completed, color purity is given a final check and adjustment as described in Step 4. Then, with the screen controls adjusted for a gray raster, adjust the field-equalizing magnets, if needed, to produce a uniform gray raster around the edges of the screen.

Steps 8, 9, and 10—White Balance Adjustments. White highlight, low-light, and tracking are set up with large-screen sets in much the same way as with sets using a 15-inch tricolor tube. Each set may call for certain special adjustments but these will be described in the appropriate service manual.

Magnetized Tubes Can Cause Trouble. When the metal shell of a tricolor tube is even slightly magnetized, good color purity will not be obtained. Color impurity or contamination is most easily seen on a white raster adjustment. Instead of being pure white all over, some areas appear to have pastel shades of yellow, pink, violet, or other colors, giving the raster a dirty appearance.

The shell can become magnetized during storage, shipment, installation, or normal use. For these reasons, it is good practice to degauss (demagnetize) the tube when it is in its final position in the set and just before it is adjusted. It is sometimes necessary to degauss it after the set has been in use for some time, because it may have been magnetized by an external magnetic field.

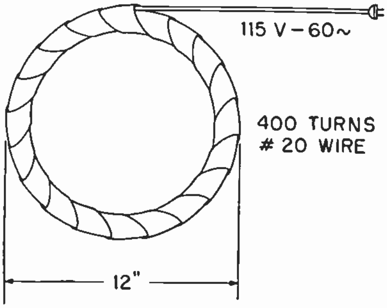


Fig. 4. Winding data for a color tube degaussing coil

The process is a simple one, but requires that you have a degaussing coil. Such a coil, fortunately, is easy to make, or one may be available from your parts supplier.

How to Make a Degaussing Coil. Figure 4 gives the essential details for the construction of a degaussing coil. One end of the coil is connected to each conductor in the power line. The wire may be enamel- or, preferably, double-cotton-covered; the latter will stand more abuse. The total length of the wire is about 1,260 feet. This is a little less than 4 pounds of enamel-covered wire or a little less than 4½ pounds of cotton-covered wire (both No. 20 B & S). The coil should be wrapped with a neat protective covering. Plastic tape is ideal for the purpose.

The line cord should be long enough to permit easy maneuvering of the coil, or an extension should be available. The coil is intended only for intermittent use, but the degaussing job takes only a few minutes. The coil may overheat if it is left on for an extended period of time.

How to Degauss a Color Tube. The color tube should be degaussed right in the cabinet in the customer's home. If field-neutralizing magnets are used, they should be fully retracted before degaussing is attempted. The set may or may not be running during the degaussing job.

The degaussing coil is plugged in and held close to the faceplate from the front of the cabinet, with the plane of the coil parallel to the faceplate. It is held in this position for several seconds. The coil is then withdrawn *slowly* away from the set until you are six or more feet away. The coil must then be turned slowly until it is at right angles to the faceplate, at which time the line cord is pulled out.

The withdrawal process is important. It should not be done rapidly. Most important, the coil *should not be disconnected* until you have backed off all the way and have turned it at right angles to the color tube. The removal of power before this time will only leave the color tube with a residual field.

The same care need not be exercised when plugging in the coil but it is better to do this while the coil is a reasonable distance from the set.

Caution. Make sure the plug makes firm contact. If the contact jiggles as you move the coil, you may end up magnetizing the tube worse than it was before.

General Color Servicing Problems. Color receivers are more susceptible to troubles than are monochrome sets because of the greater number of tubes and circuits used. The problems, in turn, are apt to be greater in a practical sense because of the increased difficulty in handling a color set and in troubleshooting the circuits.

Many of the problems will be exactly the same as those described earlier for monochrome sets and troubleshooting is done in the same way. A color set, in fact, is a monochrome set when the *color control* is reduced to zero, although the cathode-ray tube is expected to mix the primary colors to produce white. In a monochrome set, the phosphor colors are premixed right on the face of the picture tube.

Many problems can develop which are purely color problems. Because monochrome problems have already been described, only color problems will be presented to give you an idea of how they are approached.

Color-signal Troubleshooting Diagram. The diagram given in Fig. 5 shows the general paths taken by signals essential to color operation. Note that the source of signals is the video detector and that the sound signal

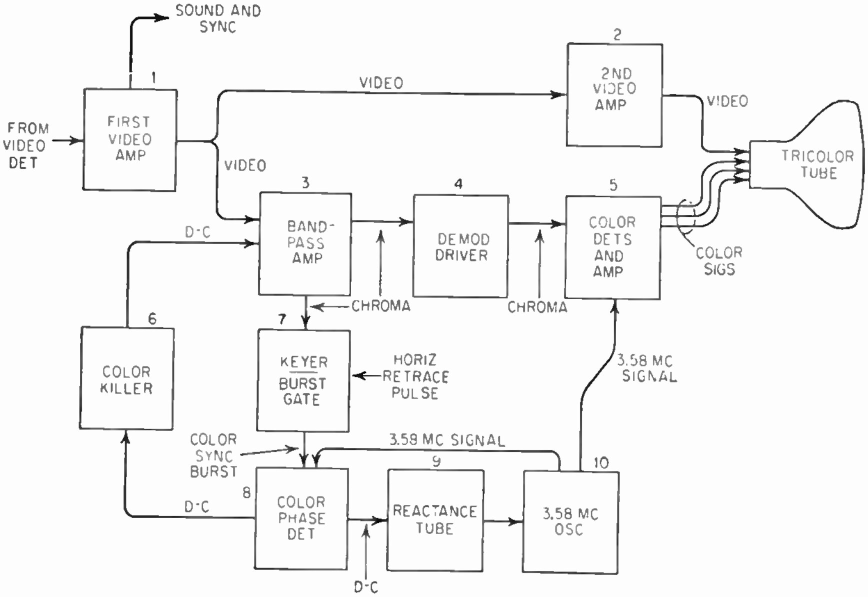


Fig. 5. Color-signal troubleshooting diagram

is taken from the first video amplifier as a general rule. This leads to the conclusion that if the sound is poor or dead, or if reception of monochrome signals is bad, the trouble is almost certainly not in the color circuits. The problem should be attacked as in ordinary monochrome troubleshooting work.

Table 2 below gives specific color symptoms and troubleshooting examples which should be helpful in tracking down color problems.

Table 2. Color Television Receiver Troubleshooting by Symptoms

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CS1. *PICTURE AND SOUND OK—NO COLOR*

A. Problem area—Rather broad, although it narrows down to a failure in one of three circuits: the chroma channel (blocks 3 and 4), the color sync circuit (blocks 7, 8, 9, and 10), or the killer circuit (block 6). A failure in block 3 or 4 will simply prevent chroma signal from reaching the demodulators and only a monochrome signal can be seen. A failure in the sync signal circuit may react on the killer as though there were no color signal and will cause the killer to block out the chroma channel. A failure in the killer may cause color-signal killing action even though color signals are present. (See also CS9.)

B. Tubes to check—Bandpass amplifier, demodulator driver, keyer, killer, color phase detector, 3.58-mc oscillator and amplifier (if used).

C. What to do—Narrow problem down by checking out the chroma circuit. Do this:

Table 2. Color Television Receiver Troubleshooting by Symptoms (*Continued*)

---

1. Locate the color-killing voltage It is usually the bias voltage of the bandpass amplifier. Measure it.
2. If the voltage is a killing voltage, short it out so as to produce a normal color-operating voltage. This voltage will be shown on the voltage charts in the service manual.
3. If the chroma circuit (blocks 3 and 4) is OK, color will be seen when the killing voltage is removed. The color may not be synchronized but it will be evident in some form (assuming you are tuned to a color broadcast).
4. If color is seen, proceed to CS1-1 below; if it is not seen, a defect in the bandpass amplifier or demodulator driver is indicated. In this case, continue with the following steps.
5. Check all voltages in the bandpass and demodulator driver. Investigate discrepancies by tracing circuit and checking the included components.
6. Check the bandpass transformer and demodulator driver transformer for shorts or opens.
7. Trace the signal with an oscilloscope. Look for video up to the bandpass amplifier and then for chroma signals through the bandpass and demodulator driver. This will identify the point of failure.

CS1-1. *Picture and Sound OK—No Color—Chroma Circuit Checks OK*

- A. Problem area—A failure in the color sync, color-killer, or 3.58-mc oscillator circuits (block 6, 7, 8, or 10).
- B. Tubes to check—Color-killer, phase-detector, keyer, 3.58-mc oscillator and amplifier (if used).
- C. What to do—Narrow problem down by checking out the 3.58-mc oscillator. Do this:
  1. Check voltages on oscillator tube, especially grid bias. If voltages are normal, including grid bias, oscillator may be assumed to be OK. Proceed to CS1-2 below. If grid voltage is zero or very low, oscillator is dead. Proceed to next step.
  2. Check crystal by substitution.
  3. Trace circuit and check components individually.
  4. A definite test for oscillator output is the measurement of r-f across the secondary of the oscillator transformer by means of a vacuum-tube voltmeter and an r-f probe.

CS1-2. *Picture and Sound OK—No Color—Chroma Circuit Checks OK—3.58-Mc Oscillator Checks OK*

- A. Problem area—A failure in the keyer, phase detector, or color killer (block 6, 7, or 8).
- B. Tubes to check—keyer, phase detector, color killer.
- C. What to do—Narrow problem down by checking out the keyer stage. Do this:
  1. Check all d-c voltages in keyer stage. Trace out discrepancies and check components in suspected circuits.
  2. Check keying pulse input with an oscilloscope. If absent, trace and test circuit up to the source of the keying signal (usually the horizontal sweep output transformer).
  3. Check for color signal input with oscilloscope.
  4. Check for color-burst output with oscilloscope.
  5. Check for color-burst signal on diodes of color phase detector.
  6. If the preceding checks reveal normal conditions, the keyer may be assumed to be OK. Proceed to CS1-3.

CS1-3. *Picture and Sound OK—No Color—3.58-Mc Oscillator Checks OK—Chroma Circuit Checks OK—Keyer Checks OK*

- A. Problem area—A failure in the phase detector or the killer circuit (block 6 or 8).

Table 2. Color Television Receiver Troubleshooting by Symptoms (*Continued*)

B. What to do—These circuits are essentially d-c circuits and can be analyzed almost entirely by means of a multimeter. The only signal which calls for an oscilloscope is the blanking signal fed into the killer. Check the circuits as follows:
   1. Check all d-c voltages in phase detector and killer. Trace out all voltage discrepancies and check resistors for value, condensers for leaks, and the circuit generally for shorts or opens.
   2. Check blanking input to killer with an oscilloscope.
   3. Check killer output waveform with an oscilloscope.

CS2. *SOUND OK—PICTURE BLOOMED*

A. Problem area—A failure which has caused an upset in bias voltage for the color tube (block 1, 2, or 5) or which has permitted the high voltage to drop.

B. Tubes to check—Video amplifiers, color demodulators and amplifiers, and the horizontal sweep output amplifier.

C. What to do—
   1. Check high voltage; readjust as described in service notes if voltage is in error.
   2. Check bias voltages (cathodes and grids) on tricolor tubes. Trace circuits with discrepancies and test individual components.
   3. Check all d-c voltages in video-amplifier and color-demodulator circuits. Trace circuits having discrepancies and test individual components.

SC3. *PICTURE AND SOUND OK—COLOR WILL NOT SYNC*

A. Problem area—Phase detector, reactance tube, or oscillator circuit (block 8, 9, or 10). Most such failures show up by d-c voltage measurement.

B. Tubes to check—Phase detector, reactance tube, and oscillator.

C. What to do—
   1. Short the grid of the reactance tube to ground. If color then rolls slowly through picture, the problem is ahead of this point (block 8); proceed to next step. If color remains badly out of sync, problem is after this point (blocks 9 and 10); proceed to step 6.
   2. Check all d-c voltages in phase detector. Trace discrepancies and test each resistor and condenser carefully.
   3. Check for sync burst (with oscilloscope) on the diodes.
   4. Check for 3.58-mc signal fed from oscillator into the phase discriminator. Use the r-f probe of a vacuum-tube voltmeter to tell if there is any voltage present.
   5. Check the hue or color control for shorts or opens.
   6. Check voltages in reactance-tube circuit.
   7. Check components in reactance-tube circuit, especially tuning of reactance coil.
   8. Check voltages in oscillator circuit.
   9. Check coupling condenser from reactance tube to oscillator, by substitution.

CS4. *PICTURE AND SOUND OK—COLORS IMPROPER*

A. Problem area—Hue control or demodulator circuit (block 5).

B. Tubes to check—All color demodulators and amplifiers.

C. What to do—
   1. Check hue or color control tuning. Make sure it is tunable through the proper range. Check the coil and tuning condenser for shorts or opens.
   2. Check voltages in color-demodulator and color-amplifier circuits. Trace discrepancies and check components.
   3. Check all choke coils in the circuit for shorts or opens.
   4. Test demodulator drive transformer for shorts or opens.

Table 2. Color Television Receiver Troubleshooting by Symptoms (*Continued*)

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5. Test 3.58-mc oscillator transformer for shorts or opens.
6. Check color-tube grid and cathode voltages.
7. Check for correct screen voltages (pins 3, 7, and 11 on large-screen tricolor tube).
8. Check color tube for an open filament in one gun (by looking for glow or by measuring total filament current and comparing with tube rating).

CS5. *OPERATION OK BUT CONVERGENCE POOR*

A. Problem area—Static and dynamic adjusters and circuits, blue lateral beam adjuster, or high-voltage regulation. Tricolor tube may be poor (incapable of good convergence).

B. Tubes to check—All convergence tubes, if used. (Some sets use special convergence-signal amplifier tubes.) Tricolor tube, if problem cannot be solved otherwise.

C. What to do—

1. Check high-voltage regulation and adjustment.
2. Check placement of convergence assembly and set up static convergence as described in service manual.
3. Make certain that horizontal and vertical linearity and size are set up properly.
4. Set up dynamic convergence adjusters as described in service manual.
5. Check convergence coils in assembly at neck of tube. Check for open coils, coils shorted to ground, or shorted out. (Compare all three for resistance—all should be the same.)
6. Check convergence adjusters for shorts and opens.
7. Trace and check circuit up to the source signals at the horizontal and vertical sweep circuits.
8. Check convergence waveforms with oscilloscope against appropriate service manual illustrations.

CS6. *OPERATION OK BUT COLOR PURITY IS POOR*

A. Problem area—Improper adjustment or magnetized metal shell of tricolor tube.

B. What to do:

1. Check adjustments affecting color purity—purity magnet, yoke position, and field equalizer adjustments.
2. Retract the field-neutralizing magnets and degauss the tricolor tube as described earlier in this chapter.
3. Readjust color purity.

CS7. *INTERMITTENT BLOOMING OR MISCONVERGENCE*

A. Problem area—High-voltage adjustment unstable. May be adjusted on the ragged edge or voltage supply may be just about enough to work when the line voltage is high.

B. Tubes to check—Low-voltage rectifiers, horizontal sweep amplifier, damping tube, high-voltage rectifier, and high-voltage regulator.

C. What to do—

1. Adjust horizontal sweep as described in appropriate service manual.
2. Measure voltages on horizontal sweep output stage.
3. Check for low line voltage.
4. Check high-voltage adjuster for noise by noting whether high voltage jumps as control is jiggled or turned slightly.
5. Make certain high-voltage connectors are properly plugged in.
6. Clean accumulated dirt out of high-voltage compartment.

CS8. *SOUND OK—COLOR IS BADLY BLURRED—DEAD ON MONOCHROME SIGNALS*

A. Problem area—The tricolor tube is driven with the chroma signal only; i.e., the luminance signal is missing. The defect may be in block 1 or 2.

Table 2. Color Television Receiver Troubleshooting by Symptoms (*Continued*)

B. Tubes to check—First and second video amplifiers.

C. What to do—

1. Check voltages in first and second video amplifier stages. Trace suspected circuits and test components.
2. Check for short circuits in delay line and contrast control.
3. Check video compensating coils for opens.
4. Check cathode circuit of tricolor tube for shorts or opens.

CS9. *SOUND AND MONOCHROME PICTURE OK—COLOR WEAK*

A. Problem area—The antenna system may have a response valley in the frequency range of the chroma signal, resulting in weak chroma.

B. What to do—

1. Inspect the transmission line for opens, shorts, or evidence of bad installation practice.
2. Check to make certain that the line impedance value agrees with the input impedance of the set.
3. Install a new line if the situation suggests this action.
4. Try a new antenna, preferably a suitable broad-band antenna.

CS10. *SOUND OK—VERTICAL YELLOW STRIPE NEAR LEFT SIDE OF PICTURE*

A. Problem area—The color sync burst is getting through the color circuits and appears on the tube as a yellow stripe. A defect in the horizontal blanking is indicated since this blanking serves to block out the color tube during the burst (end of retrace).

B. Tubes to check—Horizontal blanking tube.

C. What to do—

1. Check voltages on blanking tube.
2. Check components in circuit, especially coupling condensers for opens or leakage.
3. Check blanking waveforms with oscilloscope against illustrations in appropriate service manual.

Caution: The voltages used in color television sets are appreciably higher and contain more energy than those used in monochrome sets. The greatest care should be exercised at all times to avoid shock. Remember, even the so-called low-voltage supply can be dangerous.

QUESTIONS

1. Why is it more important in color than in monochrome to have a proper antenna match?
2. If a customer has had a 10-element Yagi antenna for channel 2 on monochrome, what should be done for color reception?
3. How should the HUE CONTROL be adjusted? The SATURATION CONTROL?
4. How can you tell when convergence needs correction?
5. What adjustments should be made on a color set before color adjustments are started?
6. What is meant by "purity"?
7. What is the purpose of the field neutralizing adjustment?
8. What effect does a magnetized color tube envelope have on the picture?
9. What defect is suggested if convergence is intermittent?

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