ELIMINATING MAN-MADE INTERFERENCE

by JACK DARR

Here are the solutions to all your noise and interference problems in broadcast, communications, and TV receivers.

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by

JACK DARR

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PREFACE

Noise and interference present problems to all electronic technicians everywhere. With the tremendous "electrification" of this country, even the once quiet rural scene is now troubled with interference. Most technicians have become pretty adept at keeping electronic equipment operating. However, troubles which do not originate within a unit, such as noise and interference, still represent a thorn in the side of the average serviceman.

This book is presented in the hope that it will make the job of finding and eliminating interference easier. It is obviously impossible to cover *all* the causes and cures; however, enough of them have been included in this book to guide you in locating and correcting practically any kind of noise problem. The material has been derived from years of experience in hunting noises of different kinds, and is presented for the benefit of those who can't afford to start from "scratch."

My sincere thanks to the many manufacturers who supplied some of the illustrative matter for this book. Also, my thanks to the FCC for the material from their files on unusual noise cases.

September, 1960

JACK DARR

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1

Introduction

SINCE MAN first began to communicate by means of electromagnetic impulses, his worst enemy has been interference created by the intentional or unintentional transmission of other electromagnetic impulses. This interference—better known as noise—comes from everywhere: the atmosphere, outer space, and here on earth. Marconi's first, feeble three dots would have been a lot easier to receive from Poldhu, Cornwall, England, if it hadn't been for noise! In fact, if it weren't for noise, man could communicate to the farthest planets with only a few watts of radio-frequency power.

In the beginning, radio operators actually communicated by means of noise: the old "spark" transmitter was nothing but a coded noise generator.

Noise originates in every part of electrical apparatus—in the vacuum tubes, transistors, and resistors, and even in the wiring itself. The random flow of electrons through a conductor generates a few microwatts of noise; so do the many megawatts of a lightning flash.

Tremendous strides have been taken, in a comparatively few years, toward reducing noise generated in the circuits themselves. From the cascode tubes in the TV tuners to the ruby masers working in a bath of liquid helium, every effort has been made to reduce self-generated noise in receiving equipment. Specially-designed radio receivers are used in space communications and telemetry, some with a bandwidth of only *ten* cycles, to reduce the effects of noise.

So, amidst the crackles, bangs, pops, and roars of natural static, there stands out the worst offender: man himself! Random noises originating in the myriad electrical units surrounding us make up a very large proportion of the total. Fortunately, this is the one kind of noise we *can* do something about.

There are several means of reducing the effects of noise on communications—frequency and phase modulation, narrow-bandwidth receivers, special low-noise receivers such as the supercooled masers, parametric amplifiers for UHF and SHF, and so on. However, we will be concerned with only the everyday problem of how to improve radio and TV reception by reducing man-made noise in our own area. The ways of doing this will be covered in great detail and in plain language. These methods and the equipment used have been field-tested and will be successful if properly applied.

DEFINITIONS

The first thing to do is get our definitions straight . . . we'll get along a lot better if we're all speaking the same language! So, let's begin by defining some of the terms used throughout the rest of this book.

What is noise? For that matter, what is a signal? Both are electrical disturbances—but with a difference! Look at Fig. 1-1; Fig. 1-1A shows a signal which consists of variations in water out of the other! This brings us to the second point: if we can't separate the two once they are mixed, then our only hope is to keep the noise out in the first place (see Fig. 1-2). We can't do very much about natural static, lightning, atmospherics, and such; but we *can* stop man-made noise. The best and

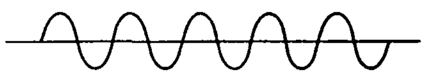
(A) Signal.

(B) Noise.

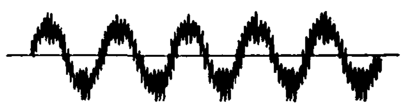
Fig. 1-1. Comparison of a signal and a noise voltage.

the amplitudes of the waves. From these variations we recover the "intelligence"—the modulation put there originally—in order to hear sound or make a TV picture. The signal in Fig. 1-1B shows similar variations, but of a completely random nature. By random nature we mean there is no recognizable pattern—these are small electrical impulses of all kinds, sizes, shapes, and frequencies. Feed this mess into a radio and it will come out a loud "rushing" sound. In fact, this is what we would see if we connected an oscilloscope to the output of a radio and turned the gain wide open with the set off-station. This is the all-too-familiar "hash" we hear between stations.

So now we can make one statement: both signals and noise are fundamentally alike—they're both electrical disturbances. Combining a pure signal with noise is like pouring milk and water into the same pitcher. From then on, we simply can't pour milk out of one side and



(A) A noise-free signal.



(B) Signal at A combined with an almost equal amount of noise.

Fig. 1-2. Effect of noise on a signal.

about the only way to do this is to go directly to the source and keep noise from being produced at all. This we *can* do with the proper methods and equipment.

NOISE *VERSUS* INTERFERENCE

You noticed that the title of this book refers to *interference,* and here we are talking about *noise.* Well, the difference is merely one of definition. Actually, *anything* that interferes with reception of a desired signal can be classed as interference, whether it is a flash of lightning, Grandma's kitchen mixer, or the neighbor's 50-watt hi-fi running at full output. However, there is one small difference: By noise, we mean a purely random effect such as that shown in Fig. 1-1B. Noise does not become interference until it is actually interfering with the reception of a signal, as shown in Fig. 1-2B. This may sound as if we're splitting hairs— but we need some way of differentiating between noise (which is present at all times) and interference (which is not, except when a station is being received).

There is another type of noise, called *RF interference,* due to radio-frequency signals from a station other than the one to which we are listening (or viewing). Most of the time, however, we will be concerned with the purely random-noise type of interference.

SPECTRAIL DISTRIBUTION OF RANDOM-NOISE ENERGY

To select a signal, we tune it in by setting a frequency-selective device to respond to the frequency of the desired radio or TV station. By virtue of the selectivity of our receiver, we can exclude all other stations. Now look at Fig. 1-1 again. No matter what the frequency is, there's a little noise in there somewhere! So, here is another characteristic of random noise to remember—it occurs at all conceivable amplitudes and frequencies. No matter to what frequency we tune our receiver, there is bound to be some noise energy floating around somewhere on that frequency!

A random-noise waveform has a certain typical frequency distribution; that is, it shows peaks at certain frequencies (see Fig. 1-3). This is the frequency *versus* amplitude characteristic of a burst of random noise, such as the typical arc noise. Notice how the amplitude varies with the frequency: the higher the frequency, the lower the noise (and consequently, the lower the amplitude of the random-noise interference). The high-band TV stations are less affected than the low bands, and the UHF stations are affected the least of all. As a demonstration, listen during a thunderstorm to a broadcast receiver at about 1200 kc and a short-wave receiver at about 10-15 mc while watching Channel 9 or 10 on a TV receiver. You'll notice that the noise bursts from the broadcast receiver are deafening, but that those from the short-wave set are quite a bit less and the TV picture is hardly affected.

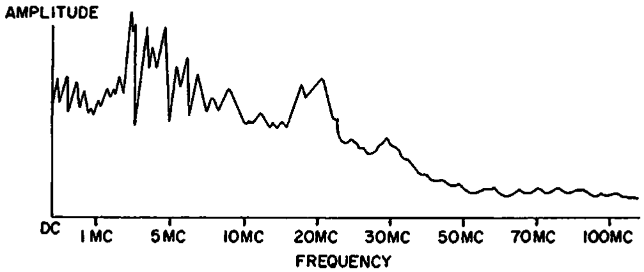
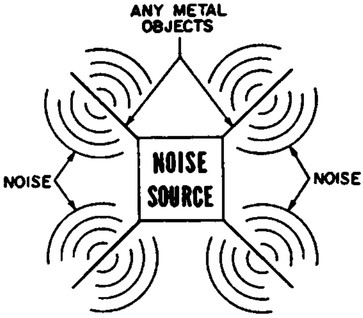
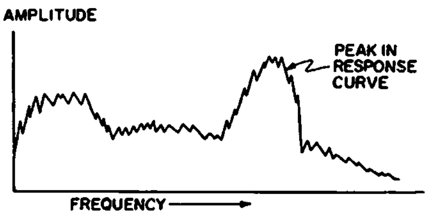


Fig. 1-3. Amplitude versus frequency spectrum of a typical arc noise.

It *is* possible for this type of noise to show a frequency-peak effect as a result of peculiarities in the device generating it. For instance, if a machine is creating random noise and pieces of wire or metal which resonate at 20 megacycles are attached to it, the resonance effects of these conductors will increase the amplitude of the noise—often far above the normal amplitude found in random distribution. This is sometimes a valuable clue—by hunting for objects which show these peculiarities, it is often possible to track down an obscure source of noise. Fig. 1-4 illustrates this effect. In Fig. 1-4A the metal objects attached to the noise source act as an antenna. Thus, they radiate much more noise at their natural resonant frequency than at other frequencies. The metal objects can be guy wires, mounting brackets, or anything else which can be excited by the electrical energy from the noise source. The frequency *versus* amplitude graph of the noise source in Fig. 1-4B shows how the noise spectrum is affected when the conditions in Fig. 1-4A exist.



(A) Radiating noise source.



(B) Frequency versus amplitude curve.

Fig. 1-4. Radiation from metal objects attached to a noise source.

SIGNAL-TO-NOISE RATIO AND THE BANDWIDTH OF A RECEIVER

The operating bandwidth of any receiver has a lot to do with its signal-to-noise ratio. For example, the telemetering radio receiver mentioned before, with its 10-cps bandwidth, will be much less affected by random noise than a commercial TV receiver with its 6-mc input. Fig. 1-5 shows why. The narrow-band re-

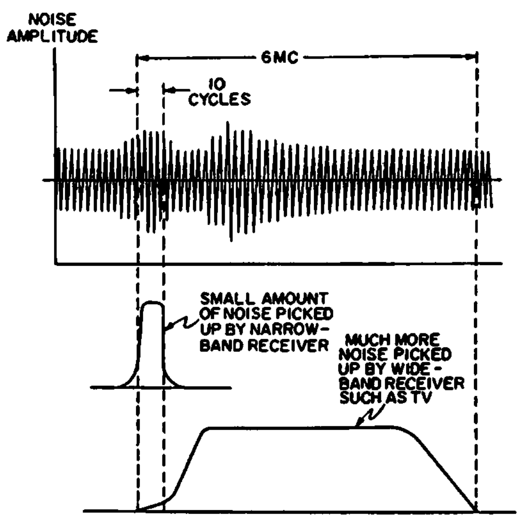


Fig. 1-5. Comparison of noise pickup by a receiver with 10-cycle bandwidth to that of a TV receiver.

ceiver accepts only a very small percentage of the total noise energy present, whereas the wide-band TV receiver receives a much greater portion.

At present, there is no known way to build a TV receiver with less bandwidth and still get a usable picture. So, if we can't redesign the receiver, we'll just have to reduce the amount of noise present while the signal is being received. This applies equally to radio, television, or any other kind of communication. The principal objective of this book is to aid the technician in reducing or eliminating man-made interference. This we will do by showing how it is generated, what its modes of transmission are, and some field-tested methods of dealing with it.

CHAPTER

2 Noise and Its Elimination

WE'VE TALKED a lot about noise. Now let's find out a little more about it . . . what it is, and how it is generated. In order to deal intelligently with noise, we must first understand all we can about its true nature and origin before we can take steps to reduce or eliminate it.

Noise, for purposes of this book, is a completely random collection of electrical impulses containing elements at all frequencies and at varying amplitudes. Where does noise come from? The answer is simple—*everywhere*! Every piece of electrical equipment of any kind is a potential source! In other words, there is no such thing as an electrical apparatus that does not generate signals which could cause interference. Under some circumstances, even radios and TV sets are capable of causing interference.

CAUSES OF MAN-MADE NOISE

The basic cause of all random noise is an electric arc. An arc is a rich source of radio-frequency "hash," which is a short word for a "completely random signal" (see Fig. 2-1). In any electrical apparatus, from the simple light switch to the most complicated device, conditions exist which are capable of causing an arc and thus creating noise. Now, let's work out its basic concept, so we can deal with noise in whatever form we find it.

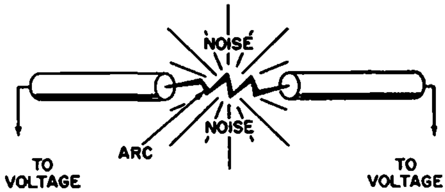


Fig. 2-1. Random noise created by an electric arc.

Why does an arc create noise? When an electric current jumps a gap, an arc is created as the current travels through the air instead of through a conductor. To set up an arc, sufficient voltage must be present to allow the air to "break down" and become ionized. The current then travels through the ionized path. The flow of electrons is highly irregular; they move at random, compared with their smooth travel through a conductor. Because of the constantly changing "resistance" of the ionized air, the instantaneous value of the current varies rapidly. These rapid variations set up a series of disturbances, not only in the arc itself, but also in the conductors carrying the supply current, and finally in the associated power supply. So, we get noise.

There is a definite relationship between the length of an arc and the voltage of the source: the longer the arc, the greater the voltage needed to sustain it, and the higher the noise level it is creating.

TRANSMISSION OF ELECTRICAL NOISE

Now that we've created the arc and made the noise, how does it get from the source to our receiver? Any electrical apparatus consists of two major parts—the device itself, and the power supply that runs it. This may be the AC line, internal batteries, solar cells, an atomic pile—anything at all. Let's look at conditions within these circuits.

Take the simplest of all—a DC motor, and a power line carrying pure DC. If we connect this power line to a radio, all we will hear is a small "pop" when we make the initial connection (a small arc!). What happens as the motor starts making noise? The noise flows around the circuit, back to the power supply and through it, and then back to the motor. Now we have a pure DC supply with a wildly varying AC voltage superimposed on it. Also, there are *two* voltages in the system—the noiseless DC supply, and the noise. This noise is *varying* in amplitude—which brings us to the most important point in this section. Because it *is* varying (if it weren't, it wouldn't be noise at all, but DC again!), we can see that noise is always, in effect, an *alternating current* (or voltage; for our purposes, it makes no difference at all).

Actually, the noise voltage in this example is not true AC, but a pulsating DC. However, this is the same as we'd find in the plate circuit of an amplifier tube; in radio work it is treated like DC with an AC component.

So, if we can recognize this voltage as AC, we can treat it like AC. But we must always remember, with any kind of noise, that we have two distinct potentials in the supply wiring—the supply voltage itself (DC in this instance), and the AC noise voltage superimposed on it. Here we have used an ideal situation, where the power supply is absolutely pure DC. However, even in 60-cycle AC-powered equipment, we can still treat the supply voltage as a pure signal—noiseless as it were, and one which will not interfere with reception—and concentrate on ways of separating the noise from it.

To repeat, if the noise *is* AC, we can treat it as such, and by using various electrical components, do things to it according to standard AC theory. AC will pass through a capacitor; so will noise. AC is slowed down, or impeded, by a coil; so is noise. High-frequency AC (radio-frequency signals) can be confined inside a metal box; so can noise. Therefore, if we can remember its fundamental AC nature, we'll find noise a lot easier to handle!

TRANSMISSION CHARACTERISTICS OF NOISE

Let's see how this disturbance gets from its source to our radios and TV's. Like all electrical signals, noise has two methods of travel—conduction and radiation. If the radio or TV and the noise-generating apparatus are connected to the same power source, there will be a good, solid metallic path between the two, as shown in Fig. 2-2. The noise signals will travel along the power-supply lines (always taking the easiest way) and enter the chassis through the power-supply wiring

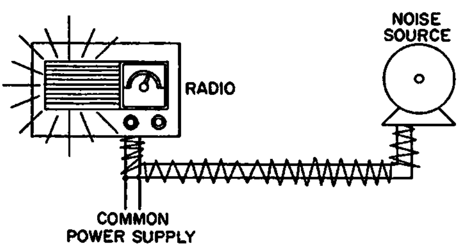


Fig. 2-2. Transmission of noise through the power lines.

of the set. There, it will be coupled into the sensitive input circuits and appear in the output as noise, along with the desired signal. So, instead of music we will get a lot of uproar.

If the radio and the noise source aren't connected to the same power supply (for example, a battery set), then the noise apparently must travel through the air. This it does, being "broadcast" from the power-supply wiring of the noise source, which acts as a transmitting antenna as shown in Fig. 2-3. Magnetic impulses, exactly like those of a broadcast signal, are created. This radiated noise field cuts the turns of the antenna and induces a signal in it, the same as the signals from the radio station do. So, once again we get a lot of uproar.

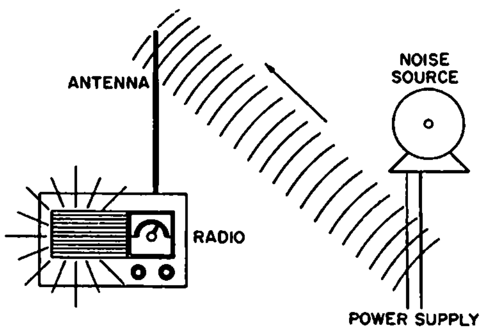


Fig. 2-3. "Broadcasting" of noise from the power lines.

Of course, just as there are no pure radiated signals, there is no noise conducted entirely by wiring. All noises are a combination of the two. The stronger the noise, the greater the intensity of the noise field radiated from the wiring. In a way this is fortunate: it is no problem to locate the wiring and trace the noise back to its source. Noise signals are attenuated in transmission according to the same formula as radio broadcast signals.

NOISE-REDUCING COMPONENTS—FILTERS

Now that we've identified noise, what are we going to do about it? What kind of components can we use to reduce its intensity, and how do they work? First, let's throw in another definition. Although there are many types of noise-reducing apparatus, most technicians lump them together and call them filters. This is quite an appropriate term, too—more so than many other electronic terms. A filter "strains out" the noise from the power-supply voltage or other circuit, and leaves only the pure DC or signal voltage.

How They Work

Although ranging from a simple capacitor to elaborate multisection, sharply-tuned traps, all noise filters have the same basic function—they must remove as much undesired noise as they can from the circuit, while leaving the original current or voltage relatively unaffected. Let's see how they do this.

Capacitive Filters—Bypassing

A capacitor, because of its ability to pass AC while blocking DC, is the simplest noise filter. Fig. 2-4 shows how it works. The DC supply voltage is unaffected by the capacitor; however, the noise, being AC, takes the path of least resistance through the capacitor, which bypasses the noise to ground, where it is absorbed or dissipated. The by-

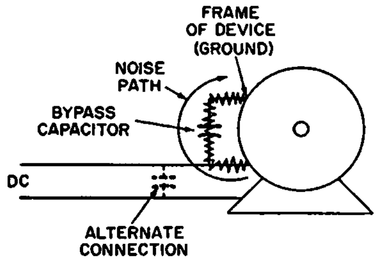


Fig. 2-4. Applying a bypass capacitor to the noise source.

pass capacitor should be connected as close to the noise source as possible. This way, we also shorten the "transmitting" antenna formed by the power line and thereby reduce the amount of noise radiated by it.

In Fig. 2-5 the noise source is the variable contacts between the carbon

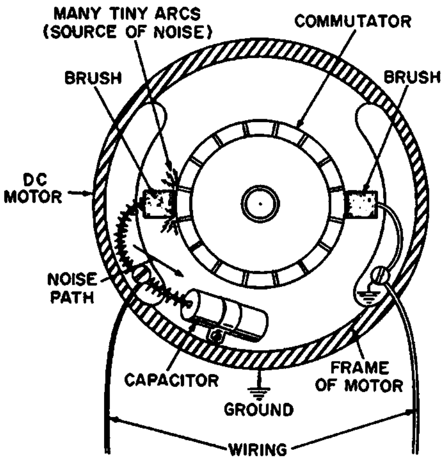


Fig. 2-5. Using a bypass capacitor to eliminate noise from a DC motor.

brush and commutator bars. The motor, turning at a high speed, causes the brush to make and break many thousand times each second. Each time, a small arc is formed. If the motor is heavily loaded, or if the brush holder is defective and allows the brush to bounce and make a poor contact, arcs will be longer and of higher intensity, and so more noise will be created. To reduce or eliminate this noise, we use as large a bypass capacitor as possible and connect it as close to the brush as we can. Since space inside motor housings is always limited, we're restricted as to the maximum size. However, the newer capacitors combine maximum electrical capacity with minimum size.

In Fig. 2-5 the frame of the motor is grounded to provide a return path for the noise. With the bypass capacitor connected directly to the brush, the noise finds an easy low-impedance route back to the chassis. In other words, it takes the path of least resistance! For simplicity, we have used a DC motor, which ordinarily has one brush grounded to the frame. Many variations are found in commercial equipment. For example, if this were an AC motor, both brushes would be "hot," so we would need two bypass capacitors, one for each brush; however, we could still ground the frame of the motor. (More about this in a later chapter.)

Chokes—Inductive Filtering

Let's assume the brush noise in the motor of Fig. 2-5 is so bad that a simple bypass won't stop it all. From Fig. 2-6 you can see that, although part of the noise is going through the bypass capacitor, there is still some left which is flowing happily off down the power wiring, looking for a radio or TV to get into. So, we use another kind of noise-reducing device called a choke, which is simply a coil of the proper inductance. The flow of the noise (AC) through the coil generates a back emf which opposes the noise. As a result the noise currents grow smaller and smaller, until they are all "choked out." Meanwhile, the DC supply current is allowed to flow unimpeded.

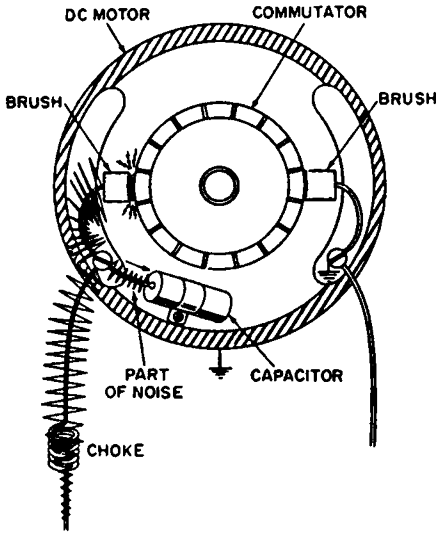
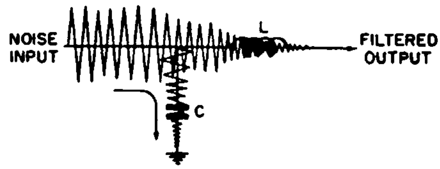
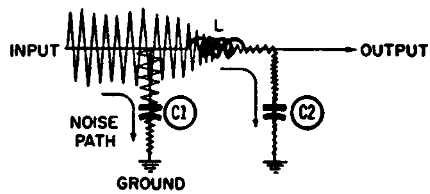


Fig. 2-6. Using a bypass capacitor and choke coil to eliminate noise from a DC motor.



(A) A simple LC filter.



(B) A pi-section filter.

Fig. 2-7. Two types of noise filters.

There are two points to consider in selecting a choke. First, it must be wound with large enough wire to carry the maximum power-supply current without any voltage drop. Second, it must have enough turns to remove the noise voltages. For purposes of illustration, the choke in Fig. 2-6 has been drawn quite a way from the brush terminal. In actual practice, it would be connected as close to the terminal as possible, in order to reduce the length of the "antenna" radiating the noise signals.

Combination Filtering Devices

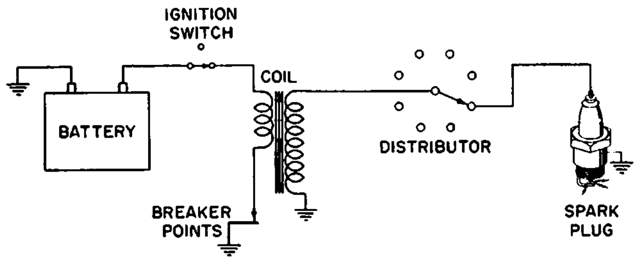
So far we have used a bypass capacitor alone and with a choke. Now let's see what happens when we put them together. By taking advantage of the characteristics of each component, we can build a combination filter that will be much more efficient than either of the parts used separately. Fig. 2-7A shows it schematically. This is about the simplest combination filter—a single section, sometimes called an "L" filter. By adding another capacitor at the output of this filter (Fig. 2-7B), we will have one of the most common filter circuits used. Because of its similarity, in schematic notation, to the Greek letter π, it is called a pi-section filter. If you're thinking that this circuit looks exactly like the filter circuit used in radio and TV receiver power supplies, you're exactly right. It has been used in such applications for many, many years.

The action of the pi-section filter is exactly like that of the simpler units discussed, only carried a bit further. The AC noise energy finds a pretty good path to ground through the first bypass capacitor, C1. The rest tries to get through coil L, but suffers quite a bit of loss in amplitude from its choking action. What little noise is left, after this struggle, simply gives up and flows off to ground through output bypass capacitor C2, leaving the line free of noise voltages and carrying only the original power-supply voltage.

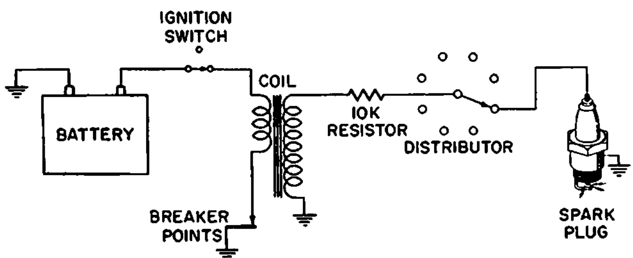
There are many combinations of this basic circuit—one with filter chokes in both legs of the circuit, double sections, plus many others. However, no matter how complicated a filter appears to be, its action is always just as simple as the ones described in the previous paragraphs.

SUPPRESSION

Suppression is a term with several meanings, but in noise work it takes on a specific one. When we say *suppression* from now on, we mean the insertion of a *resistance* (as opposed to *impedance*) in series with the circuit. Pure resistance has the same stop. However, there are many other circuits in which we can use pure resistance to good advantage. One is in the high-tension ignition system of an automobile. Here, the noise comes in "bunches," or as we'll call it from now on, a pulse noise. Each of the pulses represents a single burst of noise from the ignition coil and distributor; the purpose is to fire the spark plugs. If allowed to feed into the car's electrical wiring, this noise will reach the radio and cause a "popping" sound each time a plug fires. Fig. 2-8A shows the basic



(A) Basic schematic.



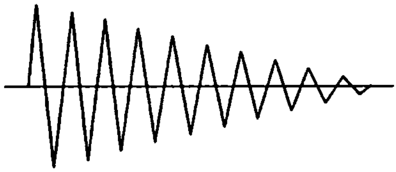
(B) Addition of suppressor resistor to reduce noise pulses.

Fig. 2-8. Automobile electrical system.

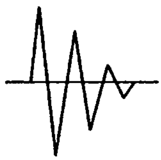
ohmic value, whether used in a DC circuit or in one carrying radio-frequency currents, whereas impedance varies according to the frequency of the applied AC voltage.

As a rule, resistive suppression is restricted to those circuits which carry very high voltages and very small currents. Obviously a large resistor, in series with the input wiring of the motor in Fig. 2-6, would cause the motor to slow down or even circuit of an automobile ignition system. The voltage in this system will resemble the pulse shown in Fig. 2-9A. That is, at first a high-amplitude pulse appears; this is succeeded by several alternations with slowly decreasing amplitude. Unfortunately, we can't get rid of the noise entirely; so we will have to settle for reducing its amplitude and duration—this is called damping.

We do this by inserting a 10K



(A) Undamped fluctuations in unsuppressed system.



(B) Fluctuations when suppressor resistor is used.

Fig. 2-9. Pulse voltages in automotive electrical systems.

resistor in series with the high-tension side of the circuit, as shown in Fig. 2-8B. With the resistor in the circuit, the pulse will look more like the one in Fig. 2-9B. The original high-voltage pulse is there, almost as high as before and still with plenty of voltage to fire the spark plug, but the resistor damps the circuit so that succeeding fluctuations die away much more rapidly. Because we have reduced not only the amplitude of the pulse, but most of its duration as well, we have cut down drastically on the total "noise power." A long burst of noise will have a greater effect than a series of short ones; there is much less actual power—"noise watts," we might say—in the short bursts.

SHIELDING

Well, we've done about everything we can to the poor little noise signals. We've poured them down the drain of bypass capacitors; we've strangled them in chokes; and now we offer them the final indignity: imprisonment! This is the last basic method of noise reduction, and is known as *shielding*. If the use of sufficient noise-reducing devices of the kinds we've been talking about isn't practical, or if they won't quite get rid of the noise, then we must resort to another method: keeping the noise fields from escaping from the vicinity of the device causing them.

Noise fields, as we have said, are electromagnetic waves. Like radio signals, they will set up an electric current whenever they cut a conductor. So, to eliminate them, we place in their path a solid box of highly conductive material, as shown in Fig. 2-10. The noise fields strike the surface of this box and immediately induce currents in the metal.

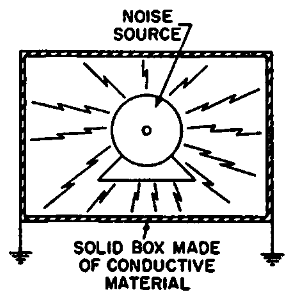


Fig. 2-10. Shielding a noise-producing device.

The currents don't go anywhere; they simply flow around in circles until their energy is dissipated. The energy which causes these currents to flow must come from the original noise fields, of course; therefore, it is quickly exhausted, and harmlessly eliminated.

The box is shown grounded in Fig. 2-10. In many instances grounding will not be necessary; the noise-energy level will be sufficiently reduced by the losses in creating the current. However, if the noise is exceptionally high, it may be necessary to ground the shielding box, in order to furnish an easy path for the current to return to earth-ground and be dissipated.

We used the term "solid" box just now in order to make the analogy a little clearer. Actually, shielding boxes are seldom really solid. They must be solid as far as radio-frequency energy is concerned; this means they can be made of screen wire, or that small holes can be punched in the solid sheet metal to provide ventilation for the device inside, and still offer a solid surface to the RF noise fields trying to escape. As long as there are plenty of paths for the current to flow, the shield will be solid enough for practical purposes.

In typical applications, the shield would be used with some kind of filter to reduce the noise. Shielding is used principally to reduce direct radiation of noise, whereas filters are connected into the power wiring to prevent the escape of any noise through that path.

CHAPTER

3

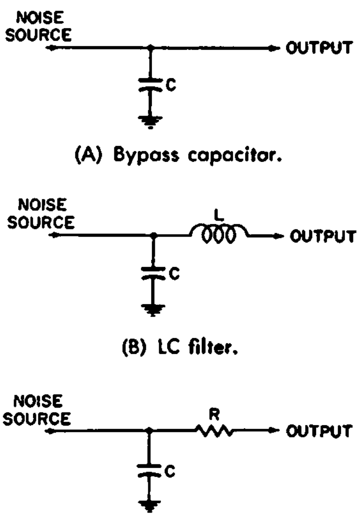
Noise Filter Design

IN THE preceding chapter, we discussed the three basic components used in noise-suppression work and the part each one plays in the final design of a filter. Each component—capacitor, inductor, or resistor—has its own specific application and characteristics, for which none of the others are suitable. If you know exactly what each part does, you'll be able to use it more effectively. Now, let's venture a little further into the principles of filter design, so you'll know what to do with the various parts.

You'll never have to make any of the parts you use in noise work (unless you want to wind a small coil or two for some specific job). Building a filter is a task very seldom encountered. There are now on the market many types of noise filters for every conceivable application; your job will simply be to select the right one. This is exactly like building a hi-fi or radio—we don't actually make the components; we buy them ready-made and select the right one for each job. It is the same principle here—you know just what each component does and how it reacts in various combinations, so you will be able to choose intelligently between them. Of course, there will always be that one job calling for a very special filter which is more easily built than bought; this is the exception that proves the rule, and we'll deal with it later on.

THE BASIC FILTER CIRCUITS

The simplest filter circuit is just a bypass capacitor from the noise source back to ground. No other name is needed; we just call it "bypassing" (Fig. 3-1A). The next type of filter is the inductor. You will seldom see inductors alone used in filtering, for an obvious reason: capacitors are usually cheaper. If the bypass capacitor doesn't get rid of all the noise, then the inductor is added to complete the job. Resistors are used in special cases.



(A) Bypass capacitor.

(B) LC filter.

(C) RC filter.

Fig. 3-1. Simple filter circuits.

The simplest filter configuration is the single capacitor and inductor in Fig. 3-1B, called an "L" section because of its shape. In radio and TV circuits, it is used to prevent interaction between stages. Nevertheless, the purpose is still the same—it's a filter. In TV circuitry, LC filters are found mostly in video and in VHF stages, such as the video IF, etc. These tiny chokes, which are only a few turns of wire, are cheaper than resistors. In power-supply circuits, however, small resistors are more common. For example, the familiar "1K resistor, .01 capacitor" so often used in screen-grid circuits, etc., is actually the RC circuit shown in Fig. 3-1C.

In both the LC and the RC filters there is one pertinent characteristic we should discuss—the time constant. Notice the resemblance of all LC filters to a resonant circuit, and indeed, that is what they are. Each one will resonate at a frequency determined by the inductance and capacitance, according to the familiar formula:

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

where,

f_R is the frequency in cycles per second,

L is the inductance in henrys,

C is the capacitance in farads.

Later, we'll make good use of this formula in specific applications.

The RC filters, of course, do not really "resonate" at a given frequency, as the LC combinations do—but they do have a very important property known as the *time constant.* Briefly, this means the combination of resistance and capacity will have maximum effect at a given frequency.

The time constant of an RC circuit is the time in seconds the capacitor takes to charge to 63% of its peak voltage through resistor R. The formula for this is:

$$T = RC$$

where,

T is the time in seconds,

R is the resistance in ohms,

C is the capacitance in farads.

Since these values are rather unwieldy to work with, we can use R in megohms and C in microfarads and still obtain the same answer.

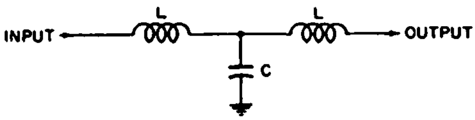
An RC combination can be used as a sort of "semiresonant" filter in a circuit carrying AC, by making the product of R × C equal to the time taken by one cycle. This increases the efficiency of the filtering action. Filter circuits using this principle are much more efficient than those which simply use very large capacitors or inductors to "swamp out" the noise. The latter are called, with justification, "brute-force" filters.

FILTER EFFICIENCY

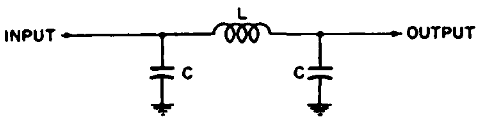
The efficiency of any filter is rated by the amount of undesired noise, signal, etc., it takes out of the circuit. This is called the *attenuation* (loss) of the filter; the filter *attenuates* or *makes less* the unwanted parts of the composite signal. Hence, filters are rated in terms of attenuation. In the more elaborate applications, they are rated in decibels (db), which is the ratio of the original noise in the input to the noise remaining in the output. For instance, a filter with an attenuation of 3 db would remove exactly half the noise voltage in the circuit, and so on.

FILTER CONFIGURATIONS

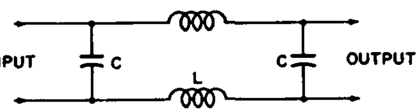
The circuit configuration gives us the name of different filter types. We've already seen "L" sections; if we add another inductor in series with the first and connect the capacitor to the junction of the two, we get a "T" section (Fig. 3-2A). By adding another capacitor to the cir-



(A) T-section filter.



(B) Pi-section filter.



(C) Ladder-section filter.

Fig. 3-2. Filter configurations.

cuit of Fig. 3-1B, we get the pi section shown in Fig. 3-2B. In some applications, inductors must be used in both legs of the circuit, as seen in Fig. 3-2C. This is usually called a "ladder" type, or a double pi. (A true double pi consists of two pi sections in series.)

Filter sections can be connected in series if greater attenuation is needed. Fig. 3-3 shows two ladder sections in series. However, a multiple-section filter can be a series of pi, "T," or "L" sections, or whatever type is best for the purpose. The attenuation of filter sections is usually added arithmetically (in db) to get the total attenuation. Because this is all done with AC, we have to contend with phase angles, etc., in computing the actual attenuation. Since the mathematics needed is extremely complicated and quite unnecessary in a book of this kind, it will not be discussed any further.

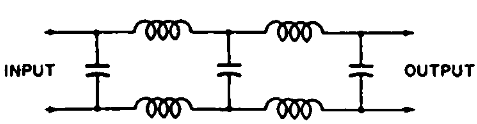


Fig. 3-3. A multiple-section ladder filter.

BASIC FILTER TYPES

Low-Pass Filter

In everyday filtering work, we are interested mainly in removing noise, fluctuations, etc., which may be present. For example, in a power-supply filter system we must remove the ripple from the supply current before we can come out with pure DC. To remove ripple, we use a simple pi-section filter (Fig. 3-4). This filter requires very little "designing": we just keep piling on capacitance until the output has no ripple left! Commercial values of such filter capacitors often run over 100 mfd.

However, in certain applications the filters must have very special characteristics, such as the ability to pass certain frequencies and attenuate others. There are three types of filters, known by very descriptive names. The first one, which has been shown in all illustrations up to this point, is called a low-pass filter. Translated, this means the filter will

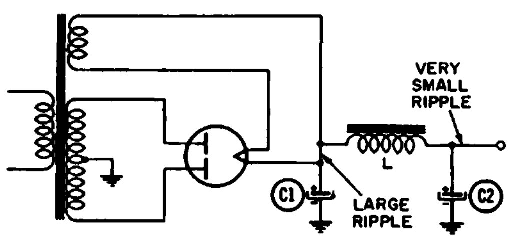


Fig. 3-4. A typical power-supply filter as used in radio and TV sets.

pass low frequencies without loss, but offer a high attenuation to high frequencies.

Fig. 3-4 shows a low-pass filter which passes DC with very little loss, but has a high attenuation for the 120-cycle ripple frequency. There is an easy way to remember the difference between the two types: just keep in mind the basic characteristics of the components and how each one behaves when the applied frequency increases (or decreases).

For example, one of the first things we learned when we began studying electronics was that an inductance offered a reactance (AC resistance) which was directly proportional to the size of the inductor and the frequency of the applied current. Also, we learned the formula for inductive reactance is:

$$X_L = 2\pi fL$$

where,

X_L is the inductive reactance in ohms,

f is the frequency in cps,

L is the inductance in henrys.

Translating from Greek into English, we find that the higher the frequency applied to an inductor, the higher the reactance. As its frequency increases, the current finds an ever-increasing opposition to its flow through the coil. A capacitor acts exactly the opposite: at DC, it is a completely open circuit (infinite reactance) and no current flows at all. As the frequency increases, the current finds less and less resistance (lower reactance) to its flow. So, the reactance of a capacitor is inversely proportional to the applied frequency, or:

$$X_C = \frac{1}{2\pi fC}$$

where,

X_C is the capacitive reactance in ohms,

f is the frequency in cps,

C is the capacity in farads.

By looking at the circuit used in any filter, we can now tell what its basic type is. The components connected in series with the circuit determine its characteristics. In Fig. 3-4, we have inductance in series—low opposition to DC (zero frequency) and high opposition to AC. Across the circuit, or in shunt, we have capacitance—low reactance to AC and high reactance to DC. Now what happens? Look at Fig. 3-5; here we have placed an obstacle (inductor L) in the path of the high-frequency

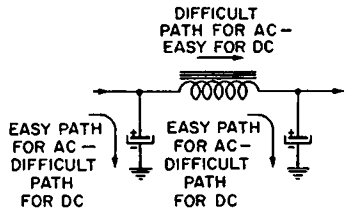
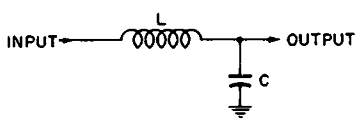
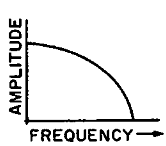


Fig. 3-5. Current paths for pi-section filter in Fig. 3-4.

currents. At the same time, we have provided an easy path for them to go through the capacitor to ground. Hence, we have a low-pass filter. The pi section shown is used often in power-supply filtering because it is more efficient. However, you'll find the L-section filters used in other circuits, and the action will be exactly the same. (See Fig. 3-6A.) The passband, or *transmission charac-*



(A) Configuration.



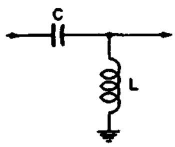
(B) Transmission characteristic.

Fig. 3-6. An L-section, low-pass filter.

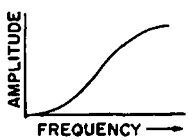
teristics, of a low-pass filter are shown in Fig. 3-6B. Remember: inductance in *series* equals a low-pass filter.

High-Pass Filter

The opposite of a low-pass filter is, of course, a high-pass filter—one which passes high frequencies with little loss, but opposes the flow of lower frequencies. To make a filter with this kind of characteristic, we simply reverse the positions of the basic components, as shown in Fig. 3-7A. Now the *capacitor* is in series with the circuit and provides an easy (low-reactance) path for high frequencies only, whereas the inductor is in shunt across the circuit and gives the low frequencies an easy path back to ground. Incidentally, the order of the components in the circuit in Figs. 3-6A and 3-7A can be reversed without changing their functions. In Fig. 3-7A, the inductor can be placed on either side of the capacitor, depending on the requirements of the circuit in which the filter network is connected. Fig. 3-7B shows the transmission characteristics of a high-pass filter.



(A) Configuration.

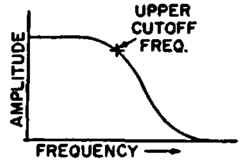


(B) Transmission characteristic.

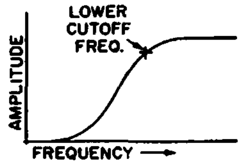
Fig. 3-7. An L-section, high-pass filter.

Bandpass Filter

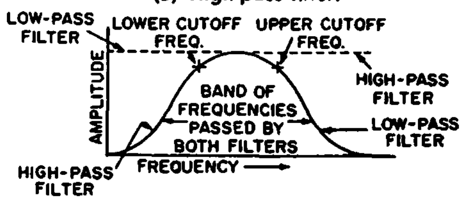
Now and then we'll find an application where a certain band of frequencies must be passed between given limits. Here, a special filter configuration called a *bandpass* is used. Each of the filter types discussed thus far has a certain cutoff frequency—a point beyond which it will not pass any perceptible current. This is illustrated in Figs. 3-8A and B. To make a filter configuration that will pass a given band of frequencies, we use a combination of high- and low-pass filters. If we make up a combination of the two filters, we will have both an upper cutoff frequency from the low-pass filter and a lower cutoff frequency from the high-pass filter, as shown in Fig. 3-8C. By selecting the component sizes used in each filter, we can make the filter pass any given band of frequencies we want. A typical bandpass filter circuit is shown in Fig. 3-9. Later on, we'll go into more detail as to specific ap-



(A) Low-pass filter.



(B) High-pass filter.



(C) Combining low-pass and high-pass filters.

Fig. 3-8. Combining the transmission curves of a low-pass and a high-pass filter to obtain a bandpass filter characteristic.

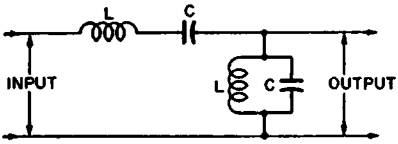


Fig. 3-9. A bandpass filter section.

plications of this principle, and also show how high-pass, low-pass, and bandpass filters fit into the requirements for noise-elimination work.

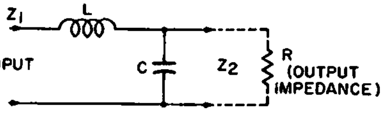
FILTER DESIGN FORMULAS

As we said before, the detailed mathematics needed for a complete treatment of filter design is far beyond the scope of this book. However, for those who are interested, here is a very brief discussion of the mathematical constants for the various types of filters.

Constant-*k* Type

In high-frequency work, the filter section must, in addition to removing the undesired noise, etc., also match the impedance of the circuit in which it is inserted. Actually the impedance of a constant-*k* filter will match the impedance of the circuit it is working into at only one frequency. The term constant-*k* is sometimes misconstrued to mean the impedance is constant. However, this is not true. The term constant-*k* merely means that a constant, termed *k*, was used in the development of the design equations.

The configuration for a constant-*k*, low-pass, L-section filter is given in Fig. 3-10A. The formulas for computing the component values are given in Fig. 3-10B, and the transmission characteristic of the filter appears in Fig. 3-10C. The quantity *R* in Fig. 3-10A and B represents the load impedance of whatever circuit the filter is working into: for example, in the grid circuit of a vacuum tube, R would be the grid-to-cathode impedance of the tube, plus whatever stray impedances are present.

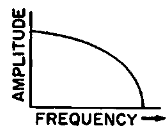


(A) Configuration.

$$L = \frac{R}{2\pi f_c}$$

$$C = \frac{1}{2\pi f_c R}$$

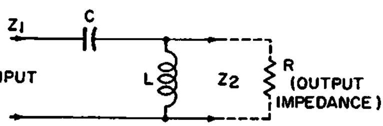
(B) Formulas.



(C) Transmission characteristic.

Fig. 3-10. A constant-*k*, low-pass, L-section filter.

The configuration, formulas, and transmission characteristics for a constant-*k*, high-pass, L-section filter are given in Fig. 3-11.

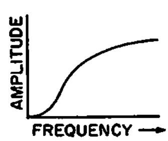


(A) Configuration.

$$L = \frac{R}{2\pi f_c}$$

$$C = \frac{1}{2\pi f_c}$$

(B) Formulas.



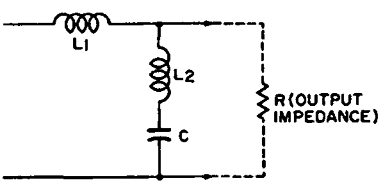
(C) Transmission characteristic.

Fig. 3-11. A constant-*k*, high-pass, L-section filter.

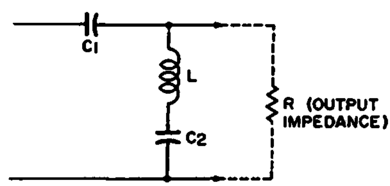
The *m*-Derived Type

If we connect a filter section into a very critical circuit without considering the possibility of impedance mismatches, we may get reflections, phase shift, etc., which will adversely affect the performance of not only the filter, but the whole circuit as well. Therefore, a type of filter known as an *m*-derived section is used to give a better match. By proper selection of values, an *m*-derived filter can be made to match the impedance of the circuit over approximately 85 per cent of the transmission band.

An *m*-derived filter is made by first obtaining the values which would be used and then modifying these values by an algebraic expression containing the number *m*. One part of an *m*-derived filter is connected to a resonant circuit, as shown in Fig. 3-12. (Fig. 3-12 shows the shunt sections connected to resonant circuits; either the series or the shunt section may be connected.) At resonance, the filter presents a theoretically infinite attenuation. Hence, this frequency is called the frequency of infinite attenuation and is designated f_∞.



(A) Low-pass configuration.



(C) High-pass configuration.

$$L_1 = m\left(\frac{R}{2\pi f_c}\right)$$

$$L_2 = \frac{R(1-m^2)}{2m\pi f_c}$$

$$C = \frac{m}{\pi f_c R}$$

(B) Formulas for low-pass filter.

$$C_1 = \frac{1}{2m\pi f_c R}$$

$$C_2 = \frac{m}{(1-m^2)(2\pi f_c R)}$$

$$L = \frac{R}{2m\pi f_c}$$

(D) Formulas for high-pass filter.

Fig. 3-12. m-derived, L-section filters.

The constant *m* is a number between 0 and 1. It can be computed from the formulas:

$$m = \sqrt{1-\left(\frac{f_\infty}{f_c}\right)^2}$$

or,

$$m = \sqrt{1-\left(\frac{f_c}{f_\infty}\right)^2}$$

where,

f_∞ is the frequency of infinite attenuation,

f_c is the cutoff frequency.

The most common value of *m* for commercial filter circuits is 0.6, because this value gives a more uniform impedance over the band. In designing complex multiple-section filters for special applications, at least one section is chosen so that *m* will be approximately 0.3; this gives the cutoff frequency of the filter a much steeper slope. By changing this constant for that one section, we can give the filter any slope desired at the cutoff frequency.

TUNED FILTERS

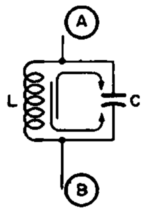
There is a special class of filters which depend for their action on the principle of electrical resonance.

They can be used to allow a desired band of frequencies to pass while attenuating all others both above and below (this is another type of bandpass filter), or to pass or block selected frequencies in a given circuit.

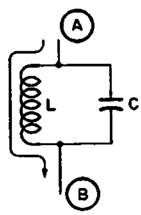
A brief review of the action of the two basic types of tuned circuits might be advisable at this point. As we said before, inductance allows low frequencies to pass, whereas capacitance passes the high frequencies. Therefore, if we combine the two in a circuit, we'll also have a combination of the two properties.

Parallel-Resonant Circuits

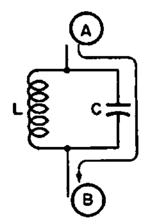
Fig. 3-13 shows L and C connected in parallel. Each one has reactance, according to the familiar formulas given before. These reactances cause phase shifts in the current—inductive reactance causing the voltage to lead the current, and capacitive reactance causing it to lag. Remember that frequency is a factor in computing all reactance. When an inductor and a capacitor are connected in parallel and their two reactances are equal ($X_L = X_C$), we say the circuit is "parallel resonant."



(A) At resonance.



(B) Below resonant frequency.



(C) Above resonant frequency.

Fig. 3-13. A parallel-resonant circuit.

To freshen your memory, at resonance the current through the capacitive leg of the circuit in Fig. 3-13A will lead the applied voltage by 90°, while the current through the inductive portion will lag by 90°. Thus we have two currents 180° out of phase flowing in the LC circuit, and even though we have high circulatory currents within the LC circuit, they will theoretically cancel and no current will flow from *A* to *B* in Fig. 3-13A. Notice that we said "theoretically"; actually, for zero current to flow, it would be necessary to design a coil with zero resistance. Since this is not possible, a small current will flow from *A* to *B*, despite the very *high* impedance of the circuit.

But, if we change the frequency, something else will happen: if we lower it below resonance, more signal will go through the LC circuit (most of it flows through the coil, as shown in Fig. 3-13B, because its impedance decreases while that of the capacitor increases). More current flows than did at resonance, so the total impedance goes down.

If we raise the frequency, the signal sees a greater impedance in inductance L, but finds an easier path through capacitor C, so there's where it goes (Fig. 3-13C). The total current once more is higher than at resonance and the impedance is lower. Thus, for the combination we have the condition in Fig. 3-14: maximum impedance (minimum

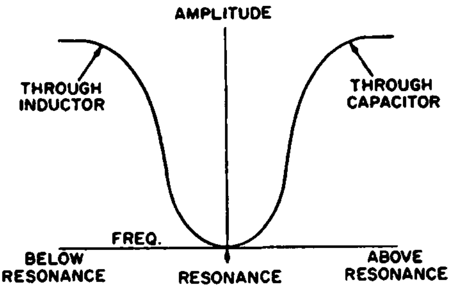


Fig. 3-14. Transmission characteristics of a parallel-resonant circuit.

current flow) at resonance and an increase in current on either side of resonance, with most of the current taking the path of least resistance as shown.

Series-Resonant Circuits

If we connect the capacitor and inductor in *series,* as shown in Fig. 3-15, we will have a circuit that will resonate at *exactly* the same fre-

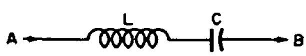


Fig. 3-15. A series-resonant circuit.

there is no alternate path! Currents below resonance flow through the inductor, run into the capacitor, and are stopped; those above resonance flow through the capacitor, run into the inductance, and are stopped. Neither finds an easy path, because the impedance on either side of resonance is high; therefore, the current through the circuit is low. At the resonant frequency the capacitive reactance and the inductive reactance cancel, leaving only the resistance in the circuit to impede the current flow. Consequently, a larger current flows at resonance and a smaller current flows on either side of resonance, as shown in Fig. 3-16.

There you have the two effects: the impedance of each circuit, of course, is exactly opposite from the transmission curves shown in Figs. 3-14 and 3-16. Now we have a parallel-resonant circuit which offers a very *high* impedance to the current at a certain frequency, and a series-resonant circuit which offers a very low impedance. By making use of these two qualities, we can do just

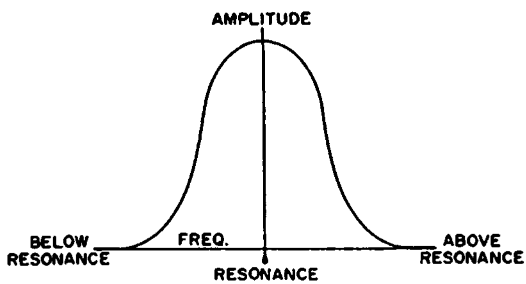
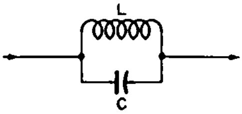


Fig. 3-16. Transmission characteristics of a series-resonant circuit.

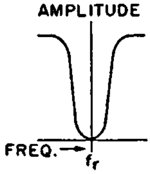
quency, but will have the exact opposite effect on the external circuit A-B. In the parallel-resonant circuit, off-resonance currents had a choice of either of two paths—the inductor, or the capacitor. In the series-resonant circuit, however, they have no such choice; all currents must flow through both components because

about anything we want in specialized filter applications.

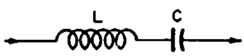
If we must remove a certain band of frequencies but allow others above and below to pass, we connect a parallel-resonant circuit in series with our circuit as in Fig. 3-17A. If we want to allow a certain band of frequencies to pass and to stop those



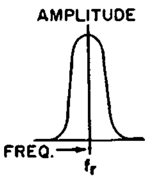
(A) Parallel-resonant circuit.



(B) Transmission characteristic of A.



(C) Series-resonant circuit.



(D) Transmission characteristic of C.

Fig. 3-17. Effect of connecting a parallel- or series-resonant circuit in series with a circuit.

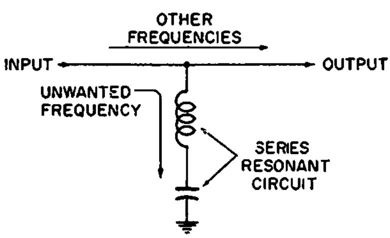
above and below, we connect a series-resonant circuit in series with our circuit as in Fig. 3-17C.

There are many other uses for these circuits. If we want to bypass only a certain frequency, we can connect a series-resonant circuit as shown in Fig. 3-18A. By connecting this frequency-selective circuit from our main circuit to ground, we allow only the current at its resonant frequency to pass off to ground. This is known as trapping out the frequency. If the undesired frequency is at a high level, a single trap may not be enough. So we connect a parallel-resonant trap in series with the main circuit as shown in Fig. 3-18B. This will create a high impedance in the path of the undesired current, while leaving it an opportunity to flow off to ground through the low impedance of the series-resonant trap. The combination of the two effects will reduce the level of an interfering frequency tremendously.

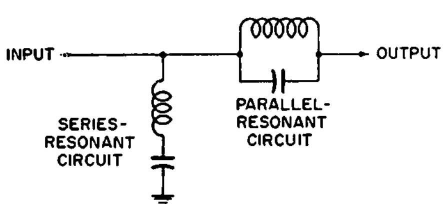
Bandpass Filters

We can also use our series- and parallel-resonant circuits to pass one frequency and reject all others. This is called a bandpass filter. The IF transformer in an ordinary home radio (Fig. 3-19A) is a common example of this application.

The action is as follows: The primary circuit (L1), being parallel-resonant, offers a high impedance to currents at that frequency and a low impedance to currents of all other frequencies (Fig. 3-19B). So, a very large circulating current is built up at the desired frequency in coil L1. This current is inductively coupled to secondary L2; maximum voltage

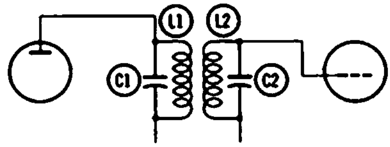


(A) Using series-resonant circuit.

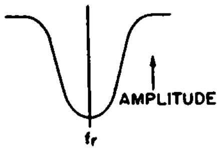


(B) Using both series- and parallel-resonant circuits.

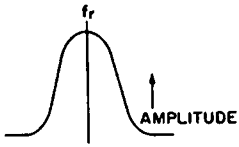
Fig. 3-18. Methods of trapping out certain frequencies.



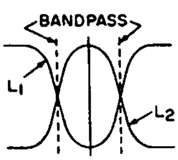
(A) Circuit.



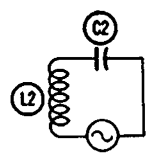
(B) Current through L1.



(C) Current through L2.



(D) Bandpass of circuit (curves B and C combined).



(E) Equivalent circuit for L2.

Fig. 3-19. Operation of an IF transformer.

(current) at the desired frequency is thus induced in L2 (Fig. 3-19C). L2 is actually series-resonant (although it isn't easy to see this from the circuit connections), because the source of the voltage in the coil is the coil itself. If you'll mentally take the "generator" out of the coil and draw the circuit to look like Fig. 3-19E, this will become clearer. Now we have a high current at the resonant frequency circulating in L2. This builds up maximum voltage at the desired frequency for application to the grid of the next stage, and that's what we want. In addition, any left-over off-resonance currents are further reduced in amplitude by the series-resonant characteristics of the secondary—which offers a high impedance to off-resonance current. So the transformer acts as a bandpass filter; it passes only the resonant frequency, plus a band of frequencies on either side determined by the *Q* of the transformer and by the circuit loading.

The resonant filter circuits in radio and other electronic circuits use capacitors and inductors of various sizes, sometimes quite large. The size depends on the amount of filtering needed and on the frequency. In television applications, short sections of transmission line are used for the same purpose. Now you can see that, no matter what kind of current you want to filter out of a given circuit or what frequencies you want to remove, it is easy to find some sort of filter that will do the job. Always begin with the simplest one—a bypass capacitor to ground. You'll be surprised at how often it is all you'll need! If a bypass capacitor doesn't work, then go on to more elaborate filters. By the proper selection, you can: (1) cut off all frequencies above or below the one wanted; (2) allow only a single frequency to pass a given point in the circuit; (3) trap out one or more interfering frequencies from a band of desired frequencies; (4) knock out random noise with a "brute-force" filter that takes out all frequencies. You name it, there's a filter that will do it. Succeeding chapters will go into details about the type of filters needed for most applications, plus specific recommendations for their use.

BUILDING YOUR OWN FILTERS

You'll undoubtedly find that many times it will be cheaper or easier to build a special filter rather than buy one. Of course, ready-made filters cost less, but they may not always do the job.

For example, in close quarters, home-made filters may have to be built to fit into a very small space. One instance might be a small adding machine with only a small space underneath.

For this kind of work, the standard LC filter circuit in Fig. 3-20 will give better results than simple bypassing. This filter is used in series with the AC line. It can be made up in a short time to fit into almost any space.

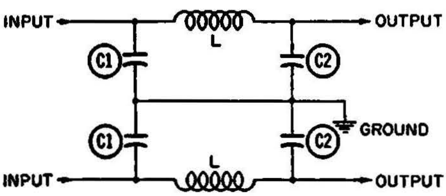


Fig. 3-20. Standard LC circuit used in series with the AC line.

The coils can be wound onto any kind of form, or made air core with no form at all. Fig. 3-21 shows an assortment of materials needed to build your own filters, and some completed coils. Ceramic capacitors permit comparatively large amounts of capacitance to be squeezed into a very small space. If there is room, paper capacitors can be used.

The coils are wound of enameled wire, which must be large enough to carry the maximum current drawn by the machine without heating up. Check the current rating plate on the machine; it will always give you the wattage, if nothing else, and the current can be calculated from it. For example, if the machine is rated at 100 watts, 110 volts, the current will be about 0.9 ampere; figure about 2 amps for a good-sized safety factor. Standard wire tables will give the safe current-carrying capacity of each wire size. In the example given, either No. 18 or 20 wire will carry the current safely. A large enough

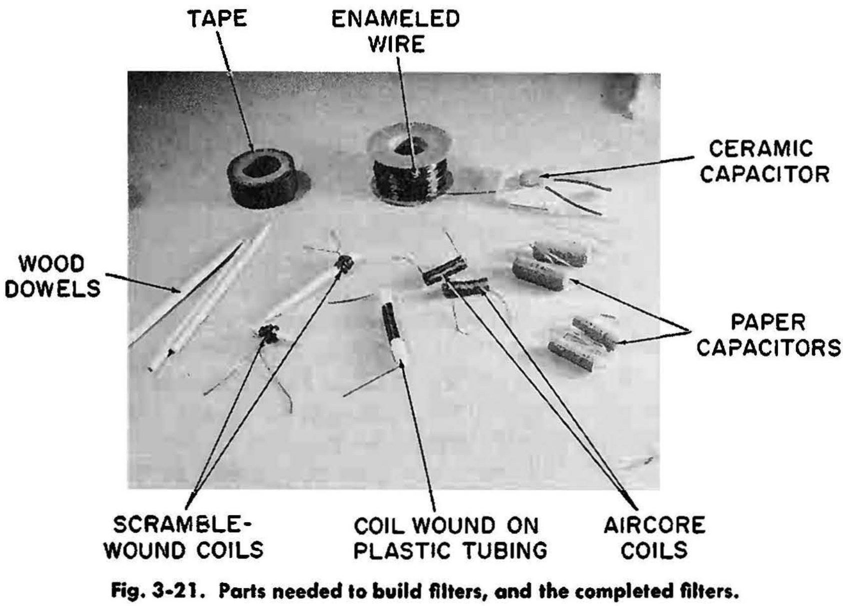


Fig. 3-21. Parts needed to build filters, and the completed filters.

wire is necessary to prevent the coils from heating under a load and causing trouble.

The inductance of the coils isn't too critical. Any practical size can be used. A common coil is about 15 to 20 turns on a ¼-inch form, or more if there is room for a double layer. The wire can be wound on almost any form—pencils, small wooden dowels, plastic forms made of short pieces of heavy spaghetti, or any other insulating material. (See Fig. 3-21.) In general, it's better to use insulating material; never use a discarded iron tuning core or the like. Although it would be more efficient, you might wind up with too much inductance and get overheating in a heavily-loaded AC circuit. The air-core coils will have ample choking action for radio-frequency work, and RF is what we're trying to remove from the circuit.

The coils can be insulated with plastic tape, or they can be painted or sprayed with one of the acrylic insulating compounds. Be sure they are well insulated, and always use braid spaghetti on the leads.

The coils and capacitors can be connected as shown in Fig. 3-20, and folded into a small space. Input, output, and ground leads should be tightly soldered and taped before the final covering of tape or insulation is applied. If the filter is intended to be cut into the line inside the machine, use standard braid-insulated wire for the leads. Never use solid-plastic insulated wire; most of it won't stand the heat, and there is a chance of shorting. It is a good practice to color-code the leads; for instance you could use red for the output, green for the input, and black for ground. Make them long enough, too!

If there isn't room inside the machine, this filter can be mounted in a small metal box and fastened to the outside, as in Fig. 3-22. If desired, a chassis-type receptacle can be mounted on one end and a male plug on the other to convert it into a plug-in type. However, for maximum efficiency it's better to mount the box in a convenient location, such as a wall, and run the line cord in one end and out the other as shown. Use clamps to keep strain off the cord.

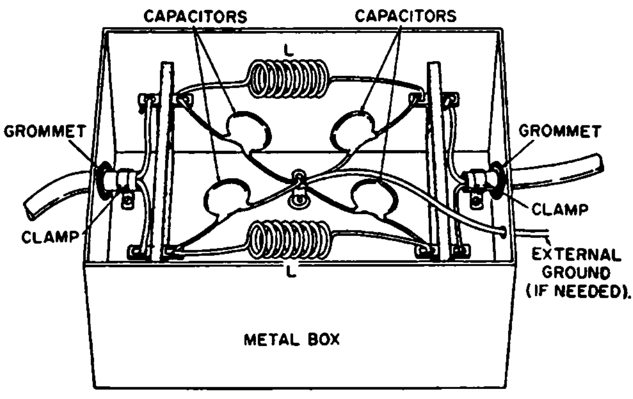


Fig. 3-22. Construction of a homemade filter.

COMMERCIAL FILTERS

Commercial filters are made in a wide variety of sizes, shapes, and configurations, and one can be found

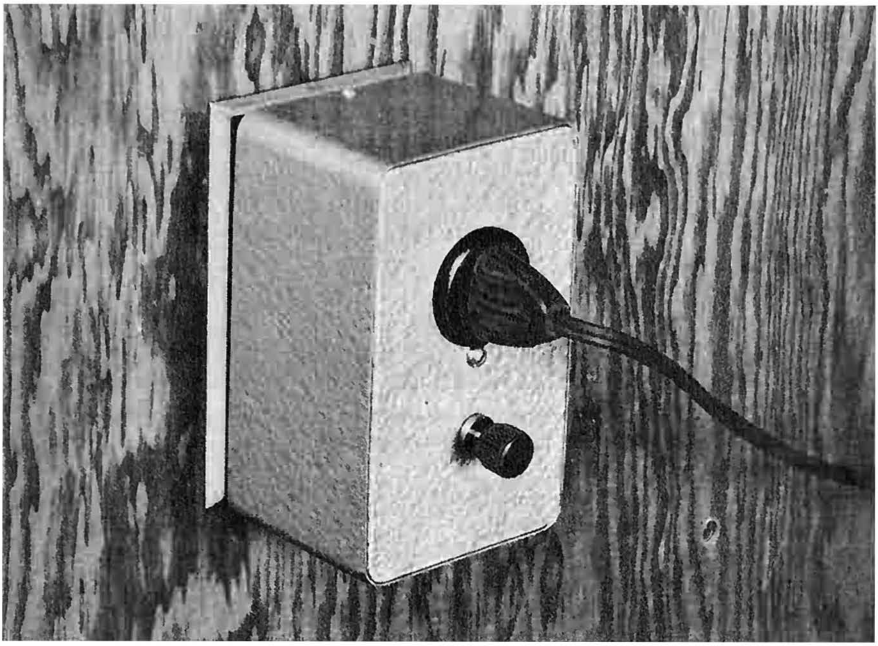


Fig. 3-23. A commercial "plug-in" filter.

for any filter application. Fig. 3-23 shows a plug-in line filter which is used at the wall outlet. The screw which holds it in place goes into the center terminal of the receptacle. If the wiring is old and the center terminal of the receptacle is not grounded, the binding post just below the plug can be used to provide an external ground. Rated at five amperes, this filter will handle most small- to medium-sized home appliances.

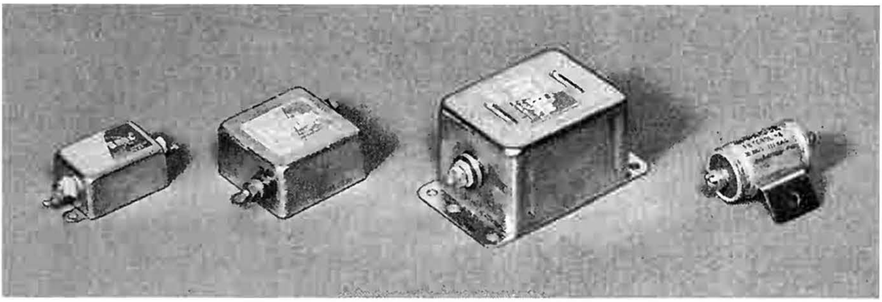


Fig. 3-24. Commercial pi-network filters.

The filters shown in Fig. 3-24 are single-pi networks of the standard LC configuration. From left to right, they are rated at 1, 10, and 35 amperes. The small one at the right is a special passthrough capacitor. These filters may be built into the machines, or added later if noise is encountered.

Fig. 3-25 shows a group of filters which are similar in circuitry but vary in size and shape. They can be built-in when the equipment is de-

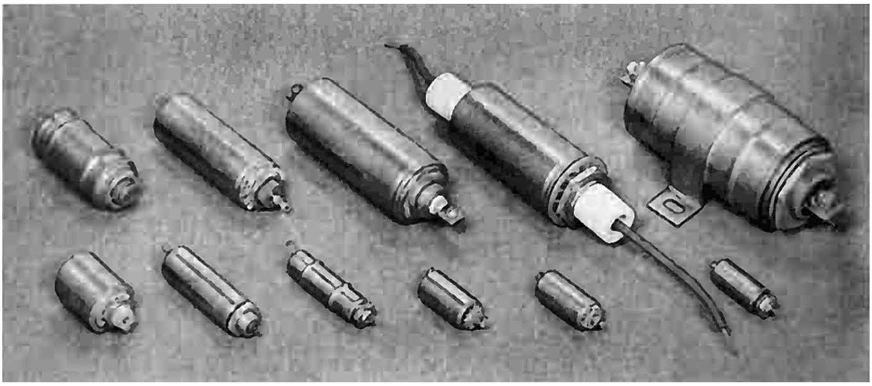


Fig. 3-25. A group of commercial filters which can be added when equipment is designed, or later.

signed. Many of them are particularly suited to marine or aircraft noise-suppression work because of their tightly-sealed construction.

Fig. 3-26 shows a group of three-terminal filters which are mainly capacitive single and dual sections, mostly with delta connections. They are intended for application to small motors, fluorescent lights, and other similar uses. They are also adaptable to automotive or marine use.

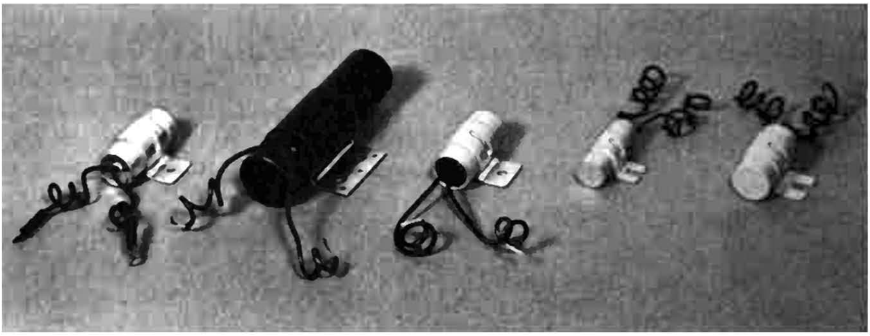


Fig. 3-26. Three-terminal filters for addition to existing equipment.

CHAPTER

4

Locating Interference

THE HARDEST part of all interference work is finding the source. The time spent doing so will depend on how quickly we can make observations and measurements of the noise, and how logical are the conclusions we draw from them. It's simply a matter of detective work!

NOISE DETECTORS

To find a noise, we must have some kind of a detector. The best one, of course, is the radio or TV being interfered with! Most of the time, though, these are too unhandy. We need a detector that can be carried from place to place easily. Most noises, and all random noises, will be audible on a radio, even though the primary complaint was TV interference. (There are special cases of TVI that are *not* detectable on radios. We will take those up in the more detailed studies in a later chapter.) Remember the noise spectrum of Fig. 1-3? If the source *is* a random noise, *some* energy will always be present in the broadcast band, especially when we are close to the source.

A portable radio makes an excellent noise locator, and a transistorized portable is ideal: almost all have earphone jacks and some have con-

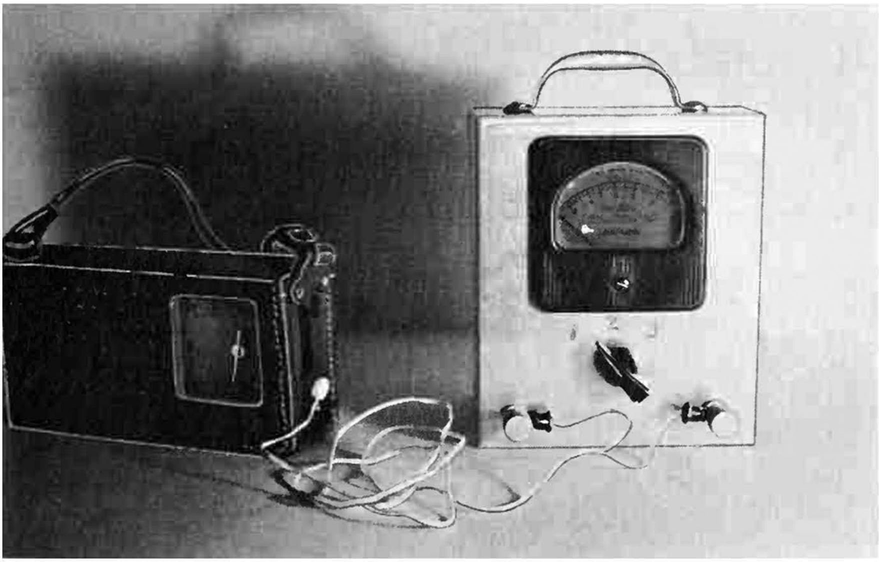


Fig. 4-1. A portable radio and meter for locating noise sources.

nections for an external antenna. These can be used for auxiliary equipment, to make the job easier.

Most of the time, the speaker alone will give an indication of the amplitude of the noise. However, if we run into a difficult case where comparative readings of noise amplitude are needed, we can make up an output meter and plug it into the earphone jack, as shown in Fig. 4-1. Many portables have dual jacks; one cuts the speaker off and the other leaves it connected in parallel with the phones. The latter is better because it is best to listen to the noise at the same time we take the meter readings. This way, we can be sure we are still tuned to the noise itself and not to a "rock-and-roll" program!

The extension-antenna jack can be used to good advantage under some circumstances. By making a probe as shown in Fig. 4-2, we can check out apparatus that would be difficult to test otherwise. Make up a length of coaxial cable, with a plug that will fit the external antenna jack and a "pigtail" on the shield that will plug into one of the earphone jacks to ground the shield. At the other end, cut the shielding back three or four inches. Leave the insulation on, and tape the end of the wire to eliminate any shock hazard. Tape the wire to a piece of light rod long enough to reach the place to be checked (which could be a fluorescent light fixture on a high ceiling). Aluminum tubing or a glass fishing rod is ideal for this purpose. The coaxial cable is handy for pinpointing odd noise sources. For average work, a piece of flexible wire can be used without the shielding.

The output meter itself can be the output section of a VOM, or you can make up a special output meter by mounting an ACVM or db meter in a small metal utility box as was shown in Fig. 4-1. If desired, series resistors or shunt capacitors and a selector switch can be added to the meter circuit, as shown in Fig. 4-3, to increase the range of the instrument. The values of the resistors

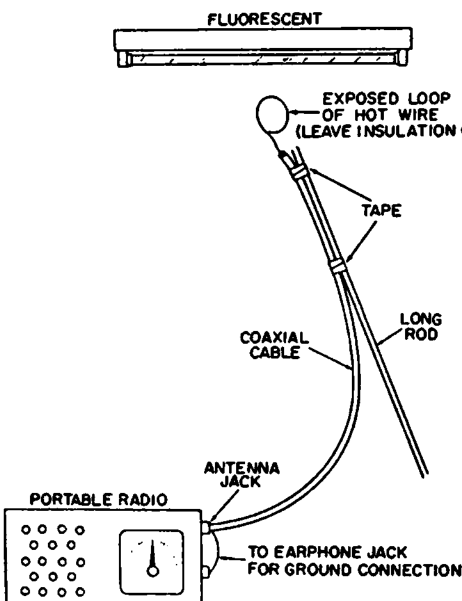
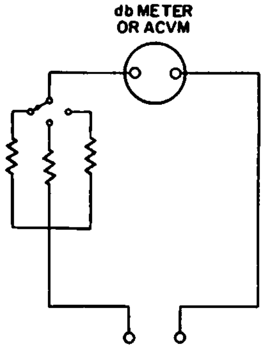
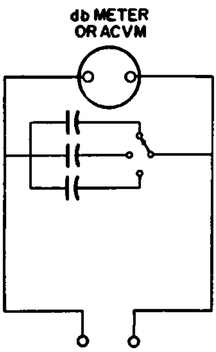


Fig. 4-2. A special probe for locating noise sources.



(A) Using series resistors.



(B) Using shunt capacitors.

Fig. 4-3. Adding a range switch to the meter circuit.

or capacitors are not critical and are best determined by the "cut-and-try" method. We will have more use for this meter later on.

NOISE INDICATIONS

There are two valuable clues to the location of a noise when you're searching for it with a radio. The first is the amplitude—the "loudness" of the noise—as indicated on the meter. Actually, there is another, much more useful clue which is the main reliance of the experienced noise hunter. This is the portion of radio dial over which the noise is heard.

Most noise heard in the broadcast band will show up first between 700 and 900 kc because of the spectral distribution of noise energy. This is true when the radio is quite far from the source of the noise. As you bring it closer, more and more of the dial will be "masked" by the noise, as shown in Fig. 4-4. When you reach the vicinity of the source, the radio will roar all the way from 550 to 1600 kilocycles!

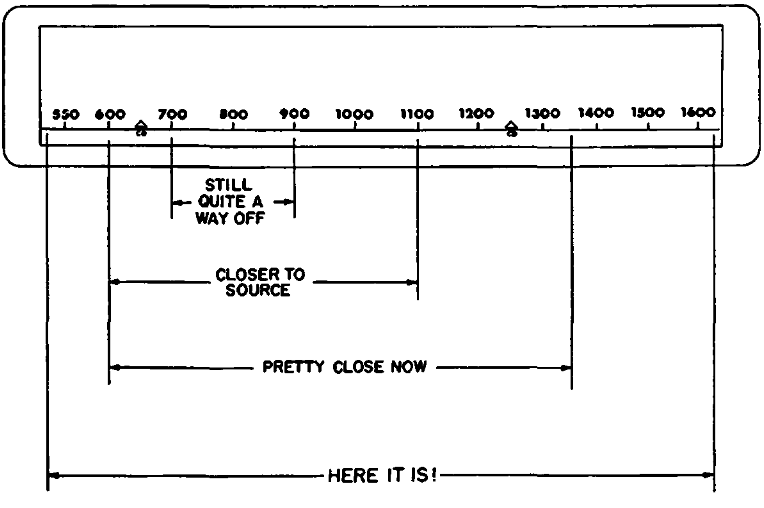


Fig. 4-4. Noise-distribution characteristics over the radio dial at various distances from the noise source.

At this point the amplitude of the noise will also be at its peak. Here, in the immediate vicinity of the source, the frequency-coverage indication won't be too useful because of the high level of noise, and you'll have to use the meter to pinpoint the source. Move the radio around the source, watching for the maximum meter reading. You'll probably begin to get an idea of what is causing the noise. Usually, two or three pieces of electrical equipment will be operating; turn them off one at a time, to see if one stops the noise.

So, there are your two indications—the amplitude of the noise, and the amount of the radio dial covered. By using these clues properly, it shouldn't take you too long to spot the cause.

"Small" Noises

Let's take the simplest possible case—a noise which is bothersome only in a certain house. Obviously, the source must be in the house itself. The average American home is full of electrical appliances, any one a legitimate suspect for noise.

The first step in dealing with noise is identification of the *type* by its characteristic sound—is it a popping, roaring, or ripping sound? Or is it flashes, streaks, or patterns of dots or stripes on the TV screen? From this, we get our first clue as to its nature and origin. Later on we will show you the characteristic TV patterns of each type, and try to describe the sound. After a little practice, you should be able to get a

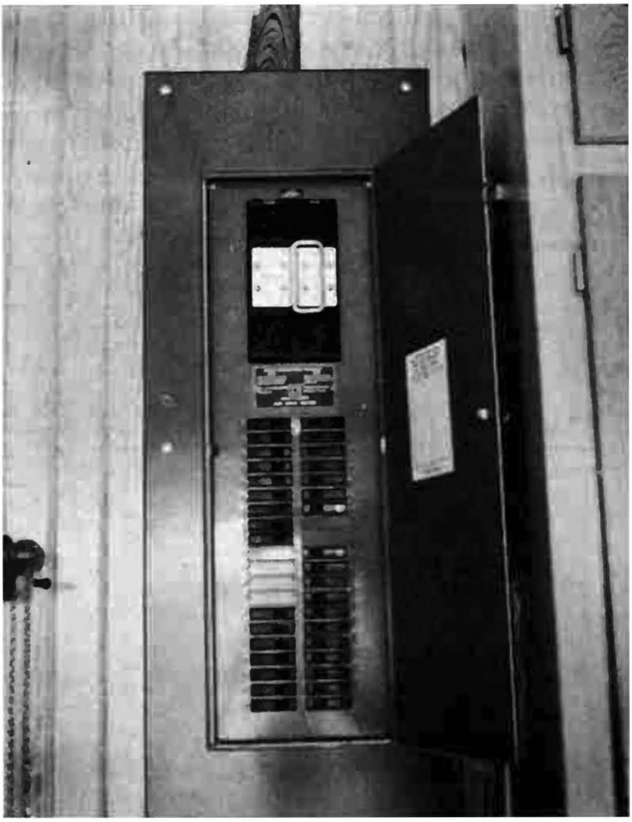


Fig. 4-5. The "breaker box" in a large house.

pretty good idea of its origin from the sound or pattern.

The first step is to ask questions. Find out from the customer just what the noise looks or sounds like . . . when it is heard, and so on. From this information we'll get our first clues. For example, if the noise is heard only when the lady of the house is cooking a meal, we'd begin our search in the kitchen!

A typical case might be a roaring, scratching sound that tears up Father's newscast while Mother is making dinner. So we grab our portable and head for the kitchen. From the description, this sounds like a small-motor noise. We turn on first one appliance and then another which uses a small motor—the ventilating fan, the mixer, and so on—until we find the one giving trouble. Then we install the proper filter, and there we are!

If the noise is continuous, we check the whole house until we find the room where the noise is loudest. There, we turn *off* each piece of equipment until we spot the one making the uproar. Don't overlook *anything* operated by electricity: no matter what, it's a potential source of noise! Appliances, fixtures, switches, lamps—anything that is

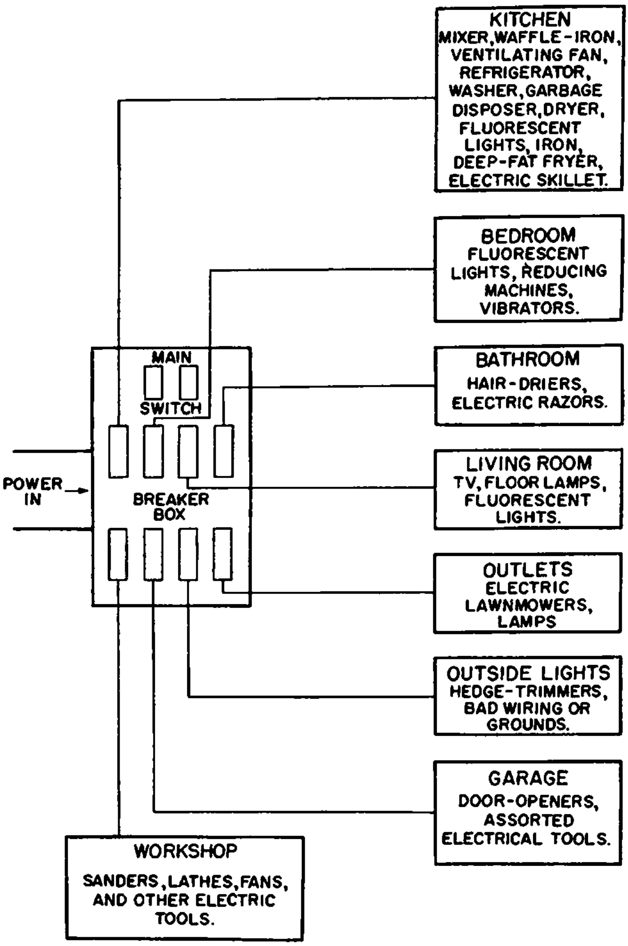


Fig. 4-6. Electrical circuits and potential noise sources in a modern home.

connected to the power lines—fit into this category.

In more difficult cases, we go to the electrical load center of the house—the fuse box, or in more modern homes, the breaker box. The box pictured in Fig. 4-5 is for a large home with 34 separate circuits. Most homes will have fewer circuits, but the procedure is the same. The house wiring is divided into several circuits, as shown in Fig. 4-6. Thus, by turning them off one at a time while listening to the noise, we can tell which circuit is causing the noise. Then, by checking each item connected to that circuit one at a time, we can pinpoint the noise source. Don't overlook the possibility that the breaker itself may be the culprit; this is not at all uncommon with today's heavily loaded home circuits. A home-type circuit breaker is nothing but a thermally operated switch, and like any switch it can develop dirty contacts from overheating. This will cause arcing—with the resultant noise—when the circuit is loaded.

The wall receptacles are another potential source. If an appliance, lamp, etc., causes noise when plugged into an outlet, try a different outlet. If it is quiet there, but another lamp makes noise in the first outlet, the receptacle itself is probably dirty, or the contact springs have lost tension with age and overheating and are not making good contact. In any event, the receptacle must be replaced.

If none of the individual circuit breakers will stop the noise, pull the main switch for a moment. If the noise does not stop then, it is definitely not originating in *that* house, and so you'll have to search further!

"Medium" Noises

"Medium" noise is one loud enough to be heard in all houses within a block or two (although, with the sensitivity of modern radios and TV sets, most noises *will* be heard

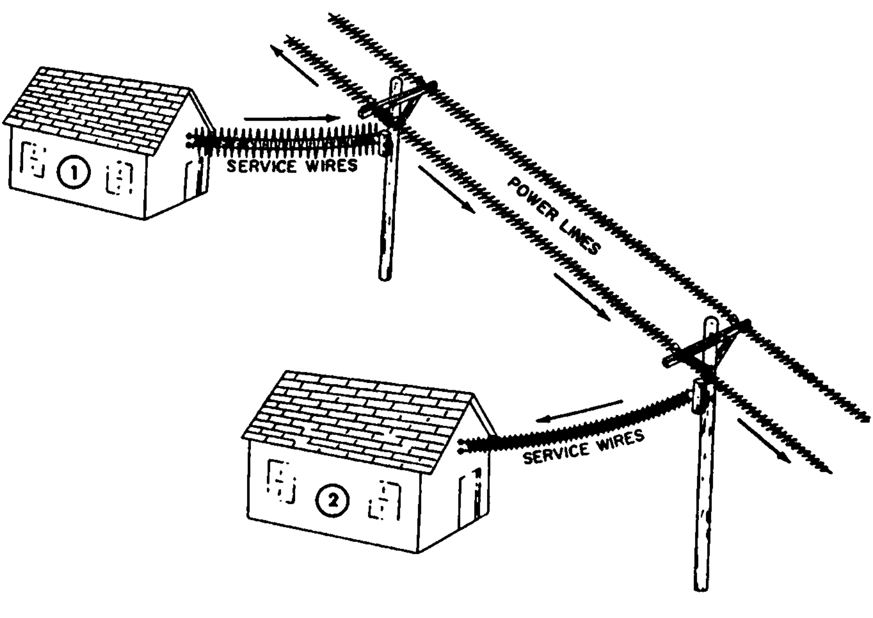


Fig. 4-7. Noise being conducted through the power lines from house No. 1 to house No. 2

over an area about this size). Anyhow, we now have the task of finding out just *which* house inside a given area contains the noise source. So we'll have to set up a search pattern.

As we said in a previous chapter, all noise has both conductive and radiating qualities: it will be conducted along the power wiring and will radiate from it all along the line (Fig. 4-7). Electrical noise from house No. 1, for example, will be conducted out of the house on the power wiring and into the service wires. From here it will flow down the power line and wind up in house No. 2. Of course, it goes in the other direction, too, and will be heard in all other houses within its range, as well as at any point within the radiated field. As the noise travels down the wiring, it will radiate from the wires, the absolute amplitude of this radiation being proportional to the distance from the source. Random noise, being a true electromagnetic signal, obeys the inverse square law. For example, if we were standing under the power line at point *A* in Fig. 4-8, we'd get a small noise; if we moved to point *B*, halfway to the source, we'd have not twice but *four* times the noise. As we move on from *B* to *C*, the noise will increase very rapidly, telling us we were approaching the source.

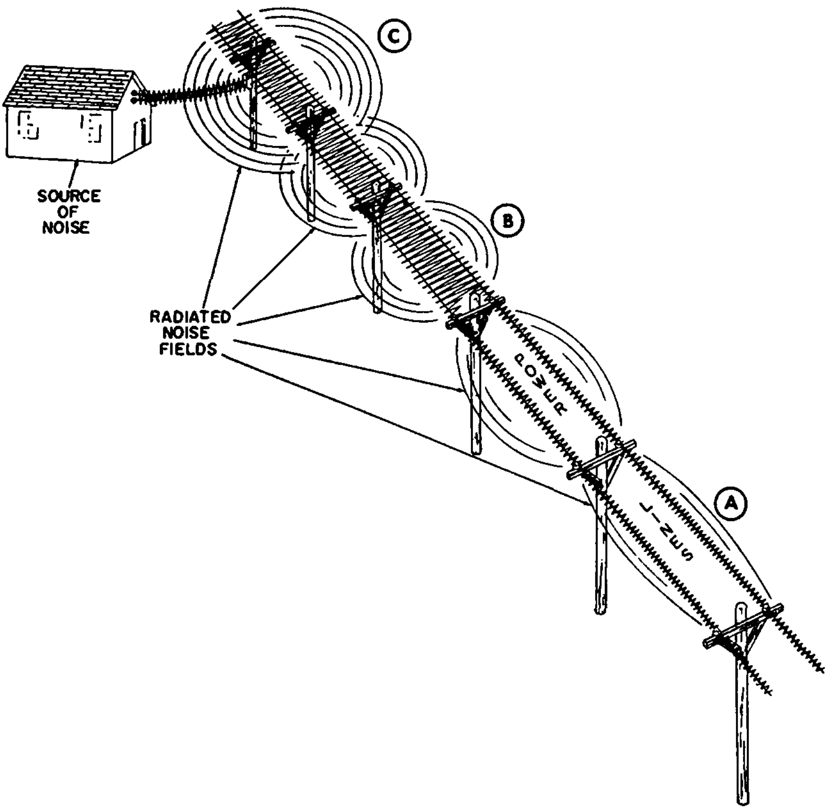


Fig. 4-8. Relative amplitude of noise being conducted along power lines.

After we had passed the house, we'd find the amplitude going down just as rapidly as it had gone up.

Thus, we'd know we had overshot the source and would start backtracking. More than one house may be connected to the service lines at this pole. So we trace out the house services, one at a time, until we find the one carrying the loudest noise.

For this kind of noise tracing, we'll probably have to use the output meter, especially as we get closer to the source. We can make preliminary checks with the sound from the portable alone, carrying it along under the wiring.

USING AN AUTO RADIO TO NARROW DOWN NOISE

For noises covering a fairly large area, there is an easier method than walking. Since the noise will be riding the power lines, we can use the standard auto radio as an indicator. Almost all modern auto radios use separate speakers connected to the main chassis through a plug and socket. Hence, we can use the same output meter we had on the portable, by making up another cable with a plug that will fit the auto-radio speaker socket (Fig. 4-9). A small wirewound potentiometer of the type used in rear-seat speaker kits, and a socket and plug which will fit the auto radio being used, are all we need. The circuit is shown in Fig. 4-10. The plug is inserted into the speaker socket on the radio, and the speaker plug is inserted into the socket on the adapter. In this way, you can hear the noise in the auto-radio speaker while watching it on the meter. The fader will allow you to turn the volume of the noise down to keep from being deafened, but still keep a usable meter deflection. If desired, a miniature jack can be added to the adapter, as shown by the dotted lines in Fig. 4-10. The jack permits leaving the plug used with the portable radio attached to the meter, and merely plugging the meter into either circuit.

The Search Pattern

Now we start looking. We know that this noise is going to be riding on the power lines. Therefore, we start out anywhere in the area where the noise is heard and take a reading, noting carefully the amount of

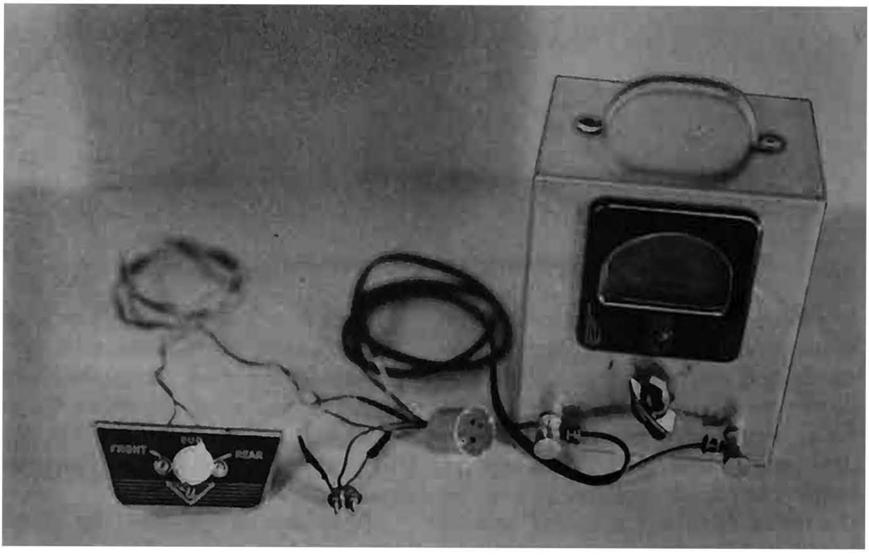


Fig. 4-9. Adapter harness for using portable meter with an auto radio.

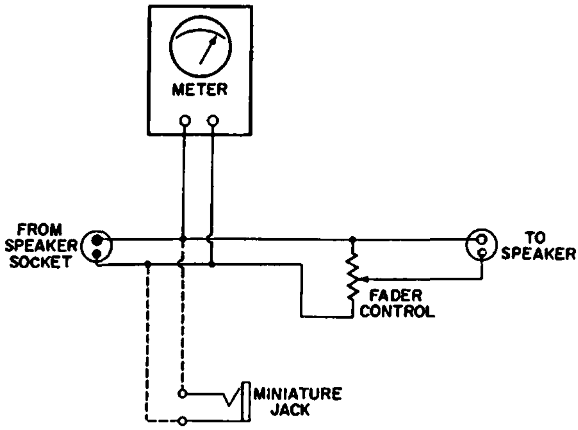


Fig. 4-10. Adapter-harness circuit.

radio dial masked by the noise. We cruise the streets, keeping under the power lines and watching to see where they run, meanwhile checking the amplitude and coverage of the noise at various points, as shown in Fig. 4-11. With the car's added mobility, we can cover a lot more ground in a shorter time. Soon we spot the area of highest noise level. There, we park the car, disconnect the meter, hook up the portable radio, and continue the search on foot. The noise will be pretty close to where the auto radio showed the highest reading. (Needless to say, the db figures in Fig. 4-11 are not exact readings; they are shown only as an example.) Always look for the point of *highest* noise level and maximum coverage of the radio dial. When trying to get a set of comparison readings, watch out for the power wires. If you run past a place where

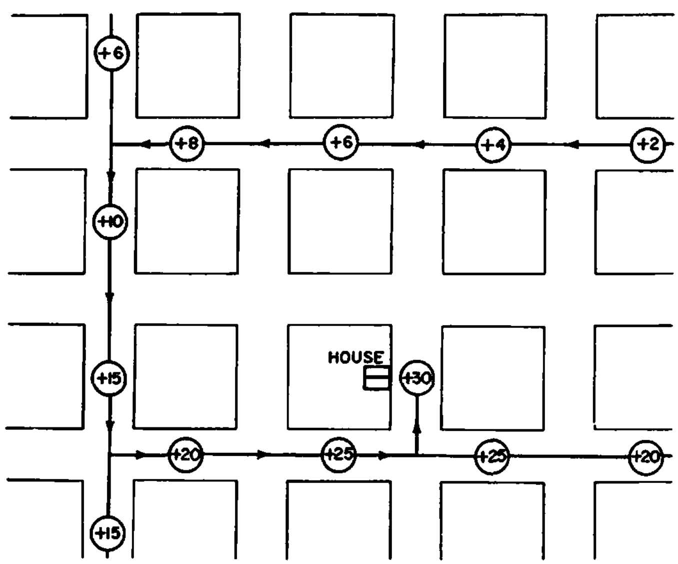


Fig. 4-11. Location of power lines, and readings found at various points along the lines.

they cross the street at a low level, you'll get a much higher reading—but it will be a false peak, caused by the closer coupling of the antenna to the wires. If possible, drive the search pattern so the car antenna is as nearly the same distance from the wires as possible, to avoid false readings. Depend more on the dial coverage than on the actual noise level; the former is slightly more accurate.

INTERMITTENT NOISES

The hardest kind of noise to locate is an intermittent. It is as hard to find as an intermittent in a TV set. If a noise shows up at regular intervals or at certain times of the day, this is at least a small clue to its origin. To be able to find an intermittent, though, you will just have to arrange to be there when it happens.

In one instance, a random noise showed up every evening just after eight o'clock and tore up every radio in the neighborhood. [This happened B.T. (Before TV).] After several nights of fruitless checking, the technician drove down the street one evening, the noise roaring in his radio. It was summer, and all the inhabitants were on their front lawns watching him. (This was a community project!) Suddenly, he saw that one house was still lit up, and he noticed that the noise was loudest in front of it. Going up to this house, he rang the bell. The door was answered by an elderly gentleman. (Meanwhile, the technician's portable radio was really roaring!) "Come right in," he said heartily. "Maw's gone to bed. These nights, she just has to curl up with her *heating pad*!" This was the only clue the technician needed! The heating pad, of course, was the culprit. Its tiny thermostats were bad and were causing a terrific frying noise! (The grateful neighbors took up a collection and bought the lady of the house a brand-new noiseless pad. After ceremoniously burning the old one, they returned to their noise-free radio programs.)

VERY HIGH-LEVEL NOISES

Once in a while, noise is so loud it blacks out a whole section of a city—or even an entire small town! It can be difficult to pinpoint because of its tremendously high level. In one actual case, the level was so high that no peak could be found anywhere in town. Over an area of 25 or 30 blocks, the meter simply laid against the peg and stayed there, while radios roared from one end of the dial to the other!

The power and light company sent a crew, the telephone company sent their men, and all the radio technicians in town also took part in the search. Finally, in desperation, the whole crew went to the substation. Monitoring the noise, the supervisor pulled switches and disconnected power from whole sections of the town at once. Finally, one switch stopped the noise! Further "sectionalizing" showed that the trouble was centered around a comparatively short 220-volt "power-only" circuit running through the business district and in the street-light wiring.

Street lights of this type (common some time ago, and still found in many towns) are connected in series and have only a single conductor—compared with the two wires in standard circuits. Each lamp has an automatic device in its base. If the filament burns out, a spring snaps a switch closed and restores continuity to the circuit. Of course, this means a fairly high voltage at the "hot" end of the line. It was standard practice in those days to break the ground end to turn the lights off.

The 220-volt circuit was traced

out, foot by foot. Sure enough, about five blocks from the substation, the trouble was spotted! The street-light wiring, the power circuit, and some other wires took a short cut through an alley to reach part of the business district. Where the lines passed some fairly good-sized trees, a high wind had bent a large branch down and swung it under the wires. When it had sprung back up, it had caught the 220-volt circuit and the street-light wires. Further movement of the branch had caused the wires to saw through the bark and into the moist cambium in the tree. Current immediately began flowing through the sap, even though the wires were almost two feet apart! The high voltage of the street-light circuit had helped set up the original arc. After it had formed, the 220-volt circuit had ample power to keep it alive. (The street-light circuit, of course, was turned off in the daytime.) Eventually, this current had burned a deep trough, composed mainly of carbonized wood, in the branch. The trough was almost an inch deep when discovered, and the arc, as the lineman said, "looked like a red-hot snake running along the bottom of it!" The tremendous noise created was coupled directly into the street-light wiring, which ran all over town. From the street-light wiring, it was radiated into the other power wiring, the telephone wiring, and everything else metallic within range! At one point, noise was found on a telephone cable two blocks from any power wires!

The local power and light company will always be glad to help in cases of high-level interference, if only to get their own customers off their necks. (People have a habit of calling the light company when noise is heard, no matter what the actual cause!) Often, the company will have specially trained crews with directional noise-locating radio equipment who will be glad to help you in the search. Actually, a directional receiver will not be of too much assistance because of the radiation of the noise from power wiring; the bearings will usually point to the nearest power line! The varying-amplitude and frequency-coverage method is much more accurate.

TRACING HIGH-LEVEL TVI SOURCES

There *are* times when directional bearings can be used to advantage. To illustrate, the writer and his associates were confronted with a very severe case of TVI a few years ago. Large black bars appeared on every TV screen in town, and the interference was so severe that it was even annoying on the community-antenna system, whose antennas were on a mountain three miles from town! The major symptom was the large bar across the center of the screen. From this characteristic, we deduced that it was mainly 60-cycle noise, possibly due to power-line troubles. It was much worse on damp or rainy days.

After several fruitless efforts, we located a house which had an outdoor TV antenna equipped with a rotator. Shooting a bearing on the direction of maximum noise intensity, we marked it on a map (Point 1 on Fig. 4-12). Going to another part of town, we repeated the process and a pattern began to show up (Point 2). A third bearing (Point 3), taken on the north side of town, confirmed our suspicions. The three bearings crossed a highway about one and a half miles out of town. Hurrying out there with our auto radio and a portable, we soon spotted the cause. A 27,000-volt high line ran alongside the highway, and there was an obviously defective insulator on one of the poles. In fact, the arc was clearly visible from the

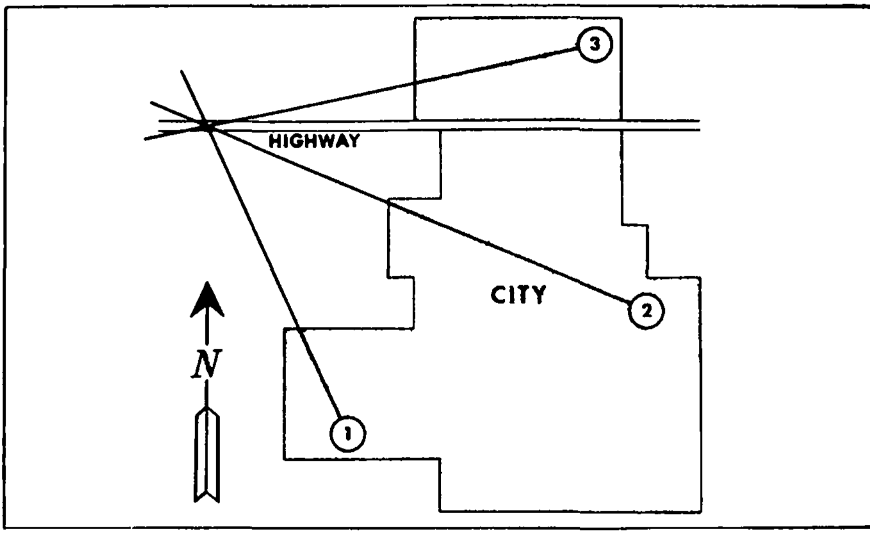


Fig. 4-12. Locating the noise source by shooting bearings on it with directional TV antennas and rotators.

ground! The wiring, which extended through the middle of the town, was broadside to the community-antenna system's antennas on the mountain. Hence, it had functioned as a most efficient antenna, impartially distributing the noise to the whole community!

In cases like this, go to the source indicated by the bearings and cruise it out. Even though the noise might be (as it was here) entirely on TV sets, when you get close to the actual source, there will always be enough *radio* noise to help you find it! The origin of this noise was immediately obvious; most won't be that simple!

If your bearings lead you to a certain area and you find yourself in a street between two or three factories, your problem gets a little more complicated. One way is to probe each factory with the portable radio, to see if one shows a higher noise level than the others. A good clue here is to wait until quitting time. If the noise stops immediately after the whistle blows, it must be coming from the machinery in the plant. For diplomatic reasons, it's best to contact the management of the plant, explain your problem, and arrange with the plant maintenance crew to make your test after working hours so you won't interfere with production. After the plant has shut down for the day, the machines can be turned on one at a time until the culprit is located. However, by probing with the portable during working hours, you can usually find the general area where the noise is located.

In many cases like this, the "time constant" of the noise can give a clue. For example, not too long ago we encountered a disturbance on TV that centered around only two channels and consisted of a loud ripping noise lasting exactly four seconds, followed by silence for about seven to ten seconds. From these clues, we concluded the noise was coming from a machine which made articles one after the other at a fairly fast rate. The noise was heard only while the machine was working, followed by the silent period while the article was being taken from the machine and another put in place. (This was an "all-over-town" type of noise, too!)

After some thought, we selected two or three places which fit these requirements. In the second one checked, we struck "pay dirt"—an industrial radio-frequency heater used to seal plastic articles. It operated on a fundamental frequency somewhere near 35 mc, at a power output of about 1 kw. We were picking up the second harmonic of the fundamental on the TV sets. The machine wasn't correctly grounded and it also had a defective tube socket. Clearing up the troubles reduced the interference to a bearable level.

Tracking Down TVI With Portable Equipment

Although the majority of TVI will also include enough radio noise to help you locate it, once in a while you'll find one that won't. The case just described was one; we couldn't hear any radio noise to speak of, even quite close to the machine. So, in cases like this, more equipment must be brought into play because noise in the sound, streaks in the picture, herringbone or beat patterns and the like, can be caused by harmonics of VHF radio signals from two-way radio transmitters (or *receivers!*), amateur transmitters, and electromedical and industrial apparatus. These noises cannot be heard on a BC radio.

A TV set would be a bit difficult to carry around. However, a battery-powered TV field-strength meter, a common item in many shops, is ideal for the purpose.

These FS meters can be used mobile, exactly like the auto radio a while ago. A probing dipole can be made from a folded dipole off a discarded TV antenna (say about Channel 7, for instance, which is a handy size). The dipole is attached to a long rod and connected to the FS meter by a piece of twin-lead or coaxial cable, as shown in Fig. 4-13. The device can be made handier by

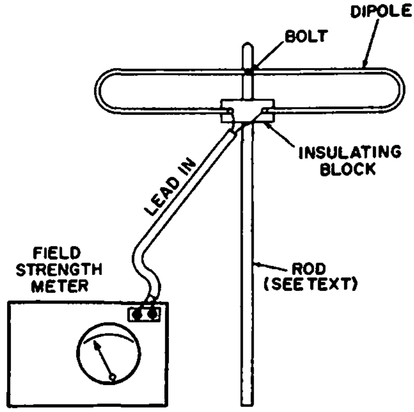


Fig. 4-13. A probe dipole and field-strength meter for locating TVI.

fastening the dipole to a piece of rod about three or four feet long which can be slipped into the top of a 10-foot section for a greater reach. If desired, a jointed wooden pole, of the type used by tree-limb trimmers, can be employed. When additional height is needed, extra sections can be added.

To use this "gadget," set the FS meter on the seat of the service truck and hold the dipole out the window while driving up and down the street in the suspected area (Fig. 4-14). When a peak is found in the noise, park the truck and continue the search on foot, just as before. Most FS meters have provision for the attachment of earphones; in the older models using a tuner similar to the one in a TV set, the earphones were connected to the detector output, and what you heard in the phones was the sharp buzz of the vertical-blanking pulses. Later models use continuous tuners, and the sound output can be applied to the phones; some include sound detectors with which the operator can hear the

Fig. 4-14. Searching the area with service truck for noise source, using probe dipole and field-strength meter.

actual sound from the TV station. All are equipped with meters so the amplitude of the signal can be read in microvolts. This is an extremely helpful feature; while hunting, you can listen to the noise in the phones while watching the amplitude on the meter.

After the general area of the noise is located, the portable meter can be taken from the truck and the service wires, etc., probed with the dipole. By detaching the dipole from its long rod, you can even use it indoors. In special situations you can make a short probe (like the coaxial probe used with the portable radio) and attach it to the FS meter, leaving a foot or so of insulated wire protruding from the end of the shielding.

TV signals can display very peculiar characteristics when traveling along power wiring. The wires act as antennas for the signals, which will always be several wavelengths between anything that might "break them up," such as transformers, capacitors, etc. Signals will also be coupled into guy wires and anything else metallic in the vicinity, leaving you with some very peculiar patterns indeed! (By "TV signals," we mean, of course, noise signals occurring at TV frequencies.)

CHAPTER

5

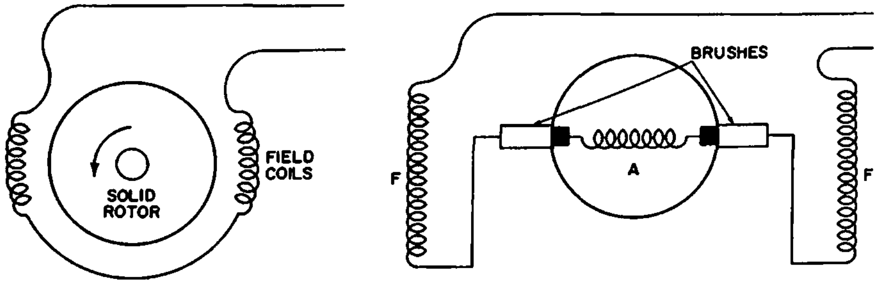
Small AC Motors

THE MODERN American home is practically filled with very small alternating-current motors. Although only a small fraction of a horsepower, they drive kitchen mixers, can openers, fans, lawn mowers, hair driers, and a host of other useful devices. Because of their number, they are probably the No. 1 source of radio-TV noise in the home. Therefore, we had better take a little time here to discuss their characteristics.

MOTOR TYPES

There are two basic types—synchronous, and brush. The synchronous motor (Fig. 5-1A), familiar to all technicians as a phonograph motor, consists of only two field coils and a solid metal rotor. Of course, with no connections to break, this type cannot cause electrical noise unless something is drastically wrong with it. However, the very small synchronous type does not have the power of the brush type; nor can its speed be controlled. Therefore, the brush type is used for more applications such as mixers, etc. Its circuit is different, too, as shown in Fig. 5-1B.

The current comes into the motor through one of the field coils, goes through a carbon brush to a bar on the commutator, through one of the armature coils to a bar on the opposite side of the commutator, through the other field coil, and back to the line. As the current flows through the armature coil, a magnetic field is created which is out of line with the fields set up by the field coils. This causes the armature to twist in its bearings, in an attempt to line up the magnetic fields. When it does it moves the commutator, and the original armature coil is dis-



(A) Synchronous. (B) Brush.

Fig. 5-1. The two types of small AC motors.

connected and the next one connected in its place. This coil also creates a magnetic field out of line with the field and the process is repeated, causing the armature to rotate. Of course, each time a coil is connected and disconnected by the brushes and commutator bars, one circuit is broken and another is made. This process is repeated many thousands of times a second.

Fig. 5-2 shows a typical armature (only one coil is drawn, for clarity). The coil is wound in a slot in the armature, and the ends of the coil are connected to commutator bars 180° apart, as shown in Fig. 5-2A. The number of coils will vary with the speed of the motor, the average being 15 to 20. This means, of course, that there will be twice as many commutator bars as there are coils. Each coil is connected to a pair of commutator bars 180° apart, as shown. Contact between the field coils and armature coils is made through a pair of soft carbon brushes which contact the commutator bars, as shown in Fig. 5-3. The brush must

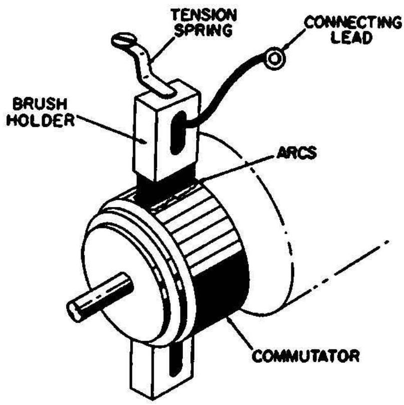
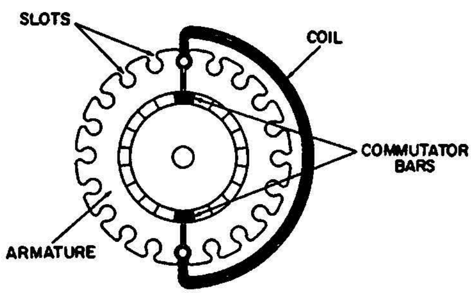
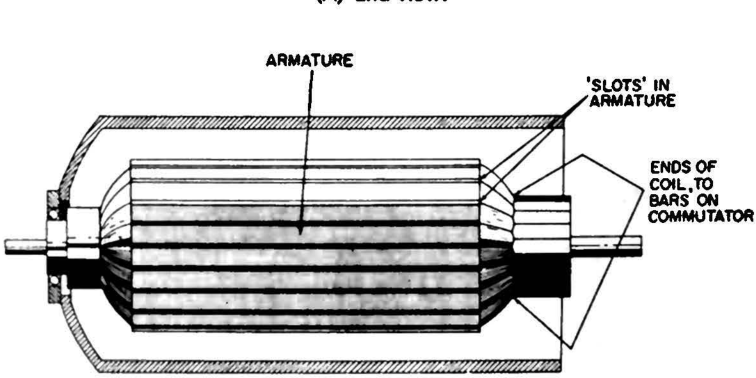


Fig. 5-3. Detail of brush holder and commutator on a small motor.



(A) End view.



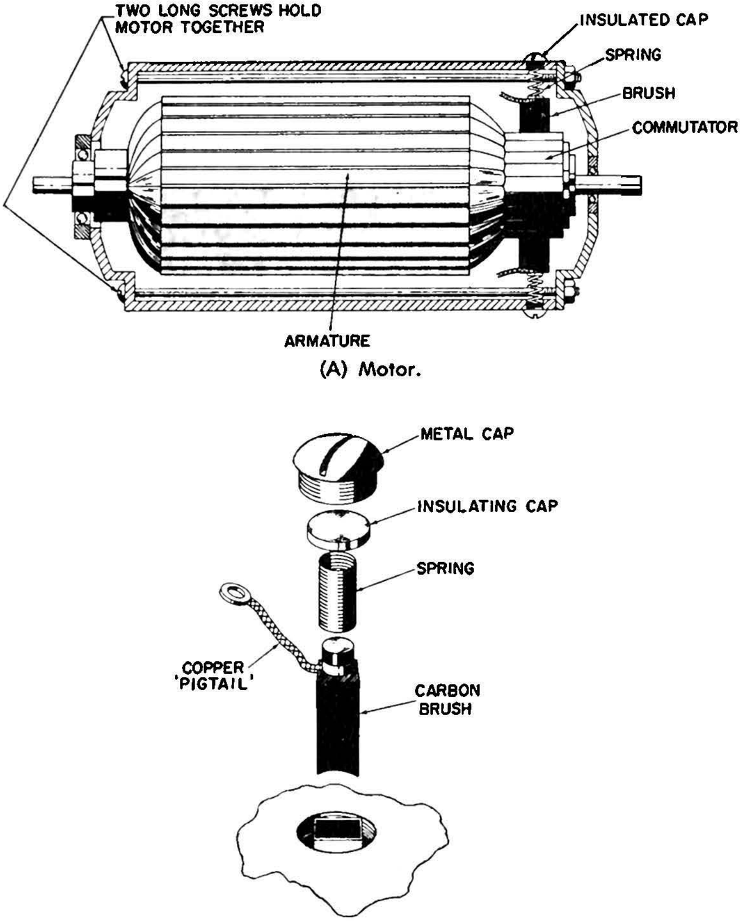
(B) Side view.

Fig. 5-2. Construction of a typical small motor armature.

slide freely in the holder, yet be held firmly enough to keep it from rocking from side to side. The spring on top (Fig. 5-3) holds the brush firmly against the surface of the commutator. If worn or loose, or if the commutator is dirty or uneven, the brush will bounce and cause excessive arcing and noise.

The constant making and breaking of the contacts causes arcing between brush and commutator, and this arcing is the source of the noise. For the least noise, the motor must run with only a minimum of arcing between the brush and commutator. Therefore, if the motor is making noise, the first step is to check the brushes and the commutator surface. These should be cleaned if there is too much arcing. The motor may have to be disassembled, which usually isn't too difficult to do in most appliances.

The motor will look something like Fig. 5-4A. The brushes are mounted in insulated holders, which are rectangular slides fastened to the body of the motor. An insulated cap holds the brush in place, and a small spring holds it firmly against the armature as shown in Fig. 5-4B. Fig.



(A) Motor.

(B) Detail of brush assembly.

Fig. 5-4. Construction of a typical small motor.

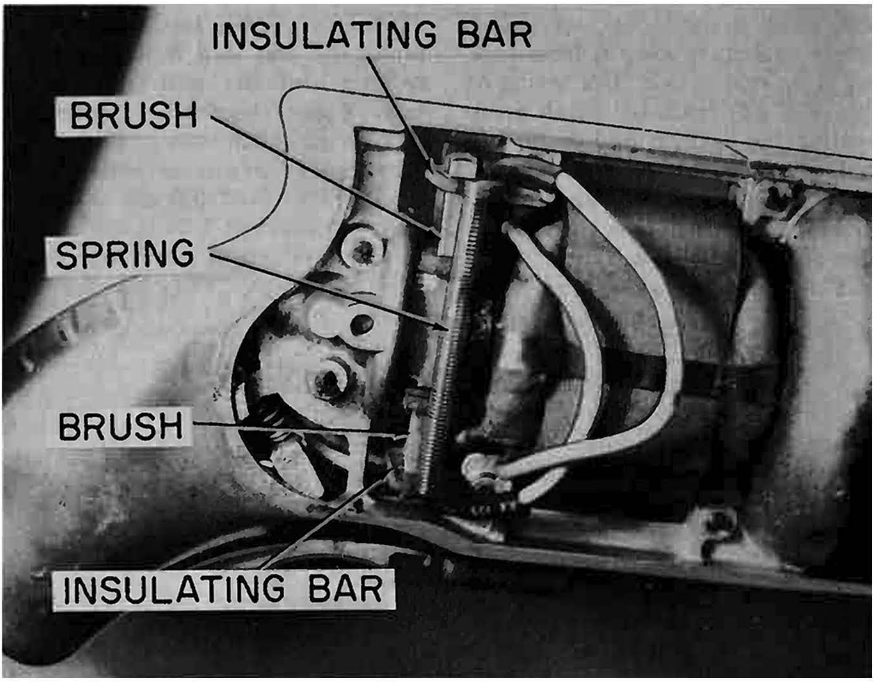


Fig. 5-5. Brush holders and springs on an electric drill.

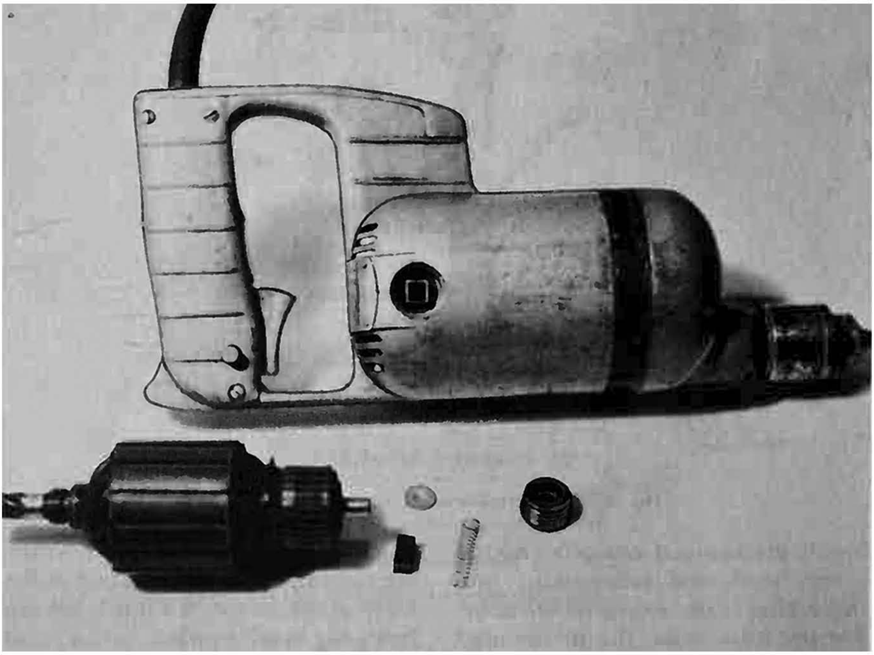


Fig. 5-6. An electric drill with the brushes disassembled.

5-5 shows another type of small motor. Here, the two long springs, which apply pressure to the insulating bars at the top and bottom, hold the brushes against the armature. In most motors the brush is held down by a small coil spring, as shown in detail in Fig. 5-4. The "pigtail" inside the spring insures good contact between the carbon brush and holder, at the cap. Fig. 5-6 shows a small electric drill with the brush disassembled. This type does not use the "pigtail," although it could be used (and should be. Without the pigtail, the spring itself must carry the current. This often causes severe overheating and the resultant loss of tension because the spring has lost its temper.)

SERVICING AND REPAIRING SMALL MOTORS

To get an idea of the amount of noise coming from a motor, watch the brushes while it is running. If there is severe arcing at the brushes, as illustrated in Fig. 5-7, the motor is making noise. Incidentally, it is not running at maximum efficiency either! Brushes on most small motors are accessible from the outside; there is no need to disassemble the unit. In some appliances, however, a cover, body, or shield will have to be removed. If excessive sparking is noticed, take a look at each brush. If its contact end is glassy-smooth over the entire surface, the brush is making good contact and the commutator is good (Fig. 5-8A). A rough commutator, one with a high bar (one which has risen above the others because it didn't wear equally), or one with an open circuit will cause rapid brush wear. The brushes must move freely in their holders, but the holders must still hold tightly enough to keep the brushes from tilting or vibrating. A chipped or broken brush like the one in Fig. 5-8B will cause arcing and noise. If long enough, it can be smoothed off and replaced. A brush which shows the symptoms of Fig. 5-8C indicates bad trouble. This kind usually throws a ring of fire around the commutator while the motor is running, and it makes enough noise to be heard for sev-

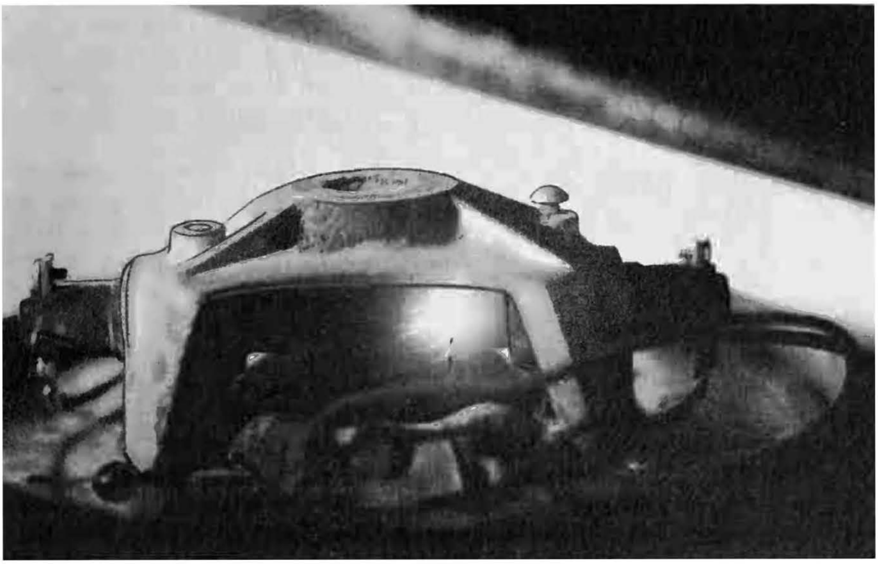
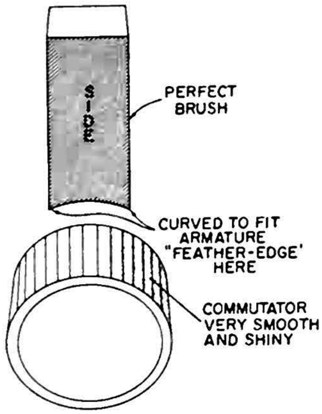
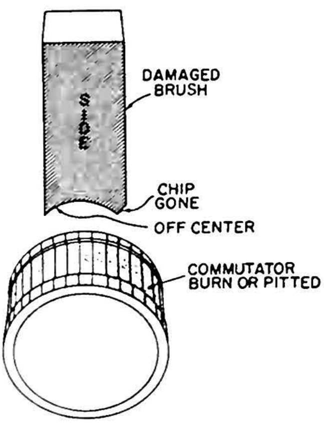


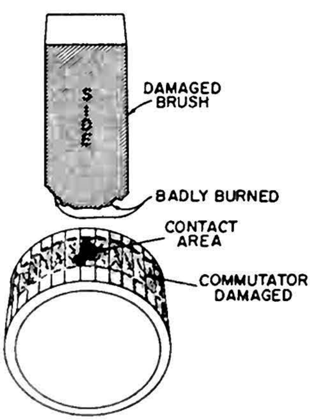
Fig. 5-7. Severe arcing at the brushes of a small motor.



(A) Perfect brush.



(B) Damaged brush.



(C) The worst possible brush.

Fig. 5-8. Appearance of damaged brushes and commutators.

eral blocks! This usually indicates a bad armature; or the brush has been sticking in the holder and jumps free as the armature turns, causing arcing. The arcing wears away the end of the brush, reducing the contact area—in turn causing more arcing, and so on.

The armature itself will cause trouble under certain circumstances. If one coil is open, the commutator bar connected to it will usually be darker than the rest, showing signs of burning or arcing. A good commutator should be perfectly smooth all the way around and have a uniform color. The armature in Fig. 5-6 illustrates this: the commutator is dark but perfectly smooth. The dark color alone is not an indication of trouble, but is merely due to oxidation in this example. The commutator in Fig. 5-9 is in bad shape. Notice the groove worn by the brushes, and the rough commutator surface. This commutator will cause brush bounce and severe noise.

If a commutator is not making good contact, its surface can be cleaned by applying fine emery cloth to it while the motor is running. If the brushes are replaced, it is a good idea to run them in until their ends have worn down concavely, indicating perfect contact over the whole surface.

Badly pitted or worn armatures can sometimes be helped by turning the commutator down on a lathe. However, unless you are experienced in this type of work, it is best to take it to an electric-motor repair shop.

Fig. 5-10 shows a typical small motor with its commutator and brush holders. This is a high-speed type; because of the tiny arcs caused by the brushes, a very high-frequency interference was created. Although not too noticeable on the broadcast band, it was quite annoying in TV

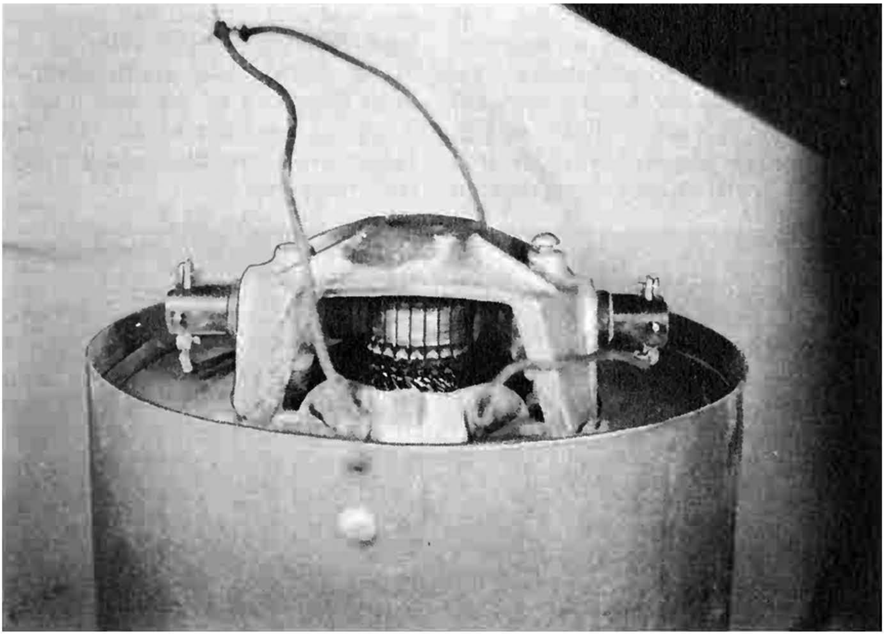


Fig. 5-9. Commutator and brushes of an AC motor, showing excessive wear.

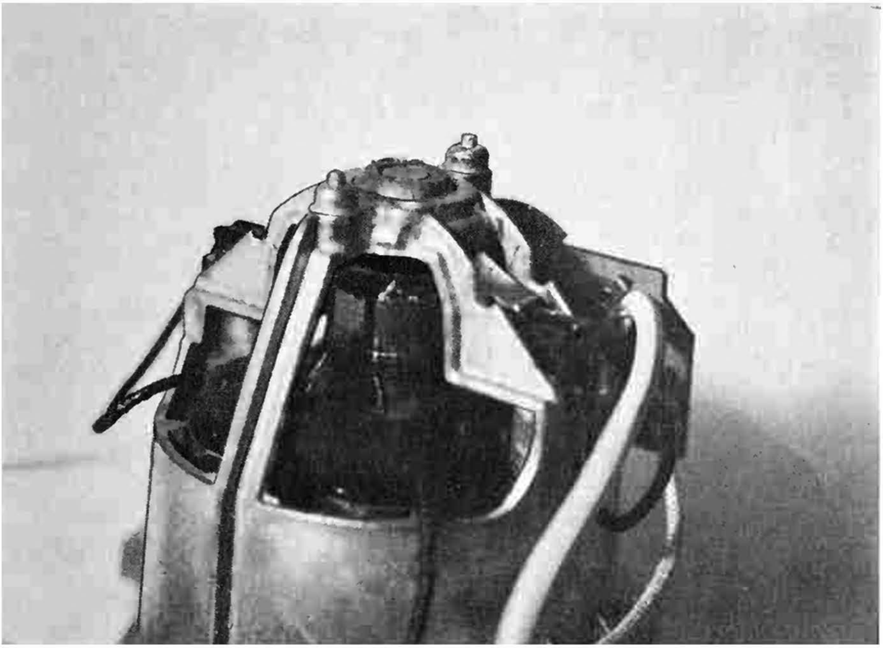


Fig. 5-10. A typical small motor, showing commutator and brush holders.

reception. The commutator was cleaned, but there was no improvement. A pair of .01-mfd ceramic bypass capacitors were then soldered to the brush leads, as shown in Fig. 5-11, and the exposed wires covered with spaghetti. After the photograph was taken, the small, flat capacitors were fastened to the sides of the motor frame with plastic tape to keep them out of the way. This is a typical example of the kind of motors you'll run into, and a typical cure for noise.

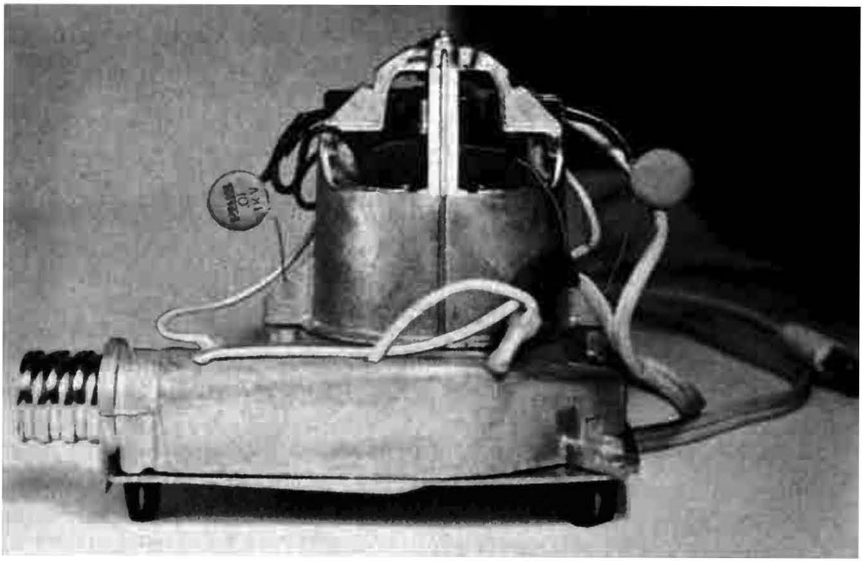


Fig. 5-11. Adding bypass capacitors to the brushes of a small AC motor.

CHAPTER

6

Case Histories

WE'VE ALWAYS felt that a book of this kind had its greatest value when it gave the reader two things—a detailed explanation of the *causes* of trouble, and a full set of practical examples. With this in mind, we will present case histories of real troubles encountered, and the methods and materials used to cope with them.

This chapter will deal with noise troubles found in the field in audio systems and home radio and television receivers. We will discuss their causes and the remedies used. Later chapters will cover specific problems encountered in auto, two-way, aircraft, and marine radio.

There will undoubtedly be some troubles we'll miss, but we'll try to give you at least a representative sample so you can find one similar to the trouble you're having! Always remember the primary axiom of filtering work: any device added for noise filtering must never interfere

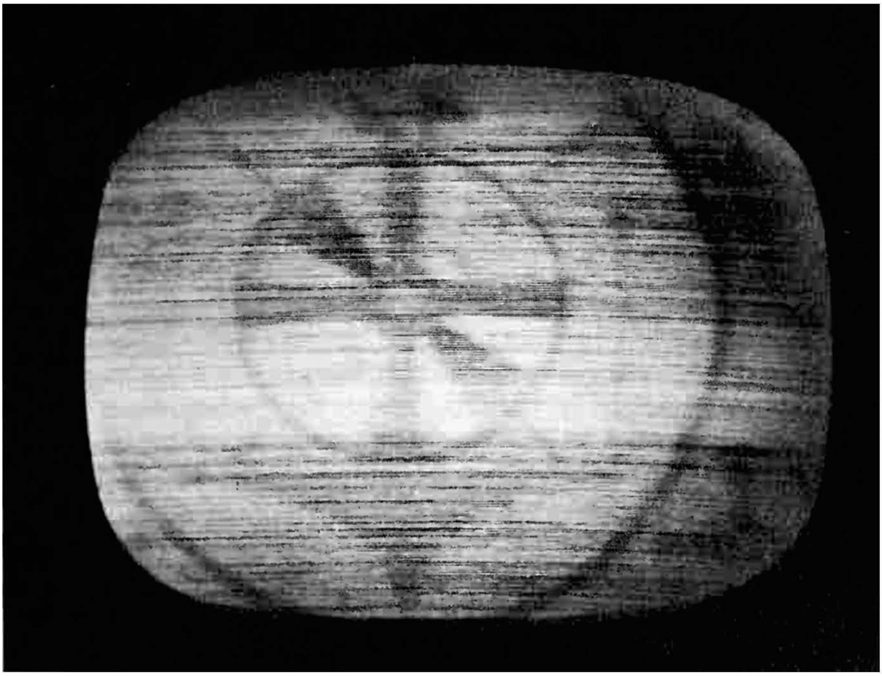


Fig. 6-1. Appearance of noise caused by an arcing motor.

with the operation of the machine or circuit. In other words, after you have taken the noise out of a motor, it must run just as well as it did before you began.

RANDOM NOISE FROM MOTORS

Small-Motor Noises

Fig. 6-1 shows the typical screen pattern when noise from an arcing small motor is being picked up. The streaking and flashing are always seen with this type of noise. To eliminate it, add a capacitor across the brushes or from each brush to ground, as shown in Fig. 6-2.

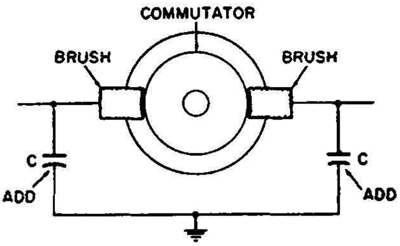


Fig. 6-2. Adding capacitors to brushes to eliminate noise.

Hair Driers

Hair driers are small blowers, usually with a long, flexible plastic tube and a plastic or fabric hood that fits over the head. Some have heating units mounted in the air stream to warm it for faster drying.

A variable-speed brush-type AC motor is employed which usually resembles the one in Fig. 6-3. The brush noise from these motors is of a fairly high frequency; therefore, it interferes with TV more than with radio reception.

If there is room inside the housing, connect a pair of .01-mfd ceramic capacitors to the brushes. Use spaghetti on the "hot" leads, and ground the other end to a screw on the motor, as shown. Before reassembling the motor, it is a good idea

Fig. 6-3. Bypass capacitor added to a small brush-type AC motor.

to tape the capacitors to the frame to keep them in place.

If it is possible, some of these troubles can be corrected by reconnecting the motor so the armature is between the field coils (Fig. 6-4). This causes the fields to act as RF chokes and thus helps prevent the noise from escaping. It is also a good idea to install the bypass capacitors as shown. Always see that the brushes are good and of sufficient length, and that their springs make good contact and have enough tension to hold the brushes firmly against the commutator. Clean the commutator surface with fine emery cloth if necessary.

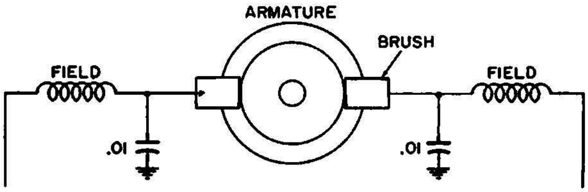


Fig. 6-4. Reconnecting small AC motors so the armature is between the field coils.

Kitchen Mixers

Kitchen mixers use brush-type variable-speed motors. The speed is controlled by changing the setting of a centrifugal switch, or by switching a variable resistance in series with the motor windings.

Some of these motors are so compact that there is no space inside the housing for even installing ceramic capacitors. Of course, a pair of them across the brushes to the frame will reduce the noise considerably.

If there is no room inside the motor, install a plug-in filter at the line plug. Try the simple type shown on the left in Fig. 6-5 first. If it does

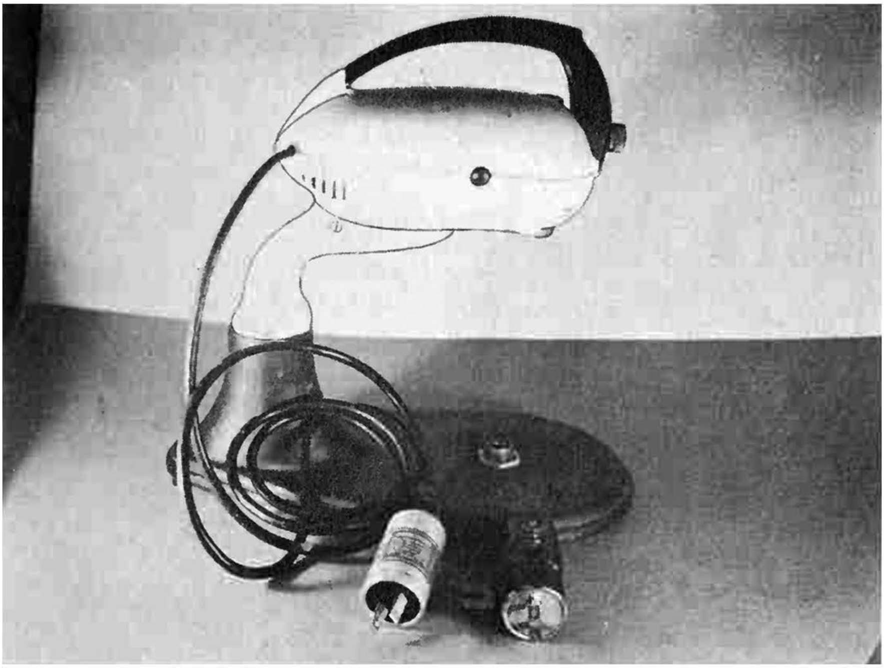


Fig. 6-5. A kitchen mixer and two plug-in line filters.

not completely eliminate the noise, use the more elaborate type with a ground-return connection shown on the right. Wind a very fine insulated wire tightly around the line cord and back to the mixer, taping it wherever necessary with plastic tape split to a ¼-inch width. Fasten the end of the wire under a screw on the mixer frame.

Electric Shavers

The average electric shaver uses a very small electric motor of a slightly unusual type. A dumbbell-shaped armature is driven by the field coils, and a pair of contact points closes the field circuit when the armature is off-center. The armature is then pulled into the fields, and the cam again breaks the circuit. This allows the armature to coast on past, to the next making of the points.

The noise comes from these points. Connecting a ceramic capacitor across them will usually reduce the noise to an acceptable level. (The newer shavers include built-in capacitors.) You can usually find room inside the case to slip in a small ceramic capacitor, as seen in Fig. 6-6.

The commercial plug-in filters are also usable with these machines. Either a small capacitive type, or in extreme cases the LC filters, can be used at the wall outlet.

Sewing-Machine Motors

The probability of radio noise in sewing-machine motors depends on the age of the motor. Newer models have factory-installed radio suppression, but older models and reconverted foot-powered machines are good prospects for noise.

The motors are small brush types with a foot-operated speed controller (Fig. 6-7). Install small ceramic capacitors across the brushes to the frame, and add a slightly larger one across the control rheostat. If the motor is too small to allow installation of capacitors at the brushes, use a plug-in filter or cut an LC filter into the line cord, as close to the motor as possible.

Electric Lawn Mowers

Electric lawn mowers use a brush-type motor which, because of its very high torque, develops tremendous amounts of power. This means high currents through the brushes and armature, and hence, a greatly in-

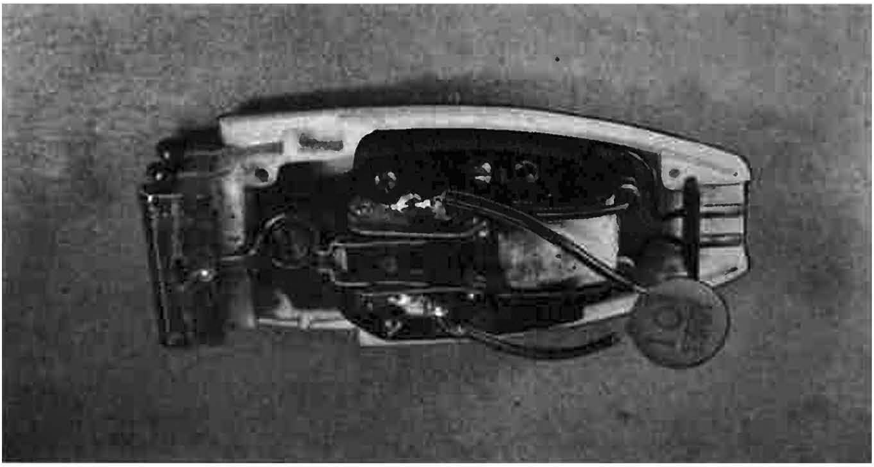


Fig. 6-6. A bypass capacitor added across the points of an electric shaver.

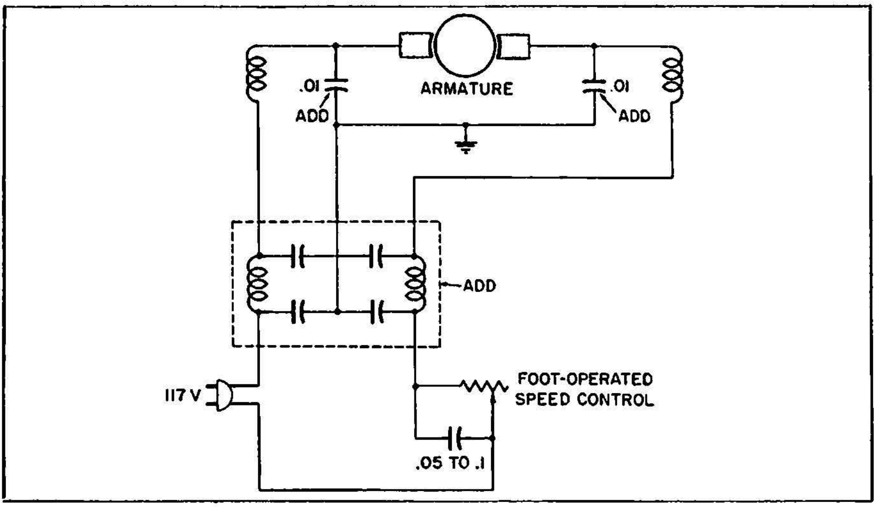


Fig. 6-7. A typical old-type shunt sewing-machine motor.

creased noise potential! In addition, these motors are of necessity at the end of a very long extension cord which makes an excellent antenna! The motor in Fig. 6-8 develops ¾ horsepower—yet is not much bigger than your fist!

Motor housings are very small, and the brush mountings are almost completely inaccessible. Therefore, the easiest way of mounting an LC filter is to cut the line cord as close to the motor as possible, and install the filter on the mower frame. Put

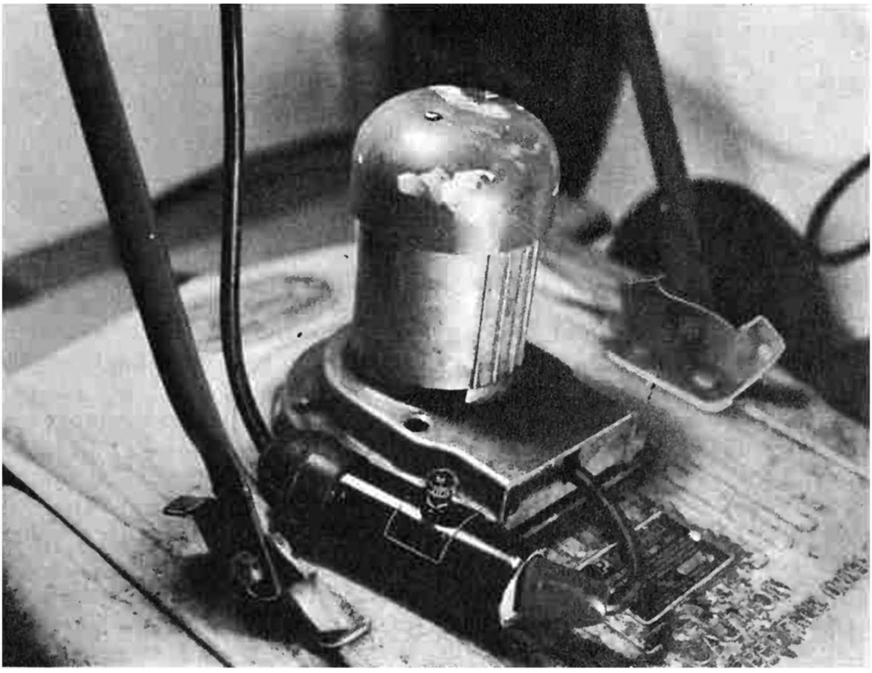


Fig. 6-8. Line filter added to an electric lawn mower.

a line plug and cable-type socket in the motor cord, and use a plug-in type filter as shown in Fig. 6-8. In this way, we can get the filter close to the motor and thus avoid most of the radiation; or at least we can reduce it to the point where it is not annoying.

Some makes of electric mowers use a terminal box just below the motor, with room inside to install a specially-built filter. Fig. 6-9 shows

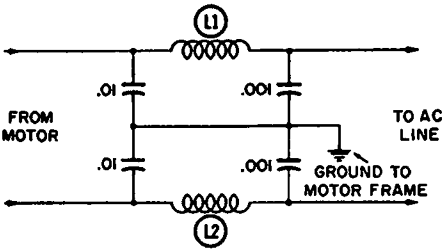


Fig. 6-9. Configuration of a line filter suitable for adding to an electric lawn mower.

the circuit for such a filter, if you want to try to build one. The coils are 15 to 20 turns of enameled wire wound on a ¼-inch wooden form. Small ceramic capacitors are used. Solder all connections and wrap the entire assembly with plastic tape. Use at least No. 14 flexible insulated wire for the leads.

Office Machines (Electric Typewriters, Adding Machines, Cash Registers, Etc.)

The characteristic sound from office machines is directly related to their action. Adding machines, for example, which start and stop the motor every time an ADD key is pressed, give a sound like "Pop! Whrrrr!" in a radio. Cash registers and all other "stop-start" machines give the same sounds. Electric typewriters, whose motors run continuously, produce a grinding roar like any other small-motor noise.

The best cure is the standard one: clean the commutators, check the brushes, and connect small capacitors across them to the frame. In quite a few machines of this type, the space inside the cabinet is *extremely* limited, even inside the motor itself. Therefore, it may be impossible to connect the bypasses where they should be, so any filtering will have to be external.

The standard LC filter should be used. It can be built into a small metal box and mounted on the machine. If it is one of the larger models with its own table, the filter can be attached beneath the table and the line cord brought out of the machine and into the filter, as in Fig. 6-10. The line cord should be shielded between the body of the machine and the filter to prevent the noise from

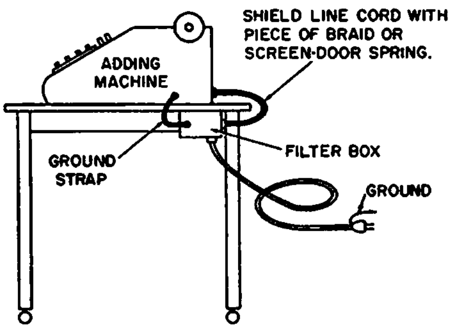


Fig. 6-10. Methods of eliminating noise in an adding machine.

radiating before it gets to the filter. A common screen-door spring is very useful for this purpose. Slip one end inside the line-cord clamp of the machine, thread the cord through the spring, and fasten the other end inside the filter housing. This is particularly useful in machines where the line cord comes out of the back and the filter must be placed underneath. Install a three-conductor line cord with ground wire; connect the ground lead between the filter box and ground, at the receptacle. (If the receptacle has no provision for a ground wire, attach the ground lead to a water pipe or other convenient ground.) It is also a good idea to attach a ground lead between the machine and the filter box, as shown.

Compact Office Machines

In the smaller adding machines, etc., used on desk tops and carried about the office, the problem of installing a noise filter can be pretty tough. A big, bulky metal box would interfere with the operation of the machine. So we usually have to rely on a plug-in filter. If possible, it should be close to the machine, and the case should be grounded to the machine there. Sometimes the line cord can be cut just outside the machine and the filter installed in series with it. In this way, radiation from the line cord will be minimized.

We can often make up a special LC filter, using small coils and ceramic capacitors, and mount it inside the case of the machine if there is room. Be sure it is well insulated and doesn't interfere with any of the moving parts.

If you have to use a plug-in filter at the wall outlet, either slip a shielding braid over the line cord (taking off the line plug first), or wrap a thin insulated wire around the cord and keep it in place with plastic tape, as shown in Fig. 6-11.

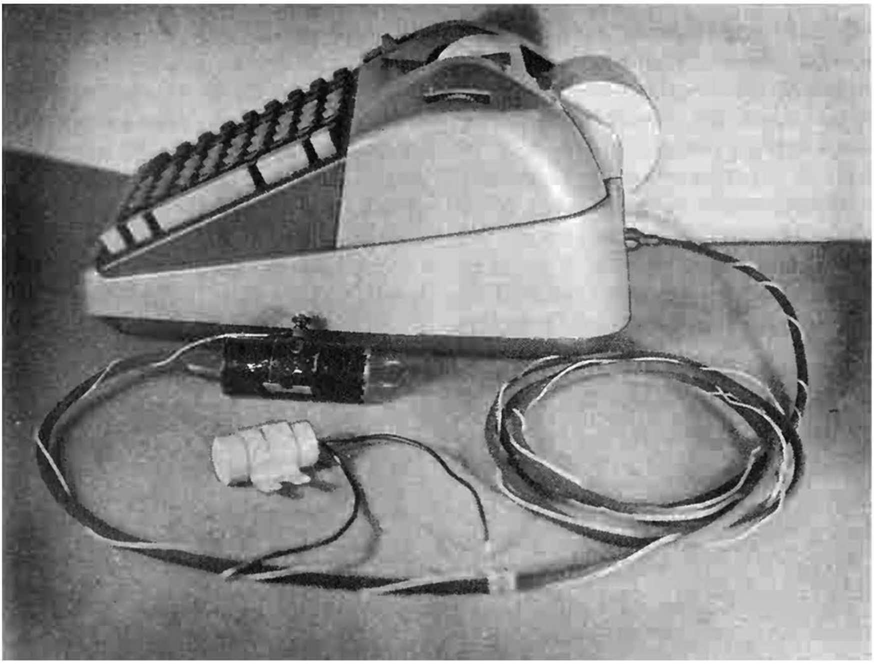


Fig. 6-11. Plug-in filter on a table-model adding machine.

Connect one end of this wire to the frame of the machine and the other to the ground terminal on the filter. If the machine is used at a permanent location, the wires can also be grounded to a water pipe.

Old Vacuum Cleaners

The reason we specifically mention old vacuum cleaners is that you'll be concerned with them most of the time. Practically all later models have built-in radio-interference suppression.

These are brush motors, and the typically noisy cleaner will usually require quite a bit of work on the brushes, commutator, etc., before you can even start to quiet it. For some reason, they are never serviced until they are in fairly bad shape. Therefore, clean the commutator, turning it down if necessary, and see that the brushes and their springs are in good condition. Then apply the noise-reducing equipment.

Most of the tank-type cleaners will have ample room for mounting an LC filter. However, after a thorough clean-up job, a .01-.05–mfd paper capacitor across each brush will usually get rid of the noise. Fig. 6-12 shows two .05-mfd capacitors mounted across the brushes in a typical installation. Always tuck the capacitors under the brush holders, or fasten them in some other way (clamp if possible) for security. Never let them hang by their leads because the continued vibration will soon break the leads. Use spaghetti on the "hot" leads, and fasten the ground lead under a nearby screw.

Old Refrigerators and Similar Appliances

Late-model refrigerators use unitized compressors which are not at all likely to cause radio or TV interference. However, the older models and many of the commercial units still present the possibility of noise.

The noise comes from the fact that the motor and compressor are usually mounted on a platform suspended from shock mounts such as rubber or springs. Sometimes the motor and compressor will not make good electrical contact with the frame of the appliance and a static charge will build up, which is discharged as the unit bounces on its springs. The cure is simple: Install at least two heavy, flexible ground-

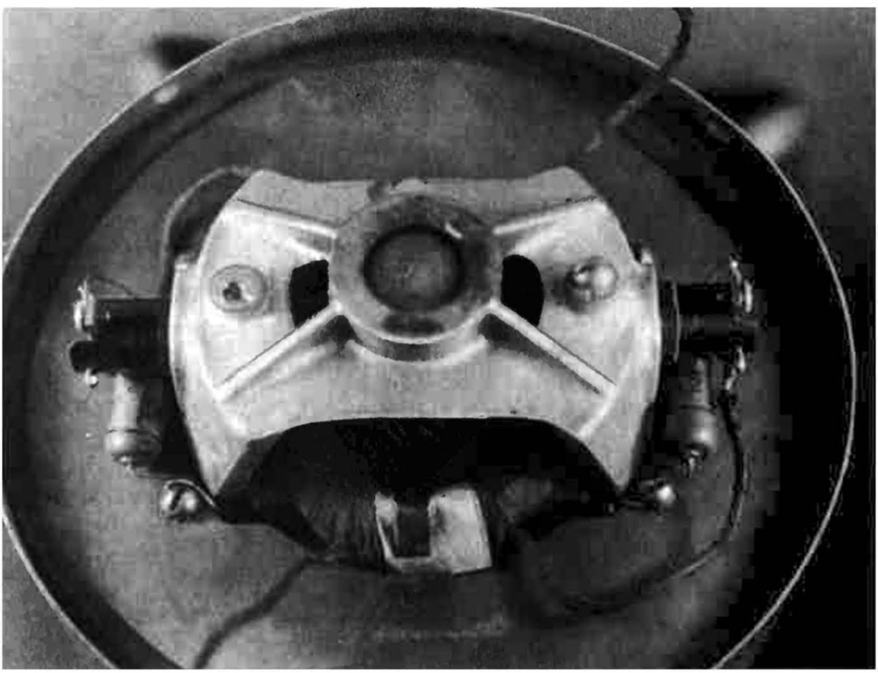


Fig. 6-12. Capacitors installed across the brushes of a vacuum cleaner.

ing straps between the floating unit and frame. Be sure to leave plenty of room for the unit to float normally on its mountings. Ground the frame to a water pipe. Mostly these are heavy-duty induction motors without brushes, so they will not cause radio noise unless defective. Broken wires, frayed insulation, etc., are easy to spot, because this usually results in a short circuit and a shower of sparks!

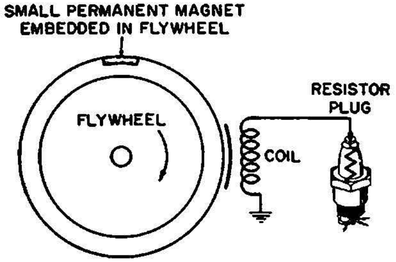


Fig. 6-13. A typical magneto ignition-system circuit.

Small Engines

Noise from gasoline-powered lawn mowers and other small gasoline engines probably won't be too troublesome. These little engines all have magneto ignition, as illustrated in Fig. 6-13. A permanent magnet is embedded in the steel or aluminum of the flywheel, and as the flywheel turns, the magnet passes the coil and induces a pulse of high voltage in it which fires the plug. Since there is no DC generator to worry about, all we have to do is reduce the ignition noise.

Because the high-voltage lead to the spark plug is usually fastened firmly into the magneto coil itself, we can't use resistance-type wiring without first disassembling the coil. Therefore, our best bet would be a resistor spark plug, or a plug-in suppressor on the plug itself. The resistor plug would be better; because of the tremendous vibration on these small high-speed engines, a plug-in suppressor might work loose and cause trouble.

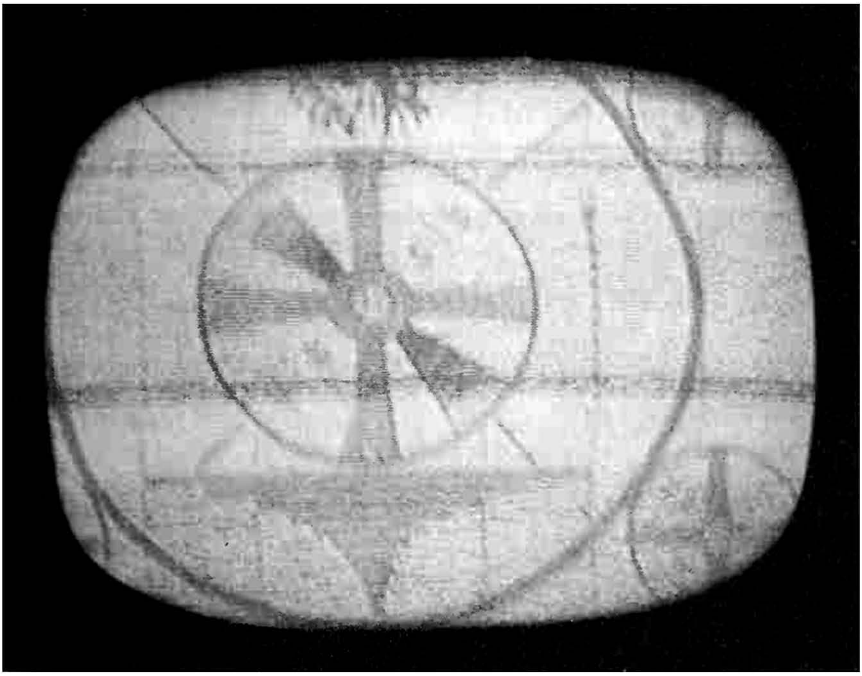


Fig. 6-14. Fluorescent-light interference on a TV screen.

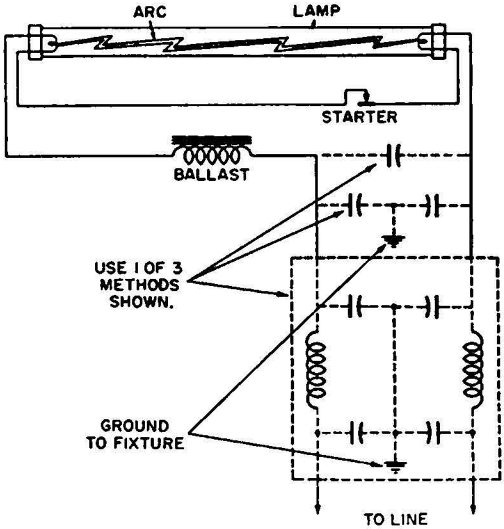


Fig. 6-15. Methods of eliminating noise from a fluorescent light.

RANDOM NOISE FROM GAS DISCHARGES

Fluorescent-Light Interference

Noise from fluorescent lights is heard on the radio as a buzzing or roaring sound, and seen on TV screens as two lines of dots or wavy forms (Fig. 6-14). This is caused by the fact that a fluorescent light is actually drawing an arc through the gas in the tube, as shown in Fig. 6-15. The starter closes the circuit through the two small filaments until they become hot; then it opens and an arc is struck through the gas-filled tube. Current flowing through this arc ionizes the gas and, in turn, excites the fluorescent powder deposited on the walls of the glass tube. The irregular nature of the current flowing in the tube causes the noise.

The cure is to add a capacitor across the line, inside the lamp fixture, or a pair of smaller capacitors

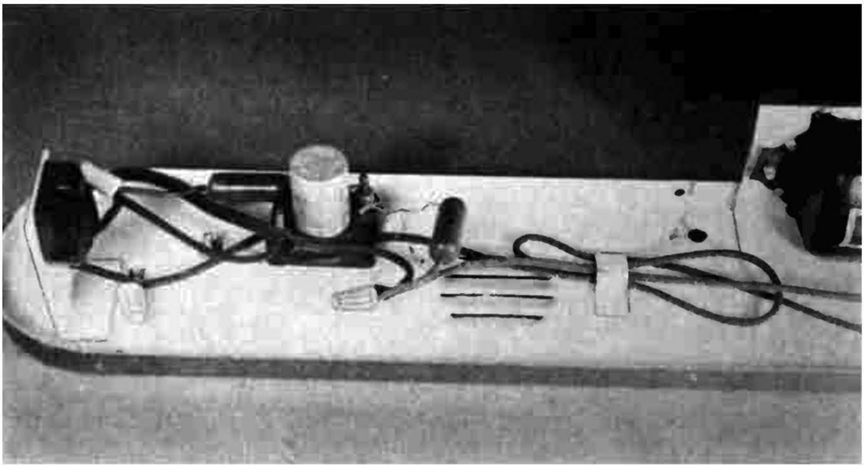


Fig. 6-16. Bypass capacitors installed inside a fluorescent-light fixture.

from each side of the line to the fixture (ground). A single capacitor should be about an .05 mfd (600V); the dual capacitors, about .01-.02 mfd. Special filters can be obtained in which the dual capacitors are all in one container; also included are flexible leads which can be installed inside the fixture. In cases of severe interference, try replacing the lamp or starter. Or install an LC filter in the line, also placing it inside the fixture housing. Fig. 6-16 shows two bypass capacitors installed in a fixture.

Neon-Sign Interference

Neon-sign interference is similar to fluorescent-light interference, and indeed comes from the same source —a very long arc inside a gas-filled tube. A transformer with a high step-up ratio must be used because the tubing requires approximately 1,000 volts per foot to fire the gas. Fig. 6-17 shows the basic circuit. The

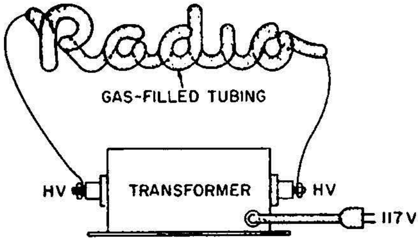


Fig. 6-17. The basic neon-sign circuit.

ionized gas itself is the light-producing agent. The arc discharge produces a very peculiar voltage waveform in the secondary, as seen in Fig. 6-18. This is actually a 60-cps wave-

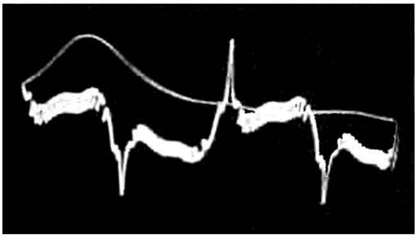


Fig. 6-18. Voltage waveform at secondary of neon-sign transformer.

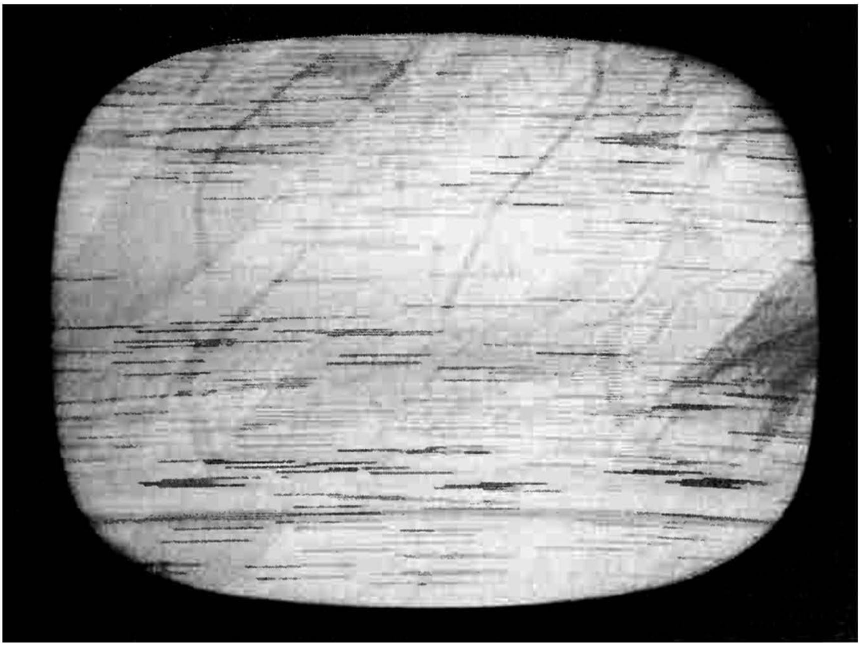


Fig. 6-19. Severe neon-sign interference on a TV receiver.

form. Notice the sharp spikes on the half cycle and the bursts of high-frequency oscillations on the waveform. Interference of this nature will give us a pattern similar to Fig. 6-19 on a TV receiver.

The voltages can run as high as 25-30 kilovolts in long tubing. This usually causes severe interference.

The cure is good grounding of the transformer housing, and filtering of the line input. Capacitors or filters similar to those used for fluorescent lights (Fig. 6-15) can be used; however, make sure the capacitors have a high enough voltage rating. Also, low-resistance (5k to 25k) suppressor resistors in series with the line will sometimes reduce the spike amplitude. If these measures don't bring the noise down enough, try wrapping a very fine insulated (enameled) wire around the whole length of the tubing and grounding it at each end. Make about two turns per foot. The wire serves as a partial shield and thus helps prevent radiation. Be sure all connections between tubing and wiring are tight; an arc at the connectors will increase the interference considerably.

Flashers in Electric Signs

Flashers are used to turn the lights in an electric sign on and off at regular intervals, to give the sign more attention value. If the contact in the flasher is dirty enough to cause arcing, it *will* attract all kinds of attention—mostly from irate radio listeners and TV viewers! Under the right circumstances, it can cause a tremendous amount of interference.

The smaller flashers are the worst offenders. Most of them are small "button"-type, thermally-operated switches which are inserted into the socket of an incandescent light. If they become noisy, connect about a .05-mfd bypass capacitor across the socket. If this does not reduce the noise to an acceptable level, replace the flasher.

On more elaborate signs such as neon displays, the flashers are larger and hence simpler to work with. Fig. 6-20 shows a typical example. The drum is driven by the motor, and the spring contacts, which connect to the different portions of the sign, contact a conducting surface on the drum. If trouble occurs, clean the contacts and connect bypass capacitors (approximately .01-mfd) across each set of contact points. Make sure the metal cover over the flasher motor and drum assembly is grounded. (If there is no metal cover, one should be made.) If the sign uses neon, an LC filter may be required in the line.

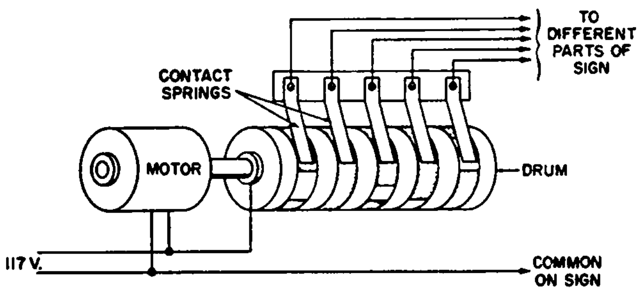


Fig. 6-20. Flasher system used on an electric sign.

"Ultraviolet Machines"

There may not be any "ultraviolet machines" left by now, but they really gave people headaches several years ago! The device consisted of a step-up transformer with a very high ratio, heavily insulated cables, and an "applicator." When the machine was turned on, a tube glowed blue because it was filled with gas. The pad on the end, when passed over the body, gave a small static-charge effect and the user could feel a very slight tingle from the leakage. This was supposed to cure various ailments.

The only thing this machine ever did was produce a high level of radio interference from the gas discharge! If you run into one, try an LC filter in the line, as close to the transformer as you can get it. This should reduce the radiation.

MISCELLANEOUS RANDOM NOISES

Power-Line Noise

Power-line noise is encountered most frequently in TV fringe areas, although it can be found anywhere around a power line. Its characteristic symptom on a TV screen is the two lines of dots seen in Fig. 6-21. This is heard as a roaring buzz in a radio, and once in a while in the TV sound if the signal is weak. The two lines of dots may be so weak that only a single line is visible, but if you'll look closely, you can almost always find traces of the second one. The dots ordinarily will be floating up and down the screen. This is due to the very slight phase difference between your location and the power-line frequency at the point where the program is originating.

These dots will also show up in the shop now and then while you're trying to align a radio with an FM sweep signal! The pattern will look something like Fig. 6-22. In fact,

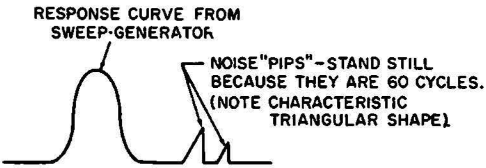


Fig. 6-22. Power-line interference in a sweep response curve.

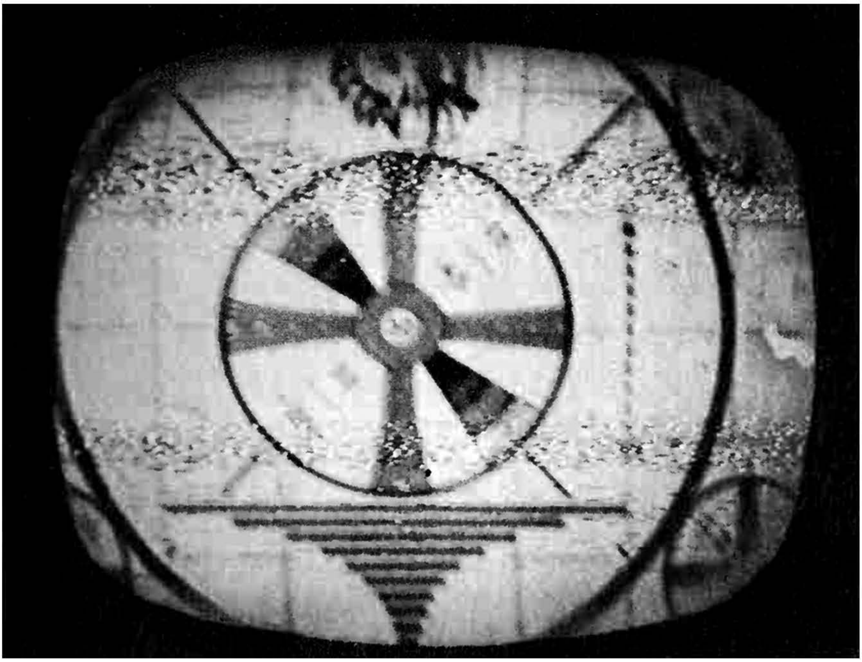


Fig. 6-21. Power-line interference in a TV receiver.

some technicians have spent quite a bit of time trying to make the two curves coincide!

The cause of this noise is a slight leakage in the power lines: power and light companies call it "hardware" noise. It is due to defective insulators or to improper or defective grounding of the "hardware" (cross-arms, metal brackets, etc.) on the pole. It can also be from a warped pole, which will cause a transformer to swing around until a wire is touching its case. The cure is to call the power company; they are always willing to clear up such difficulties, which could mean trouble in the lines later.

Battery Chargers

Although comparatively little noise comes from battery chargers, there is always the possibility, especially from the larger ones in garages and auto-parts stores. Fig. 6-23 shows a typical arrangement:

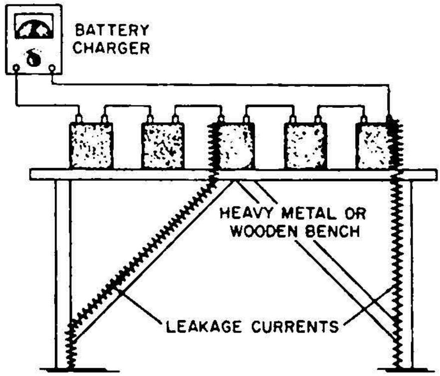


Fig. 6-23. A large battery-charging arrangement.

several 6- or 12-volt auto batteries are connected in series for charging, and a heavy-duty rectifier applies sufficient voltage to the series to send a charging current (ordinarily, 8 to 10 amperes) through them all.

Fig. 6-24 shows the appearance of such noise on a TV screen. It comes from leakage to grounded objects nearby. Sometimes the batteries are

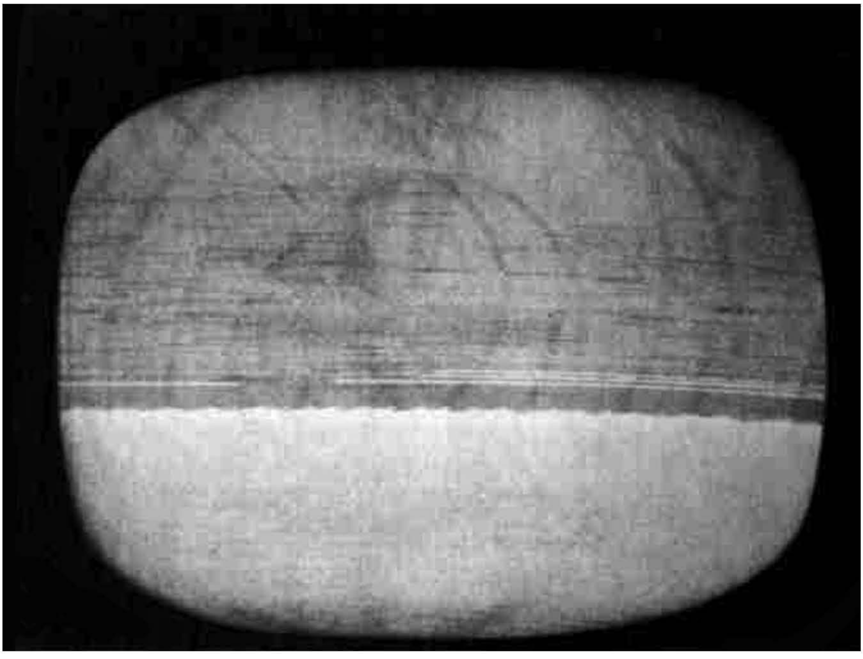


Fig. 6-24. Battery-charger interference in a TV receiver.

set on a heavy metal bench; even if the bench is wooden, moisture and the continual spillage of acid will soon make it conductive. This flow of intermittent leakage currents through the resistance of the bench to ground can cause noise. When this happens, install a heavy ground wire from the ends of the bench to a ground rod or water pipe, ground the metal case of the charger, and cover the bench top with an insulating material which is both water- and acid-proof.

Oil Burners With Electric Igniters

Some home and industrial heating systems use fuel-oil burners with electric igniters. These are similar to the spark-plug ignition systems used in automobiles, but are powered by transformers from the 110-volt AC line. This, as can be imagined, is a rich source of noise! There is usually a continuous arc inside the furnace, between the igniter points.

An LC filter added in the primary circuit (Fig. 6-25) will usually eliminate any noise. Fortunately, the furnace itself, being metal, acts as a shield. In addition, the igniter transformer is completely encased in metal, and the high-voltage igniters are inside the furnace combustion chamber. Thus, if we can prevent any noise from escaping through the power lines, we can reduce it to an acceptable level. Several companies make filters specially for this application which are encased in metal. They should be installed directly on the transformer case and be well grounded. As a last resort, resistor suppressors (R in Fig. 6-25) can also be added in series with the high-voltage side of the transformer. If the noise remains, have an oil-burner repairman check the gap of the igniter points. It may be too large, creating a much longer arc than necessary.

Arc Welders

Arc welders are somewhat like the little girl who, when she was good, was very, very good—but when she was bad, she was horrid! Most of them don't make much trouble. But when they do, they can tear up everything for miles around. The average small arc welder used by garages and machine shops doesn't seem to give too much trouble, probably because it is used so infrequently. However, an industrial arc welder on a production line, particularly the automatic type making many welds each minute, will cause pretty severe radio and TV interference. Fig. 6-26 shows a typical electric arc-welder circuit. This is a low-voltage, high-current type which generates a slightly lower level of noise than a high-voltage arc does.

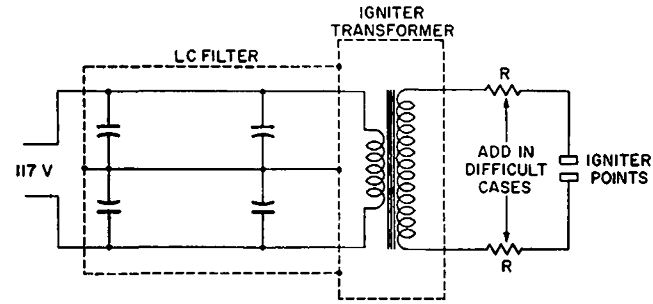


Fig. 6-25. Eliminating noise in an oil-burner igniter.

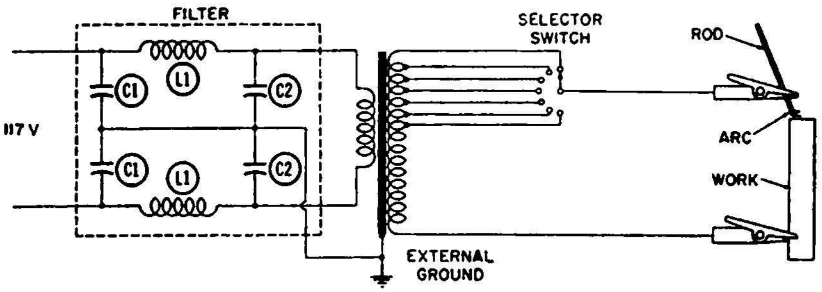


Fig. 6-26. Eliminating noise in an electric arc welder.

There is no way, of course, to suppress the arc itself. But we can reduce the radiation by adding an LC filter in the line and grounding the frame of the machine as shown. The coils (L1) should consist of approximately twenty turns of No. 6 enameled copper wire. Capacitor C1 is .01 mfd (600V) and C2 is .05 mfd (600V). If the arc welder must be reduced to absolute silence (for example, near an airport), the only thing left to do is build a screened room around it.

Ignition Noise

Ignition noise is one we can't do much about! It is caused by the radiation from unsuppressed vehicle ignition systems, mostly from older cars and heavy trucks. TV viewers living in deep-fringe areas alongside busy highways aften encounter considerable trouble from this type of noise. High-gain directional antennas can sometimes help; pointed away from the highway, they will reject part of the noise. However, if

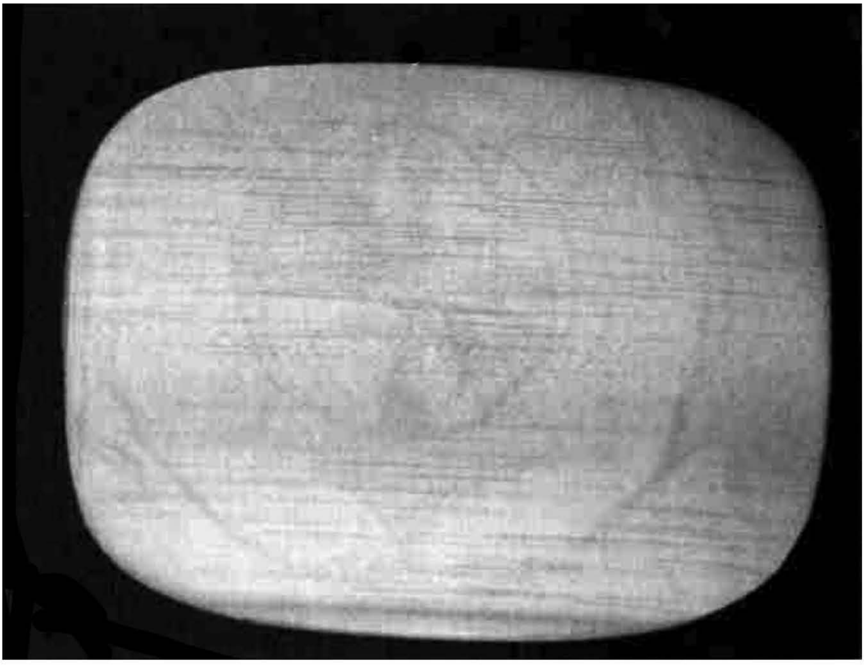


Fig. 6-27. Severe ignition noise in a TV receiver.

the station is so situated that the antenna must be aimed across the highway, it's just too bad! Fig. 6-27 shows the typical pattern of ignition noise on a TV screen. It is fairly heavy, like what you would get when a vehicle with an unsuppressed ignition system is being driven near the lead-in cable.

The use of antenna boosters will often help: these are high-gain broad-band amplifiers mounted on top of the mast, close to the antenna. Most of them use shielded coaxial cable between the booster and TV set. This, together with the increase in signal-to-noise ratio, will often help. By increasing the signal level in the lead-in, ignition noise pickup can often be minimized.

Ignition noise in your own car, annoying when someone drives into the garage during your favorite program, can be eliminated by applying suppression to it. (See Chapter 7.)

Traffic Lights, Railway Signal Systems, and Other Warning Lights

If you live close to a traffic light or railroad right-of-way, you may hear the pulsed currents from them. Traffic lights and railroad-crossing warning lights use flashers, motor-driven selector switches, and similar devices which are always potential noisemakers. There is nothing *you* can do, if the noise has been positively identified as coming from a traffic light for example, except get in touch with the traffic division. Their maintenance men will install noise filters or clean the contacts.

Railroad block-signal systems use pulsed currents which can make a peculiar sound in radio—a triple clicking, something like "ka-plick-et, ka-plick-et." Once again, your only recourse is to get in touch with the signal maintenance department of the railroad and see if they can filter out the noise.

TVI From Converted TV High-Voltage Supply

Many old TV receivers have been converted to larger picture tubes, which often required adding a new high-voltage supply. If the job was not done too well, arcing and radiation of interference can occur which can tear up the pictures of neighborhood TV sets. In one case this interference apparently was not bothering the owner of the offending set, but was causing trouble with his neighbors'!

Electric Fences

Electric fences are most popular in rural areas, of course, but now and then they are found in or near

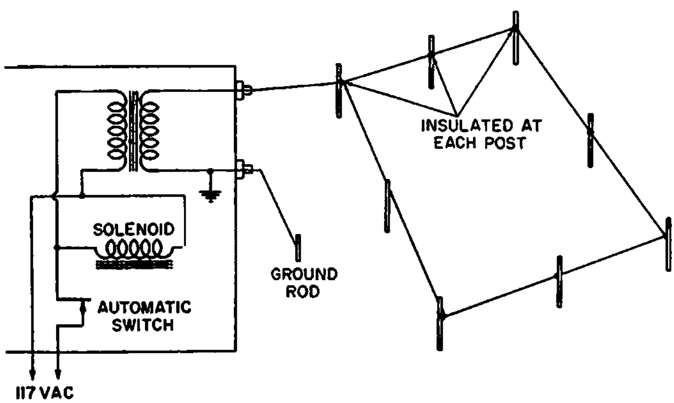


Fig. 6-28. A typical electric-fence circuit.

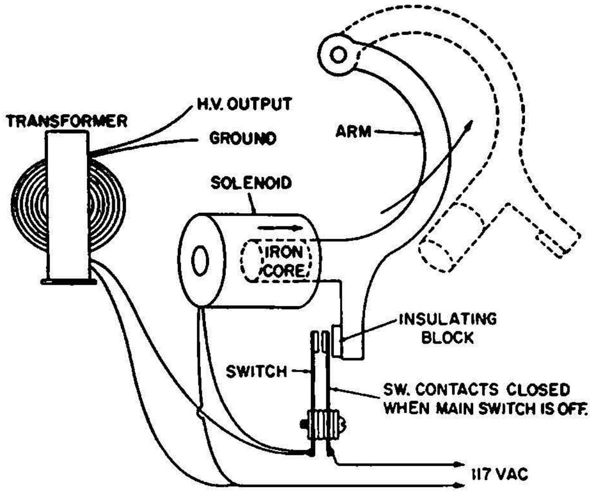


Fig. 6-29. The automatic keying device for an electric fence.

cities. They consist of a step-up transformer and an automatic keying device which sends high-voltage pulses through the fence (Fig. 6-28). One common type uses a pendulum arrangement for keying the transformer, as shown in Fig. 6-29. The arm swings down, closing the switch on the transformer and sending a pulse of current through the fence. At the same time, a solenoid is energized and throws the arm, which forms the core of the solenoid, back up. This results in a pulse of cur-

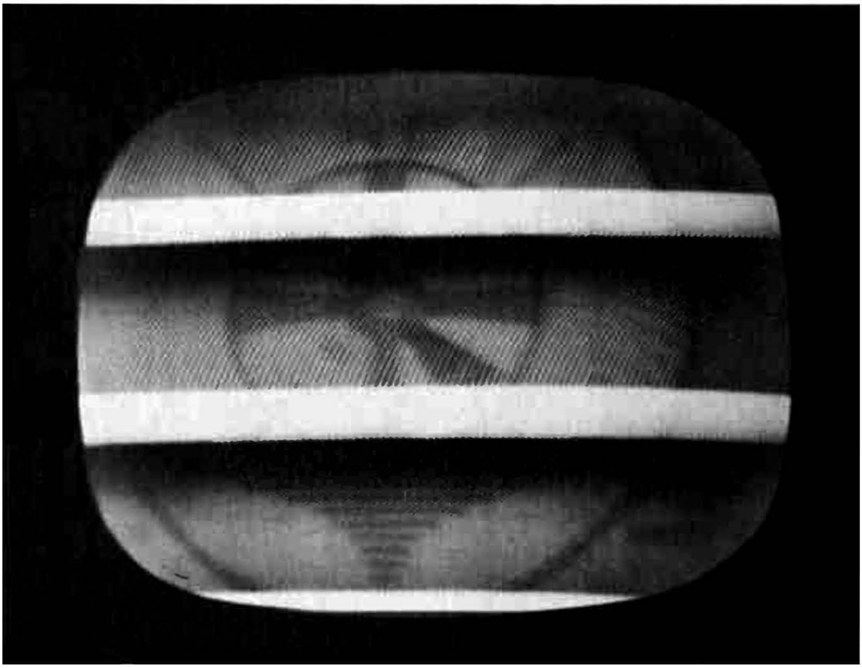


Fig. 6-30. Interference from an electric fence.

rent through the fence about once a second.

The fence itself, which requires only a single wire, must be mounted on insulators. The high voltage is pulsed for safety's sake. Otherwise, there would be a shock hazard to both humans and animals.

The fence, often over a thousand feet long, makes an excellent antenna; the popping noises from it can sometimes be heard for miles! In some instances, getting the noise —which usually resembles Fig. 6-30, although it may take on several different shapes—out of one of them can be very difficult.

A bypass capacitor (.01-.05 mfd) must be used across the contact points, and resistors (approximately 10K) can often be added in series with the high-voltage circuit to damp the pulses. An LC filter in the supply line will complete the job. This filter should have a time constant as close to that of the pulses as possible, even though some good-sized capacitors may be called for. In difficult cases, the arrangement in Fig. 6-31 may have to be used.

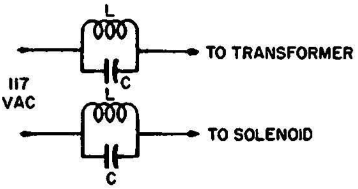


Fig. 6-31. LC filters added to the input of an electric fence.

INTERMITTENT RANDOM NOISE

Electric Ranges

Troubles due to electric ranges are always in either the switches or in bad connections on the elements. The culprits are mainly old ranges using open elements of coiled resistance wire. (There are still a few such ranges around!) The very heavy currents flowing through the

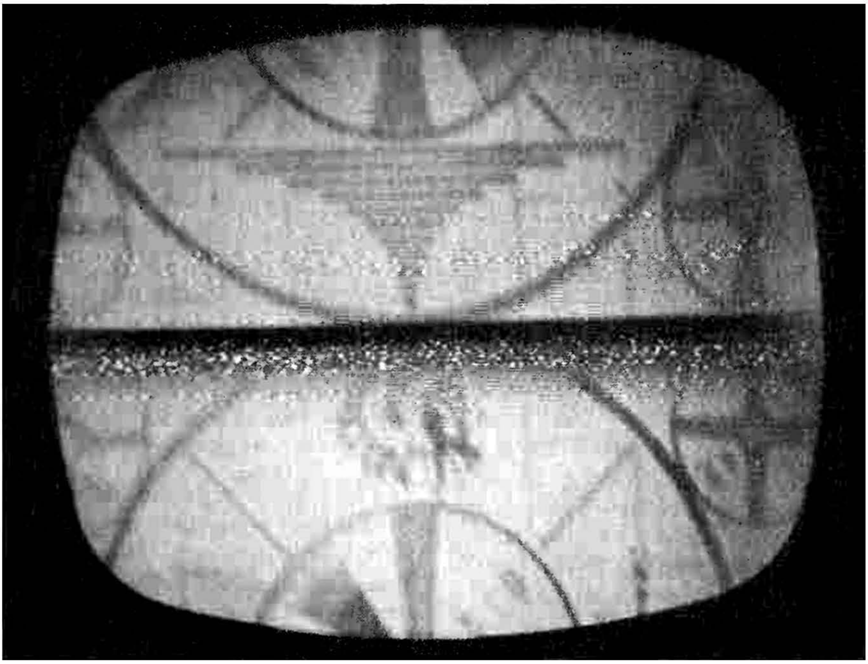


Fig. 6-32. Ragged noise pattern in a TV receiver, caused by intermittent arcing of an electric-range switch.

switches cause overheating of the contacts and intermittent arcing. This gives us the characteristic range-noise pattern shown in Fig. 6-32.

The best remedy is to clean or replace the switch, the latter being preferred. (The best cure, of course, is to replace the range! However, this is normally impossible.) Such troubles are also found in electric hot plates using open-wire elements, and in electric toasters, grilles, table ovens, or any other electrical appliance having heating elements of one kilowatt or larger.

It is usually not too good an idea to place bypass capacitors across the contacts on the switches unless the capacitors are heatproof, because they must withstand temperatures far above normal. Some of the latest "hard-shell," plastic-encapsulated capacitors might work, but check their heat range *very carefully* before installing them—a wax paper capacitor would melt entirely in about five minutes!

Immersion Heaters

An immersion heater is a resistive element, usually about 50 to 100 watts, built into a waterproof case with a handle (or sometimes, only a line cord). The heater is used to heat water, which is done by simply dropping the whole thing into a vessel. It must be kept submerged at all times. If the water is allowed to boil away, excessive heat may crack the housing. These cracks, sometimes so small they are invisible to the naked eye, allow water to get into the heating element. In addition to the shock hazard, this results in a ripping, frying noise in radios. The only cure here is to replace the heater.

Telephone Interference

Telephone interference is rarely, if ever, found in modern telephone exchanges; the culprit in this case was a small town exchange using obsolete equipment.

The noise was a rapid, crisp "pop-pop-pop" at the same speed. It was heard over several blocks; tracing

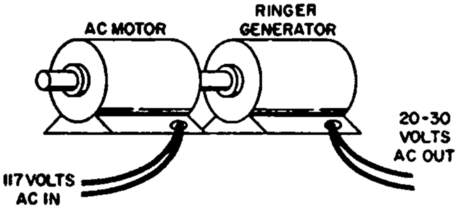


Fig. 6-33. Motor and "ringer" generator in a telephone office.

with a portable radio finally showed that the noise was more prominent near telephone wires. Investigation of the telephone office unveiled a defective "ringer" generator (Fig. 6-33), a device which supplies low-voltage AC for ringing the telephones. Slip rings at the generator output (Fig. 6-34) contact the rotating armature. In this case, a dirty spot on one of the slip rings was feeding a sharp pulse of noise into the telephone wiring, which furnished enough antenna to radiate over quite a large area!

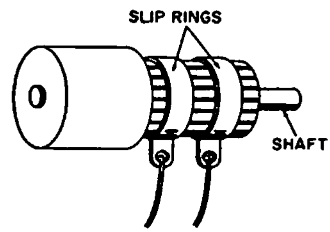


Fig. 6-34. Slip rings at the "ringer"-generator output.

The only other possibility of noise in modern equipment is an occasional "pop-pop-pop," slower than the first, as the dial switching mechanism returns to the stop. The telephone company will gladly install bypassing if notified that the noise is annoying. (Never attempt to repair telephone company equipment! It is against every rule in the company's books.)

Heating Pads

Heating pads are made of resistance wire wound around an asbestos core and sewed to a fabric foundation to keep the wire in place. Usually three amounts of heat can be selected by a switch. Thermostats smaller than a pencil eraser are inserted in series with the resistance wire to hold the heat constant. As the thermostat opens and closes, it causes arcing, especially in the older heating pads. Dirty contacts in the thermostat increase the noise. Later models are not as troublesome because of their improved contacts.

There is no known remedy or filter for this trouble except a new heating pad.

Electric Blankets

Electric blankets are similar to heating pads, but are much larger and operate at a lower temperature. The troubles caused by blankets are about the same as for heating pads—for example, a defective thermostat.

The blankets have an external thermostatic control box containing thermostats, switches, heat controls, etc. The contacts will cause noise by arcing. Connecting a bypass across them will cure most of the trouble.

RF INTERFERENCE IN AUDIO SYSTEMS

Audio Amplifiers

Under some circumstances the leads of an audio amplifier will pick up enough radio-frequency signals to be annoying. If a strong RF field is present near them, enough RF will be picked up to impress a sizable voltage on the grid of the input tube and thus cause interference.

There are two solutions: One is to shield the input leads from the phono cartridge, mike, etc. Fig. 6-35 shows how. Use shielded leads for all input leads, and bond the turntable chassis to the amplifier chassis. Be sure the amplifier metal cover is in place and tightly grounded. If necessary, ground both chassis to an earth ground as a water pipe. The other method is to install RF filtering in the grid circuit of the input tube. The upper limit of frequency response in even the "highest hi-fi"

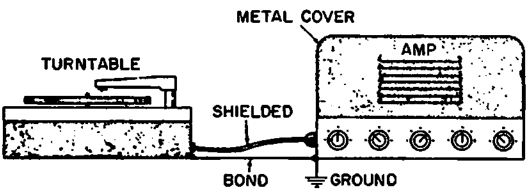


Fig. 6-35. Shielding an audio amplifier.

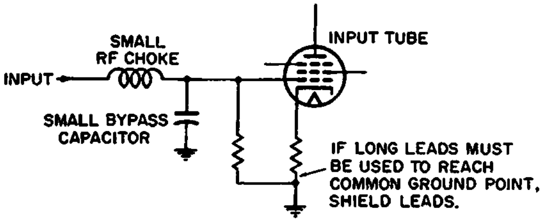


Fig. 6-36. Filter circuit added at input of audio amplifier.

is about 25 kc, to be liberal, but the RF frequencies we want to get rid of are much higher. Therefore, we can use a low-pass filter in series with the grid leads. Even with a lower cutoff at, say, 50 or 75 kc it will still cover all the necessary RF frequencies.

Fig. 6-36 shows the filter circuit. Values are not too critical; the average capacitance would be 100 mmf or smaller. The reactance of a 100-mmf capacitor at 20 kc is around 80K ohms; this becomes about 2,000 ohms at the frequency of the lowest radio station, or 550 kc. So, we can use any capacitance low enough that it does not cut off the high-frequency response of the amplifier and still offer a low impedance to RF.

By inserting a very small RF choke in series with the grid lead, as close as possible to the input grid connection at the tube socket, we can reduce the RF signals even more. A 50-microhenry choke, for example, would have a reactance of about 200 ohms at 550 kc, but only 2 ohms at 20 kc. The use of such a filter, together with careful shielding and grounding, should reduce the RF voltages at the input to a point where they are no longer annoying.

Watch out for long leads in *any* circuit around the input tube! Even cathode or filament ground leads can pick up RF under some circumstances. If a cathode lead, for example, must be run eight or ten inches to reach a common-ground point (a quite common practice to minimize hum in some circuits), it may be necessary to shield it. Ground the shield at both ends, near the socket, and at the common-ground point.

Shielding in the grid circuit, if necessary, must be of very low-capacity shielded wire; the very small shielded wire, like the type known as phono pickup leads, usually has a comparatively high capacitance. Practical hint: run a very small wire through a piece of discarded auto-radio lead-in shield, and ground the shield at both ends. This will give shielding with minimum shunt capacitance. (Shunt capacitance cuts down the high-frequency response of an amplifier.)

Drive-In Theater Sound System

The drive-in theater in this case history was located about 400 feet from the transmitting tower of a 500-watt radio station. When the station was on the air, its programs were being heard in the drive-in's sound system, sometimes slightly louder than the sound from the film!

It was thought, at first, that the large network of speaker wiring was picking up the undesired RF. A little more thought ruled out this possibility: the speaker wiring was all buried at least two feet underground, most of it in conduit! The source of the pickup was finally pinpointed to the AC power wiring. It was bringing the RF signals inside the projection booth, and from there they were being radiated from the power lines into the grid circuits of the amplifiers.

An audio amplifier working from a photoelectric-cell input has an extremely high input impedance; this caused the amplifier to rectify the signals in the grid circuit, similar to grid-leak action. The cure was a heavy shielded LC filter in the power line, thorough shielding of the PE cell leads between the sound heads and amplifiers, and small RF bypass capacitors (220 mmf) to ground from the PE cells and at the grid connections on the tube sockets.

Airport Intercommunication System

The wartime airfield had a 500-watt transmitter on 317 kc; also a large intercommunication system between the maintenance hangar, operations, flight line, supply, machine shop, etc. Whenever the tower transmitter was keyed, it came in on the intercom system louder than on any radio receiver on the field! The reason is shown in Fig. 6-37A. The system was the older type which in effect consisted of a microphone (the speaker), a very long line, and an amplifier on the other end (Fig. 6-37B). Shielded wire should have been used; because of war-time shortages, it was not. The unshielded wire picked up the high-level radio signals from the tower, and the input grid rectified them.

The cure was not bypassing, because of the very high signal level. The intercom circuits were "reversed" by rewiring the switches as shown in Fig. 6-37C. Now the microphone and amplifier were at the same end, and the long line of unshielded wire became a 45-ohm speaker wire, which does not respond to RF at all.

Theater Sound System

A small theater sound system picked up a l-kw amateur transmitter much louder than it did the film sound! Although at first the ham was blamed, a closer check disclosed that the sound system also picked up a local 250-watt broadcast station over a mile away! So, the fault was obviously in the sound system. The conventional remedies were tried—a small RF bypass capacitor across the input grid, and finally a larger one, but with no result. The PE cell inputs were taken off—no im-

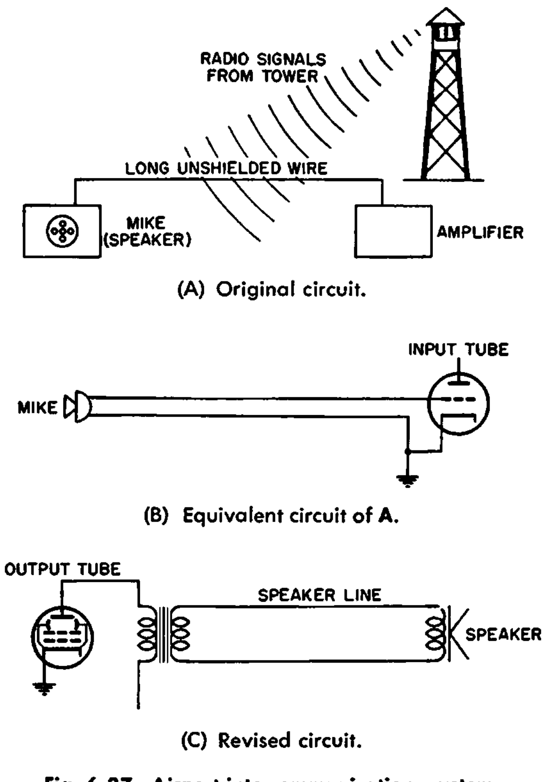


Fig. 6-37. Airport intercommunications system.

ment.
provement. Filters were installed in the AC line—very small improve-

After some "head scratching," we finally ground the input grid with a small screwdriver. No result; the music from the radio station came in as clearly as before! Finally, the cause was found. The *cathode* of the input tube was returned to a common-ground point outside the amplifier case. This lead was found to be over 18 inches long! Grounding the cathode directly at the tube socket stopped all the trouble. Evidently the RF was being picked up on this excessively long cathode wiring and was feeding into the grid of the second amplifier stage.

The general procedure in such cases is to find out where the RF is getting into the circuit. Clean and fasten all shields. The bottom plate of this amplifier had been missing for a long time; even though the amplifier was in a solid metal case and presumably was well grounded, some RF was still leaking into it from somewhere. Obvious sources were the power wiring and the PE-cell input lines.

In some instances the input tubes will have to be shielded, and you may find "GT" tubes in sockets that should have metal tubes. If so, add well-grounded external shields.

Wireless Intercommunication Systems

A variation of the standard "wired" intercom system uses a low-frequency carrier impressed on the AC power lines. The carrier frequency ranges from 100 to 150 kilocycles and has a comparatively short range, usually within a single building.

Noises riding the power and light wiring will be picked up, since the "receivers" are nothing but LF radio receivers. Arc noises, motors, and radiating fluorescent and neon lights will cause interference. It can be tracked down by tracing the light wiring throughout the building, using a portable radio, until the source is found.

RF INTERFERENCE IN RADIO RECEIVERS

Interference from TV High-Voltage Supply

Many of the older TV sets had poor shielding in the horizontal-sweep circuits and high-voltage supplies. Also, careless technicians often forget to replace the shield cover for the flyback and thus allow the 15,750-cycle sweep frequency and its numerous harmonics to escape. A large number of harmonics are generated in this 15.75-kc signal. These harmonics can cause interference in broadcast radio receivers up to two or three blocks away.

The typical symptom of such interference is a series of "tweets" or "birdies"—oscillations at regular intervals over the entire dial of a BC radio. Usually they will run about 75 kc apart, becoming stronger toward the lower end of the band.

The cure is to shield the offending TV receiver. Replace missing HV cages or covers, and in severe cases, cover the inside of the cabinet with grounded aluminum foil or copper screen. For mild cases, it is often sufficient just to wrap the yoke leads with aluminum foil and ground the foil to the chassis.

Interference from Phonograph Oscillators

The wireless phonograph oscillator consists of a tiny radio transmitter modulated by the audio signals from a phonograph pickup. Its operating range is restricted by the FCC to not over 50 or 100 feet. However, some ingenious person will sometimes find ways to extend this range quite a bit. A few have even operated their own radio stations, complete with "disc jockeys" and, in some instances, commercials!

If such interference is heard in the broadcast band, it can usually be tracked down with the auto radio and a db meter. The range is extended by adding more antenna to the transmitter, and most of the signal will ride along the power lines. Such transmissions are completely illegal, of course; and if you find one, tell the operator that if he doesn't "cease and desist," Uncle Sam will hand him a stiff fine and even toss him in the "klink."

Carrier-Current Systems

Many colleges, hospitals, sanitariums, and similar institutions use what is sometimes called "wired radio." The correct name is carrier-current system; it consists of a special transmitter which sends its signals over the AC power lines to broadcast music, announcements, or local radio programs inside the institution. Special receivers are required because the carrier must be quite low in frequency to "stay on the wires."

Now and then, too much RF power will be used and such systems will interfere with BC radios, low-frequency aircraft communication systems, etc. Such interference is usually easy to detect! The operators, who do not realize their signals are getting out, can be identified from their call letters or station identification! Resetting the power output of the transmitter to its proper level will cure the interference. In some cases, LC filters tuned to the proper frequency can be inserted in the primary supply lines to confine the signals to the internal wiring.

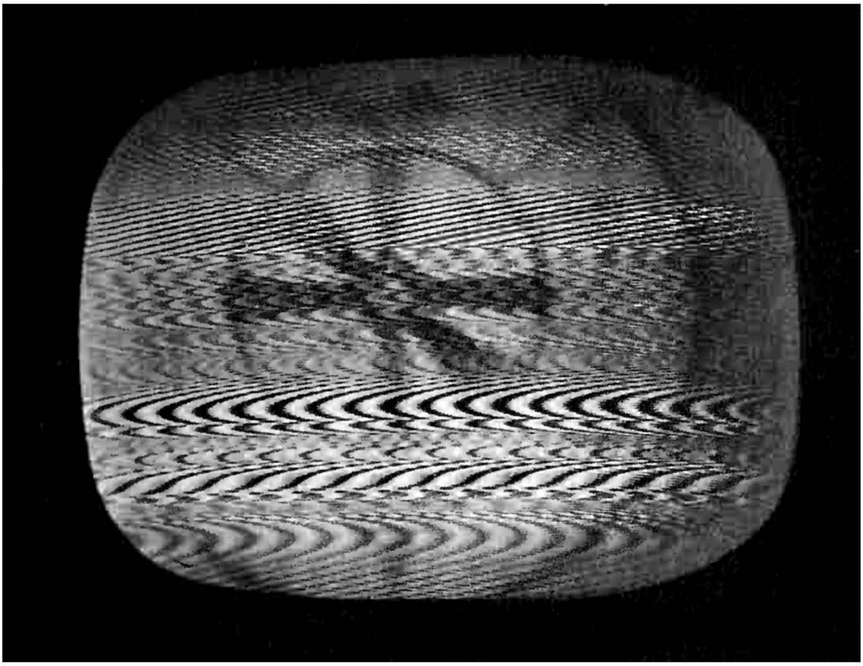


Fig. 6-38. Interference in a TV receiver, caused by a radio transmitter in a passing police car.

RF INTERFERENCE IN TELEVISION RECEIVERS

Police and Other Communications Transmitters

Fig. 6-38 shows a typical pattern when TVI from police and other communications transmitters is encountered. This is a somewhat unusual type of interference, and its occurrence depends directly upon a large set of coincidences—the TV channel being watched, the frequency of the short-wave transmitter, and its condition. The pattern will consist of herringbones, wavy lines, and assorted streaks which are continually in motion; sometimes the sound may also be heard. The reason is that these transmitters are all FM; the continually changing frequencies and sideband products result in the interference pattern seen.

This pattern usually is seen only when a radio-equipped car passes the TV antenna while transmitting. However, TV viewers living near a powerful base station may encounter this interference every time the transmitter is keyed. This definitely points to a defective transmitter, and it should be reported to the company operating the station. The interference may even be so strong it almost completely blacks out the TV screen on certain channels. Fig. 6-39 shows what happened when a station transmitting on 36 mc developed a very strong second-harmonic radiation as a result of transmitter damage from lightning. The lightning damaged the harmonic filter in the antenna line (required by the FCC); the second harmonic of the carrier was allowed to pass on to the antenna, where it was radiated the same as the carrier. It

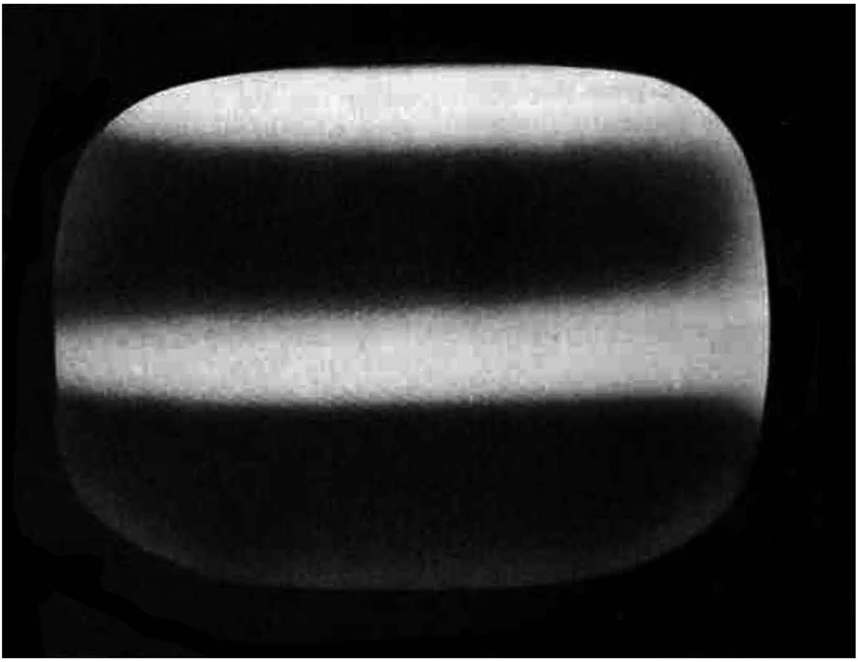


Fig. 6-39. Severe interference on Channel 4 due to strong second-harmonic radiation from a 36-mc transmitter.

blacked out Channel 4 (66-72 mc) all over a small town! This pattern also is in continual motion: the number and type of lines change with every word in the modulation.

False TVI in Color Reception

In some makes of color TV sets, beat patterns may be encountered which look like adjacent-channel interference. For instance, if a Channel-4 station is being received in a fringe area and there is a Channel-3 station nearby, a beat interference may be seen. This is caused by the nineteenth harmonic of the 3.58-mc color subcarrier oscillator beating with the incoming signal. Check by pulling the 3.58-mc oscillator tube. This trouble can usually be remedied by cleaning the short coaxial-cable link between the tuner and first video IF.

A similar case, but with a different cause, will be noted on Channel 8. The beat this time will be seen on color TV programs. It is caused by the fourth harmonic of the picture IF being generated in the video-detector circuit and picked up by the twin-lead between the antenna terminals and tuner. Shielded twin-lead can be used here or traps can be used in the video IF, depending on the make of TV. The set manufacturer usually has a service hint on this; for example, one manufacturer recommends installation of a 22-mmf capacitor across the secondary of the fourth video-IF transformer, and some wiring dress.

FM Receiver Radiation

In some cases, FM receivers which radiate a fairly high signal from their oscillator or mixer stages can cause interference in TV sets. The patterns will vary, but in general will resemble the one in Fig. 6-40. The characteristic beats may cover the whole screen or only a portion of it.

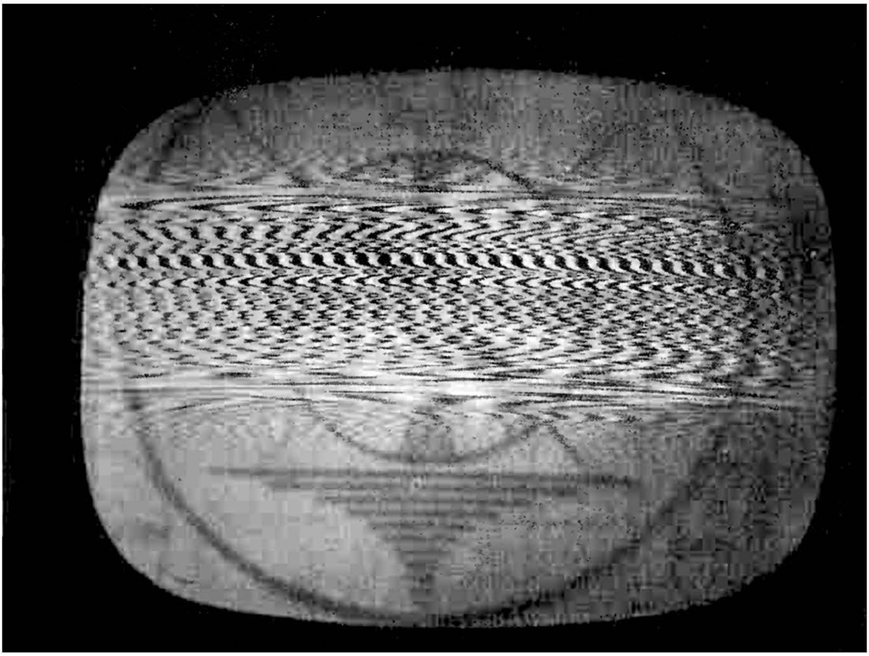


Fig. 6-40. FM receiver radiation in a TV receiver.

Locate this interference with a portable field-strength meter and probe, or by checking the neighborhood to see which FM set is on during interference. Usually, it is not too far from the TV set being interfered with.

RF Industrial Heaters

There is still some industrial heating equipment in use for sealing plastics, etc., which utilizes RF energy as the source of heat. These devices are simply radio transmitters. Some of them, with outputs up to 3 kw, operate on a fundamental frequency which can cause tremendous TVI if any is allowed to escape. The characteristic pattern of such interference is shown in Fig. 6-41. Not all heaters will make exactly this pattern, of course, but the similarity will always be there—the fringes around a single, heavy black bar. The reason is that most of the machines use half-wave rectified AC plate supplies and there is always a strong 60-cycle component in the RF signal.

This interference can be traced with several directional TV antennas, as outlined in an earlier chapter; it is usually VHF and is pretty directional. Under some circumstances it will also interfere with police radios and similar equipment, and even with AM radios.

The cure is a thorough cleaning of the machine (Fig. 6-42). Clean and tighten all shielding, replace all missing screws, and ground the cabinet. Most of this trouble is due to leakage from the cabinet and across insulators, sockets, etc., inside the final stages of the machine. All parts carrying high RF in these machines are mounted on ceramic standoffs; clean the standoffs with carbon tetrachloride, but keep your fingers away from them. Even the small amount of grease left by your fingertips is enough to catch dust,

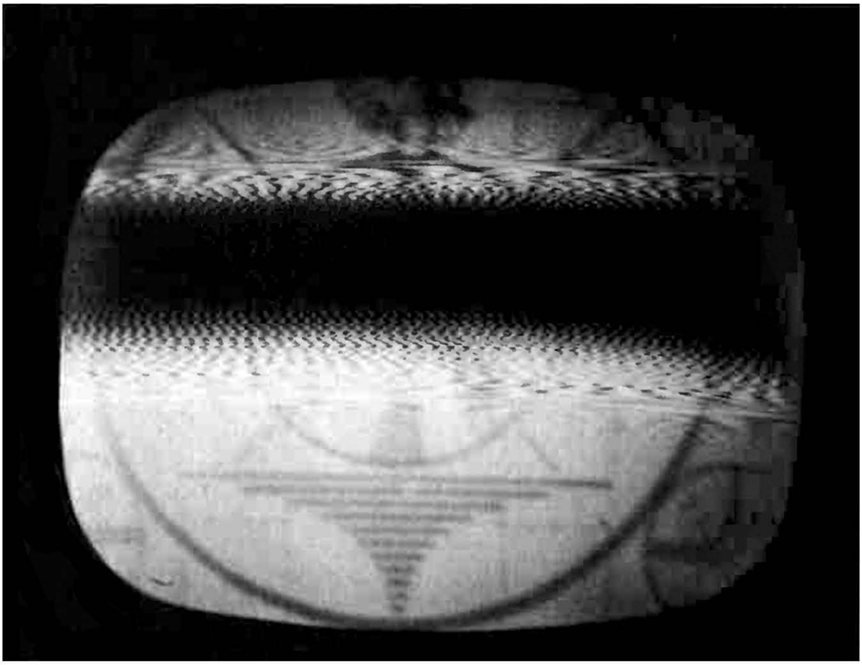


Fig. 6-41. Interference from an RF heater in a TV receiver.

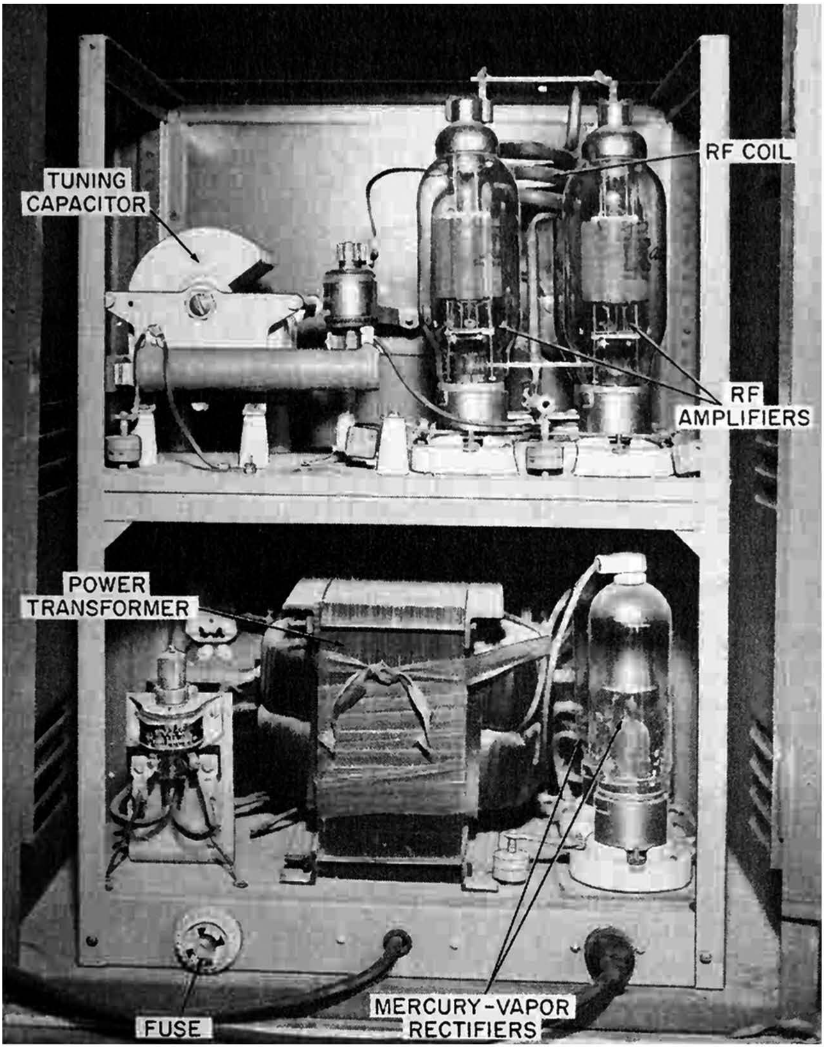


Fig. 6-42. Rear view of a typical RF induction heater.

which will eventually cause leakage.

If noise is being radiated through the AC power line, install an AC line filter. Fig. 6-43 shows the construction of one. The coils must be capable of carrying the heavy currents—50 to 75 amperes in many instances—drawn by the machine. The coils should consist of four to six turns of No. 0 or 00 solid copper wire, or ⅛-inch copper tubing. The capacitors must have a high voltage rating because of the high RF voltages which may be present. The 50-mmf, 20-kv types used as TV high-voltage filters are ideal. Mount the components on phenolic insulating blocks, as shown, and enclose the assembly in a metal box mounted as close to the machine as possible. Run the power-line leads through conduit to the machine. Be sure the case and conduit are connected to a good earth ground. Additional filter sections can be added in series if necessary.

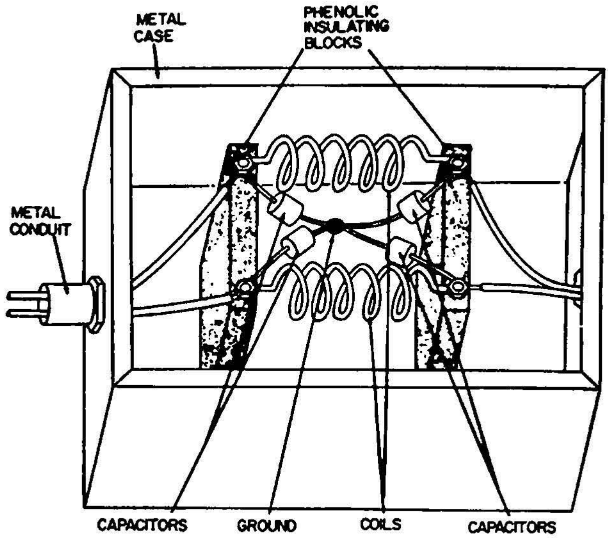


Fig. 6-43. Construction of an AC line filter for an industrial heater.

Community or Master Antenna Systems

Community and master antenna systems, or any system which transmits TV signals over cables, can cause interference if the shielding is not perfect. The FCC has issued a regulation covering the amount of radiation permissible from such systems, and it is very low.

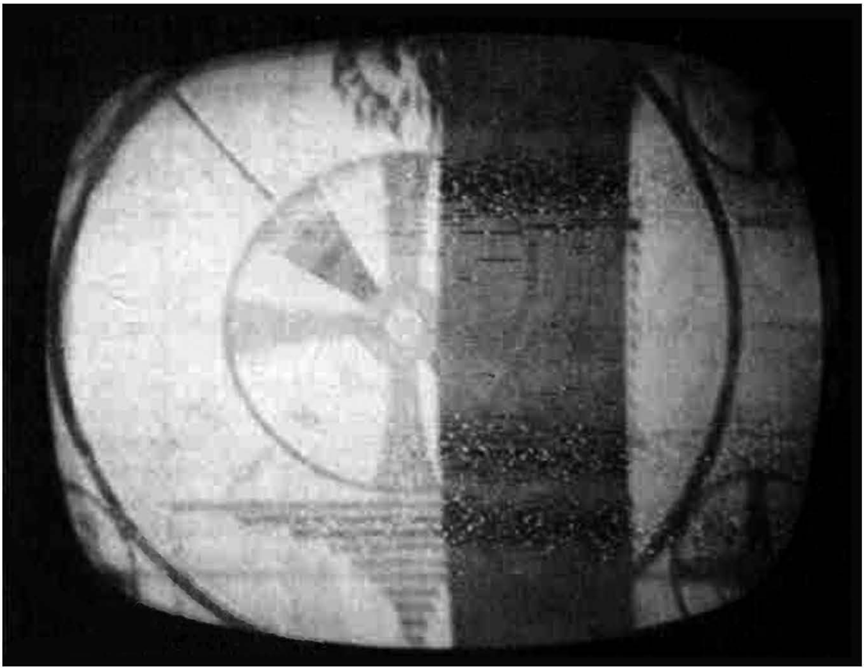


Fig. 6-44. A typical "cable bar" in a TV receiver.

The interference takes the form of ghosts in most cases. It is picked up on TV sets using antennas in the vicinity of cable systems. Usually, the characteristic symptom is a horizontal blanking bar, or sometimes an almost complete picture, picked up at the same time as the signal from the station. (See Fig. 6-44.) The bar may be either black or white. Another clue is the pickup of signals from a station while the antenna is pointed away from it!

The cause, of course, is RF leakage from the high-level transmission lines—usually in the shielded amplifier boxes. If the lids are not tightly fastened or the amplifier is run at too high a level, there will be leakage. The displacement of the blanking bar is caused by the difference in speed between the signals in free space and those in the coaxial cables of the system. This usually amounts to 20 or 25 microseconds—just enough to cause the blanking bar to appear in the center of the screen.

The remedy, of course, is to call the office of the cable system and give the location and direction of the interference. Their technicians will gladly correct the trouble. The same troubles are found in master antenna systems, but the symptoms are harder to identify. Because of the shorter runs of cable, the lag will be much less and so the characteristic ghosts may be very closely spaced. In fact, they may be so close that they only make the picture look fuzzy or out of focus. A quick check here is temporary substitution of a directional antenna to see if the signals from a station are picked up from the wrong direction (i.e., toward the cable amplifier box).

Similar difficulties may be encountered in isolated areas. Several cases of interference have been found in areas where the antenna was located on a mountaintop, with a long transmission line running

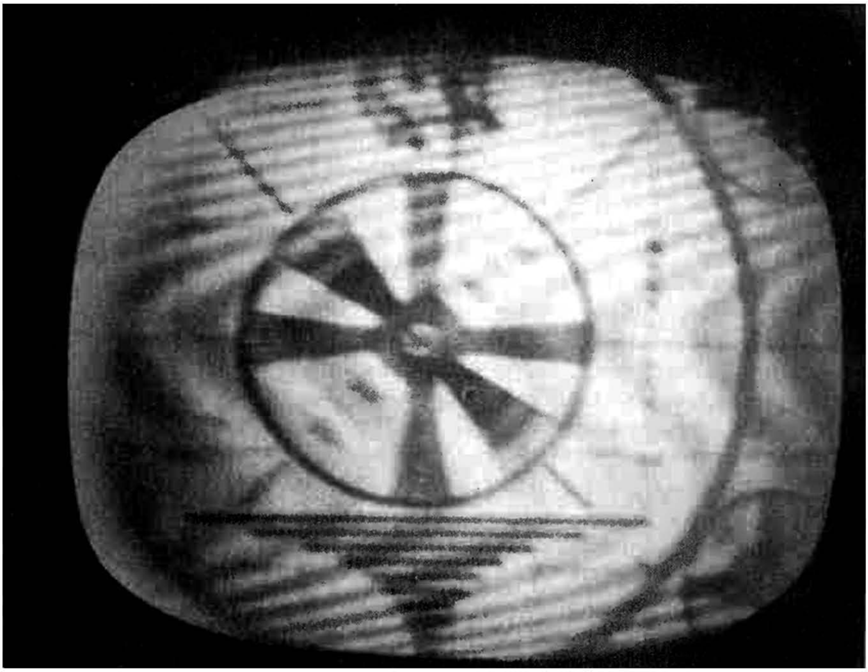


Fig. 6-45. RF beat interference in a TV receiver, caused by an oscillating booster.

down to the house. A booster was used at the antenna, and the transmission line was improperly terminated. As a result, standing waves were set up and the signals were radiating from the transmission line, interfering with other sets not connected to the system.

In other cases, the boosters themselves have been guilty. Trouble in the circuits can cause a high-gain booster to go into oscillation. This causes radiation of signals, harmonics, etc., which will interfere with other TV sets (Fig. 6-45). In some peculiar cases, this can happen without interference to the TV set connected to the booster!

Many of these boosters are automatically switched off when the TV set is turned off. If the automatic switch fails, the booster may remain on all the time and cause trouble.

INTERFERENCE FROM AMATEUR TRANSMITTERS

Although the writer isn't an amateur radio operator, he's very much in sympathy with them; in practically all cases of TVI, the customer's first thought is to blame a ham operator somewhere, even though the TVI may be caused by his own kitchen mixer! From actual experience, we have found that not one case in a hundred blamed on ham operators is actually due to them—that is, to a defect in the ham transmitter itself! A great many amateur transmitters nowadays, especially the higher-powered types (the "full gallons"; 1 kw, the amateur limit) are either factory-built or kit types with full TVI-proofing (if correctly assembled).

Actually, most of these complaints arise from poor design or defective parts in the front-end of the TV receiver! The front-end must accept signals over a 6-mc bandpass, and some sets will give a pretty fair pickup over a much wider range of frequencies! Selectivity, in a TV front-end, is merely a figure of speech!

However, because of the accusations—true or false— in this section we will depart from the brief case history type of approach and enter into a more thorough discussion. In the following paragraphs we will discuss methods of eliminating interfering signals at the receiver, as well as how to make sure the amateur transmitter is not radiating harmonics.

Harmonic Radiation

Much harmonic-radiation interference, which usually resembles Fig. 6-46, is caused by spurious or legitimate RF radiation from transmitters of other services such as police, aircraft, or two-way radios. According to FCC rules and regulations, harmonic emission by *any* licensed transmitter must be more than 60 db down to the fundamental (the carrier frequency). This is read at the second harmonic frequency (the strongest), and emission of all other harmonics must be checked at least once a year in all broadcast stations—whether AM, FM, and TV. This is checked during the "proof of performance" tests, which include amplitude readings of the second harmonic taken directly under the transmitting antenna. So, there is only the smallest chance that any broadcast station is actually radiating harmonic energy.

This is not to say there cannot be harmonic interference in receivers of any kind. Far from it! However, it is caused by the receiver itself! The simpler sets with no RF-amplifier stage aren't bothered because of the low RF gain, but receivers that do have them, especially the lower-priced sets, often are if the interstage coupling is not a very high-Q

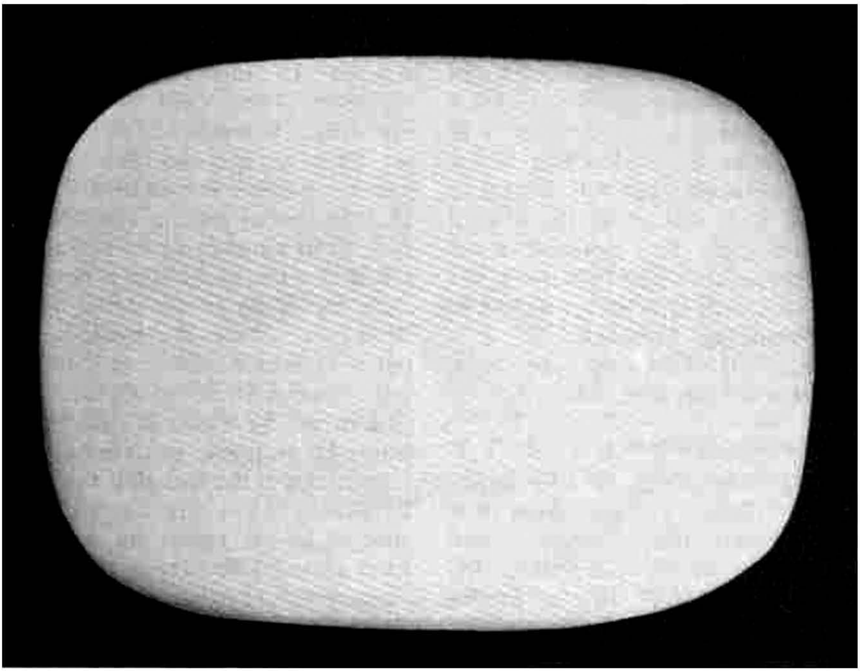


Fig. 6-46. RF beat interference in a TV receiver, caused by another transmitter.

transformer. On some sets of this kind, you can tune in a broadcast station on its second harmonic; for example, a station at 1450 kc will be heard at 2900 kc. This is the second harmonic frequency, of course. But it isn't coming from the station; it's being generated inside the receiver! The RF-amplifier stage picks up a strong signal from the station at all times; unless the front-end is *very* selective (and most usually aren't!), this 1450-kc energy will be present in the output of the RF-amplifier stage. Also, as in any amplifier circuit, the second harmonic of the received signal will be present in the RF-amplifier plate circuit. Thus, with the oscillator and mixer stages tuned for a 2900-kc signal, there will be sufficient second-harmonic signal from the RF-amplifier tube to beat with the oscillator signal in the mixer stage and produce the IF frequency. Incidentally, a trap, tuned to the frequency of the strong local station and connected in the grid circuit of the RF stage as shown in Fig. 6-47, will often help reduce these false harmonics.

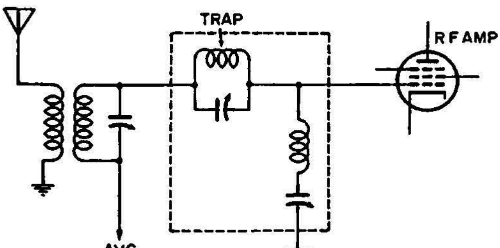


Fig. 6-47. Trap connected in an RF-amplifier grid circuit to reduce "false harmonics."

If the receiver is near a strong local transmitter, the RF stage may suffer from overloading. This is due to the presence of a very strong RF signal, whether on the frequency to which the set is tuned or not. There will be enough stray RF pickup to place a high voltage on the grid of the first stage. This can reduce the gain of the RF stage by driving the grid to cutoff; it is also very useful in generating harmonics by grid rectification! The trap just mentioned will help here, too.

Receiver Input Filtering

In radio receivers, the trap shown in Fig. 6-47 can be made from commercial coils and trimmer capacitors and installed. Connect a DC VTVM to the AVC line of the receiver, tune to the frequency of the offending station, then tune the traps for minimum AVC voltage. This trap can often be mounted directly on the frame of the tuning gang. Shielding of the gang is sometimes needed to reduce the interference.

In TV receivers we have a slightly different problem. Most of the better TV sets have high-pass filter networks built into the balun coils in the tuner input (Fig. 6-48). They may be marked "FM traps" on the schematic, since their major purpose is to reduce interference from FM transmitters and they are usually peaked in that range. Note the coils marked "IF trap" in the circuit of Fig. 6-48. These coils are tuned to the video-IF frequency of the TV set. They are included there to prevent transmitter signals in the video-IF range from getting through the tuner and causing interference. Incidentally, this will happen now and then, especially in the 21-mc video-IF stages. There are quite a few radio stations in this range, and interference is often caused by direct pickup in the video IF, or by improperly trapped front-ends. The clue to this is the fact that the interference seen on the screen is not affected by the tuner; no matter to what channel the set is tuned, the interference remains the same. This means it is being picked up directly by the video-IF stages. Better shielding will stop such interference.

If interference *is* found in well-trapped TV receivers, it is a good idea to check the traps for damage. Lightning striking the TV antenna may have damaged the balun coils or traps; enough signal could still be coming through to make a picture, but the traps may be bad.

External Trapping of Interfering Signals

In certain cases you'll come across unavoidable RF interference in TV

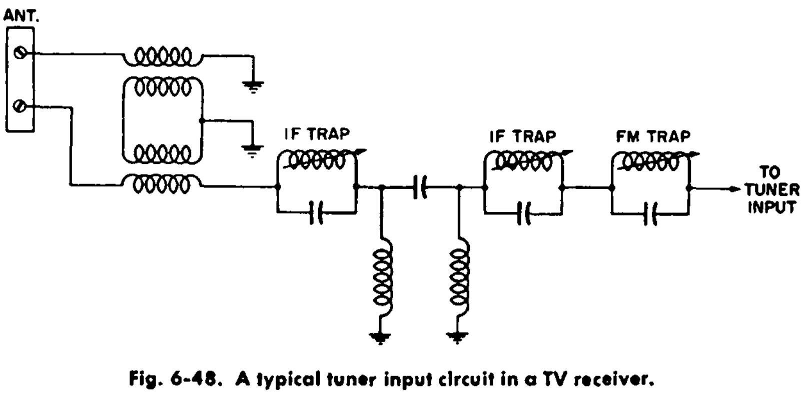


Fig. 6-48. A typical tuner input circuit in a TV receiver.

receivers, such as signals from a nearby police transmitter. Many of these troubles can be reduced or eliminated by adding sharply-tuned traps in series with the antenna lead of the TV set.

Very sharply-tuned traps for single-frequency interference can be made by connecting a piece of 300-ohm transmission line *across* the antenna terminals, as shown in Fig. 6-49. If the transmission line is open at the other end and is exactly one-quarter wavelength at the interfering frequency, it will act as a "short

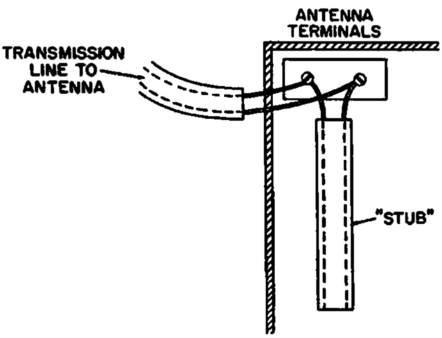


Fig. 6-49. A stub made of a length of transmission line connected across the antenna terminals of a TV receiver.

circuit" for only the undesired frequency. The same effect can be obtained with a shorted half wavelength, because an open quarter wave and shorted half wave give exactly the same effect. These are known as *stubs*. A stub is effective in removing interference because an open quarter-wave or a shorted half-wave stub will act as a series-resonant circuit to the interfering frequency. Thus, it will present a low impedance to the interfering frequency and remove, or "trap out," these frequencies from the received signal.

The stub can be connected to the antenna terminals through a switch, in case it causes trouble on another channel; or a clothespin connector can be used so it can be taken off easily. A simple way to find the proper length for stubs is to connect a piece of transmission line longer than necessary to the antenna terminals. Then cut off about a quarter inch at a time from the open end, until you can see the interference being reduced. This will leave you with an open-end, quarter-wave section. Another method is to connect the line to the antenna terminals, and short across the line at various points by gently cutting through the insulation with a pair of diagonals or a knife. (Be careful not to cut the wire in two!) After finding the best place, move down half an inch and cut the wires; then remove the insulation back to the original mark and solder the ends together. This will give you a shorted half-wave trap. After determining the half-wave length by shorting across the line, you can measure to its center and cut it here for an open quarter-wave section if you wish.

An absorption trap can also be used. To make one which will work over a range of frequencies from 40 to about 170 mc, cut a piece of 300-ohm transmission line five inches long, and strip the wires back on each end to leave the insulated portion exactly 4⅜ inches long. Short one end and connect an adjustable (2 to 14 mmf) ceramic trimmer capacitor to the other end. Tie it to the transmission line, between the antenna terminals and tuner, as shown in Fig. 6-50. Use plastic tape and be sure the trap is lying flat. Watch the screen while the interference is present, and tune the trimmer for minimum interference beats. This trap tunes very sharply, and you'll have to "hit it right on the nose" to take out the undesired frequency. You can make it tune a little broader by opening the shorted

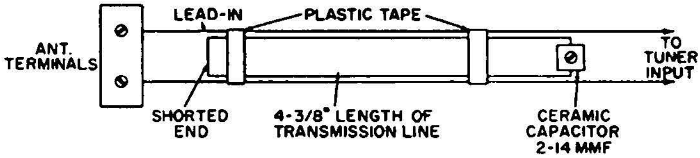


Fig. 6-50. The absorption trap attached to the transmission line.

end and adding a resistor there. This lowers the Q of the trap; the higher the resistance, the less attenuation in the trap. By the way, this resistor will also work for the quarter-wave shorted stub if it tunes too sharply.

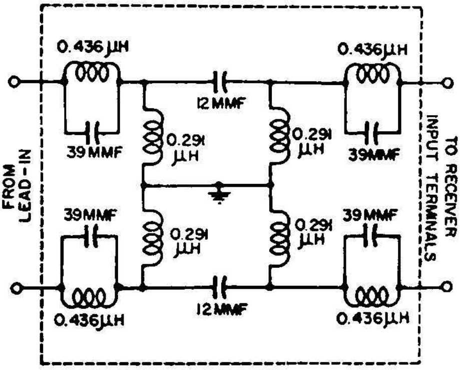


Fig. 6-52. Schematic of a typical high-pass filter.

Commercial Filters

There are several types of commercial filters on the market which will do this kind of work. A high-pass filter like the one in Fig. 6-51

Fig. 6-51. A commercial high-pass filter.

allows only signals *above* a certain frequency to pass. The configuration for such a filter is given in Fig. 6-52. This filter has a transmission characteristic which looks like Fig. 6-53.

As you can see, only signals above 50 mc can get through without suffering severe attenuation; all those below 50-mc—which include not only the amateur bands, but also the low-band two-way radio frequencies—will be attenuated. Thus, all low-frequency signals are trapped out—and even ignition noise, which has large low-frequency components, is reduced.

A tunable notch filter (Fig. 6-54) is also available; it can be extremely helpful in some cases, especially

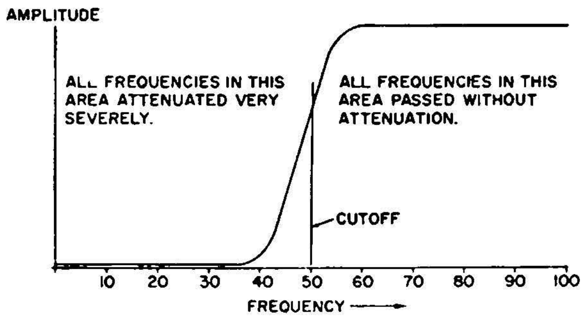


Fig. 6-53. Transmission characteristics of a 50-mc high-pass filter.

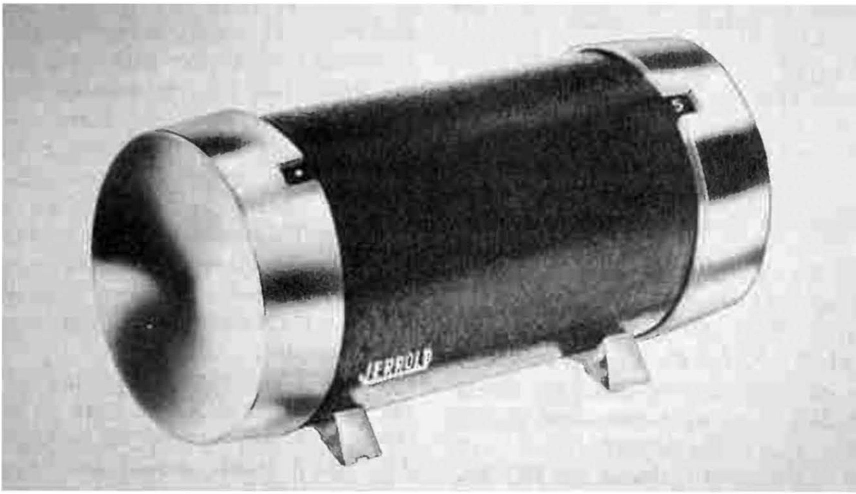


Fig. 6-54. Commercial trap for removing interfering TV station signals.

where adjacent-channel sound interference is troublesome. It is connected in series with the antenna lead, and has dual tuning adjustments for tuning and fine tuning so an interfering frequency can be clipped out of the signal with great precision. This filter has a very sharp notch in its transmission curve, as seen in Fig. 6-55, going down to about 50 db of attenuation.

in the picture. By setting the notch of the filter to the undesired signal, its amplitude can be reduced to the point where it will not give trouble. These filters are made in two models, one covering the channels 2 through 6, and the other, channels 7 through 13.

Construction of a High-Pass Filter

You may want to build a high-pass filter yourself, if a commercial unit

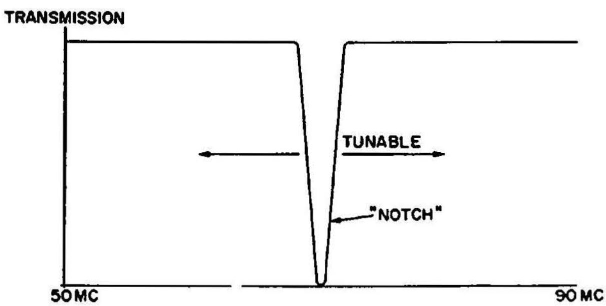


Fig. 6-55. Transmission characteristics of the filter in Fig. 6-54.

For instance, if an adjacent-channel sound carrier is being received along with the desired signal, the excessive amplitude of the former can raise the AGC voltage of the receiver and thereby lower the gain. This is in addition to the various herringbone patterns and beats seen

is not immediately available. Fig. 6-56 shows the schematic of such a filter. It can be built in a small box; shielding need not be perfect since the transmission lines are unshielded. Some of the little plastic boxes in which parts are packed are ideal. Coils L1 and L3 are 23 turns

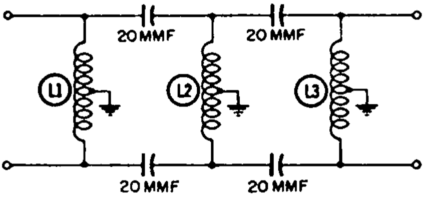


Fig. 6-56. A high-pass filter schematic.

of No. 24 enameled wire closely wound on a 3⁄16-inch polystyrene coil form. L2 is the same except it has only 11 turns. Center-tap each coil by pulling out a ½-inch loop in the middle turn; then clean and tin the loop and solder to ground.

This filter is balanced for 300-ohm twin-lead and has a low frequency cutoff at about 53 mc. Insertion losses at higher frequencies are very small. By using two 10-mmf silver-mica capacitors to make up the 20-mmf units shown, lead inductance can be made somewhat lower and better performance obtained. Keep the ground leads of all components as short as possible. Be sure to mount the coils at least an inch apart to avoid inductive coupling between them.

TVI-proofing the Amateur Transmitter

All amateur transmitters must be checked to make sure they are not radiating illegal harmonics. This is a comparatively simple procedure. Tune the transmitter, using a dummy load such as a light bulb of appropriate wattage. If you can get the bulb inside the transmitter cabinet, this part of the tests will be much easier. Close and latch all doors and lids.

You can use a communications receiver that will cover the harmonic frequencies, or a grid-dip meter if one is on hand. Key the transmitter and search the band for harmonics. For instance, if the transmitter is working around 7 mc, check 14, 21, 28, 35, and other multiples of the frequency. If you find no readable harmonics up to the fifth, you can be pretty sure the transmitter isn't radiating too many of them! Of course, higher-order harmonics, even at pretty low amplitudes, can cause trouble. So, to be sure, place a portable TV receiver with a rabbit-ear antenna close by, and tune to each active channel in your locality. Key the transmitter while watching each channel.

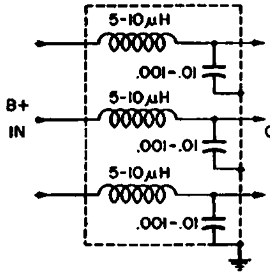
If any TVI is detected in this test, the cabinet or rack will have to be cleaned to prevent any RF leakage. All bolted joints should be taken apart, sanded clean, and retightened. (Some may have to be bonded.) If the cabinet can't be made "RF tight," you may have to add more shielding. Make an inner box of copper screen to enclose the transmitter compartment. (You may be able to get by with just copper screening over the louvers and ventilating grilles.)

Before going too far with extra shielding, be sure the TVI isn't leaking out through the AC input and the B+ supply leads. Add filters to these leads, as shown in Fig. 6-57. The microphone or keying leads should be shielded, too, to prevent any signal from escaping. Use key-click filters on keying leads to keep these pulses from interfering. Usually, just a single bypass capacitor is enough; but in bad cases, small chokes may be necessary.

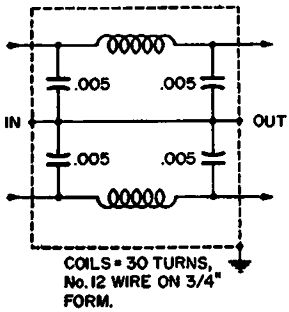
After you get through, make a thorough test with the portable TV set. If all signs of interference have disappeared after the transmitter has been keyed, you can feel sure this part of the job is all right.

Antenna Filtering

Reconnect the antenna and tune the transmitter. Recheck with the TV set (keep it at least 15 or 20



(A) B+ supply filters.



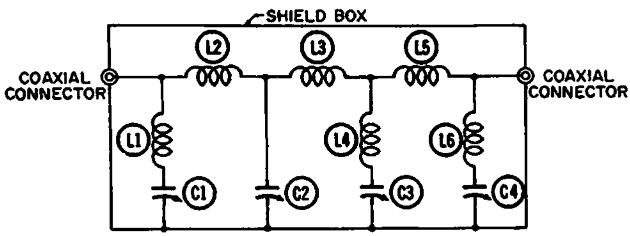
(B) AC line filters.

Fig. 6-57. Filters for amateur transmitters.

feet away, if possible). If any interference is seen on any of the channels available in the area, harmonics are being radiated from the final stage and from the antenna, which will have to be filtered.

A good low-pass filter will clear up the interference. The ideal filter will transmit all amateur frequencies without loss while attenuating all harmonics which can cause TVI. Fig. 6-58 shows a low-pass filter which will come close to doing this. It has almost 100 db of attenuation at all TV frequencies, and less than 0.2 db of insertion loss in the amateur bands. Also, by making the capacitors variable and by using small low-loss ceramic trimmers for C1, C2, C3, and C4, the filter can be tuned to hit exactly on the interfering harmonic. The trimmers can be set for preliminary adjustments, according to the parts list, by using a good capacitance tester or a coil and grid-dip meter.

This is the *m*-derived filter section described in Chapter 3. There are enough elements to insure attenuation of all frequencies which might fall within the TV bands. The filter should be built in a tight metal box,



(A) Configuration.

ITEM	DESCRIPTION
C1	41 MMF (50 MMF AIR PADDER)
C2	136 MMF (150 MMF AIR PADDER)
C3	106 MMF (150 MMF AIR PADDER)
C4	41 MMF (50 MMF AIR PADDER)
L1	4 TURNS, No. 12 ENAMELED SOLID WIRE, ON 1/2" FORM, 1/2" LONG.
L2	5 TURNS, No. 12 ENAMELED SOLID WIRE, ON 1/2" FORM, 5/8" LONG.
L3	6 TURNS, No. 12 ENAMELED SOLID WIRE, ON 1/2" FORM, 13/16" LONG.
L4	4 TURNS, No. 14 ENAMELED SOLID WIRE, ON 1/4" FORM, 5/8" LONG.
L5	5 TURNS, No. 12 ENAMELED SOLID WIRE, ON 1/2" FORM, 3/4" LONG.
L6	4 TURNS, No. 12 ENAMELED SOLID WIRE, ON 1/2" FORM, 1/2" LONG.

(B) Parts list.

Fig. 6-58. Low-pass filter suitable for amateur transmitters.

and the coaxial connectors used as shown. The lid should have not less than two screws per side if the box is of average dimensions (about 4" x 5" x 6"). This is not to keep the lid from falling off, but to insure its having good RF grounding!

After taking these precautions, the amateur operator can be fairly sure any interference complaints are not the fault of *his* transmitter, but are caused by defects in the receiving equipment itself.

CHAPTER

7

Automobile Radios

ALTHOUGH noises in home radios and television sets can be quite annoying, for some reason they don't seem to make the average customer nearly as angry as a noise in his car radio! The reason is probably that most home set noises tend to be intermittent, whereas noise is present every time a faulty auto radio is turned on. Ever since 1927 or so, when the first auto radio was installed, electrical noise in auto radios has been the subject of much research. Fortunately, they are not too hard to quiet down if the proper equipment and methods are used.

The auto radio leads a hard life anyhow. It is not more than two feet from a spark transmitter, which was the cause of much interference in the early days of radio. The spark transmitter in automobiles is, of course, the ignition system. Designers of auto radios have been highly successful in finding ways of preventing noise from entering the radios themselves. In the old days, chassis pickup (noise entering the radio through power wiring and paths other than the antenna socket) was a major problem. Because of improvements in design, however, a true case of chassis pickup is extremely rare today. Nowadays any noise present will enter through the antenna socket. Our efforts must be turned toward reducing this noise level so it cannot be heard.

NOISE SOURCES IN A CAR

Noise in an auto radio can come from either the electrical system or the body. In the electrical system there are several noise producers, such as the ignition and battery charging systems. The car body furnishes a much smaller share because of only intermittent contact between parts. We will deal with both causes in this chapter.

THE AUTOMOBILE ELECTRICAL SYSTEM

The modern automobile packs a tremendous amount of electrical equipment. The operating power is furnished by a 6- or 12-volt battery which is kept charged by a generator driven from the engine. There have been hints that cars of the future may have 24-volt DC or even 400-cycle AC systems. This is pure speculation, and in any event, the principle of noise elimination will be the same!

Fig. 7-1 shows a typical electrical system for a medium-priced American automobile. Others may include such luxuries as electrically-operated window lifts and radio antennas, plus a host of other gadgets—all potential sources of noise. The diagram is quite complicated. However, if you'll remember that all complicated circuits are merely a number

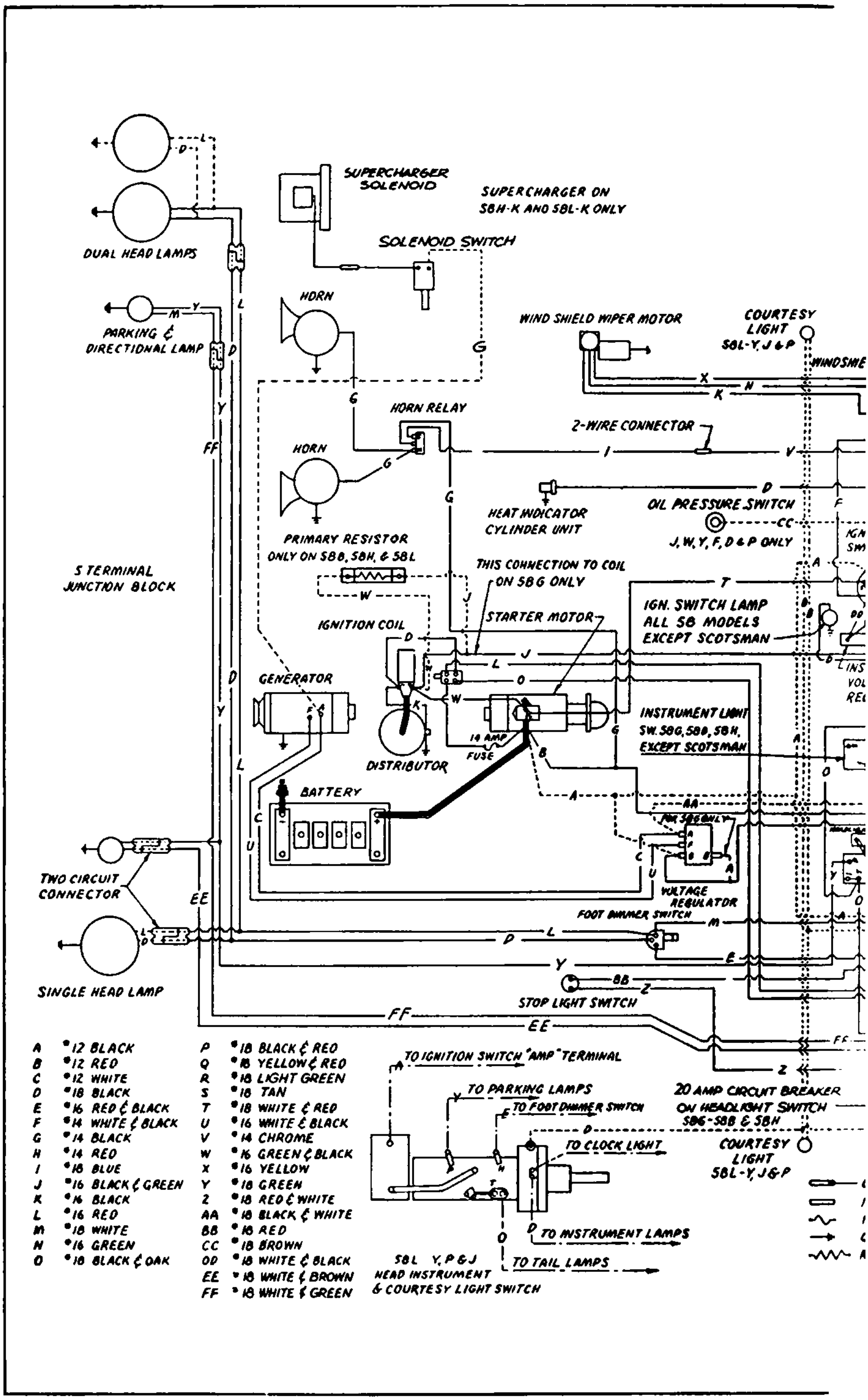
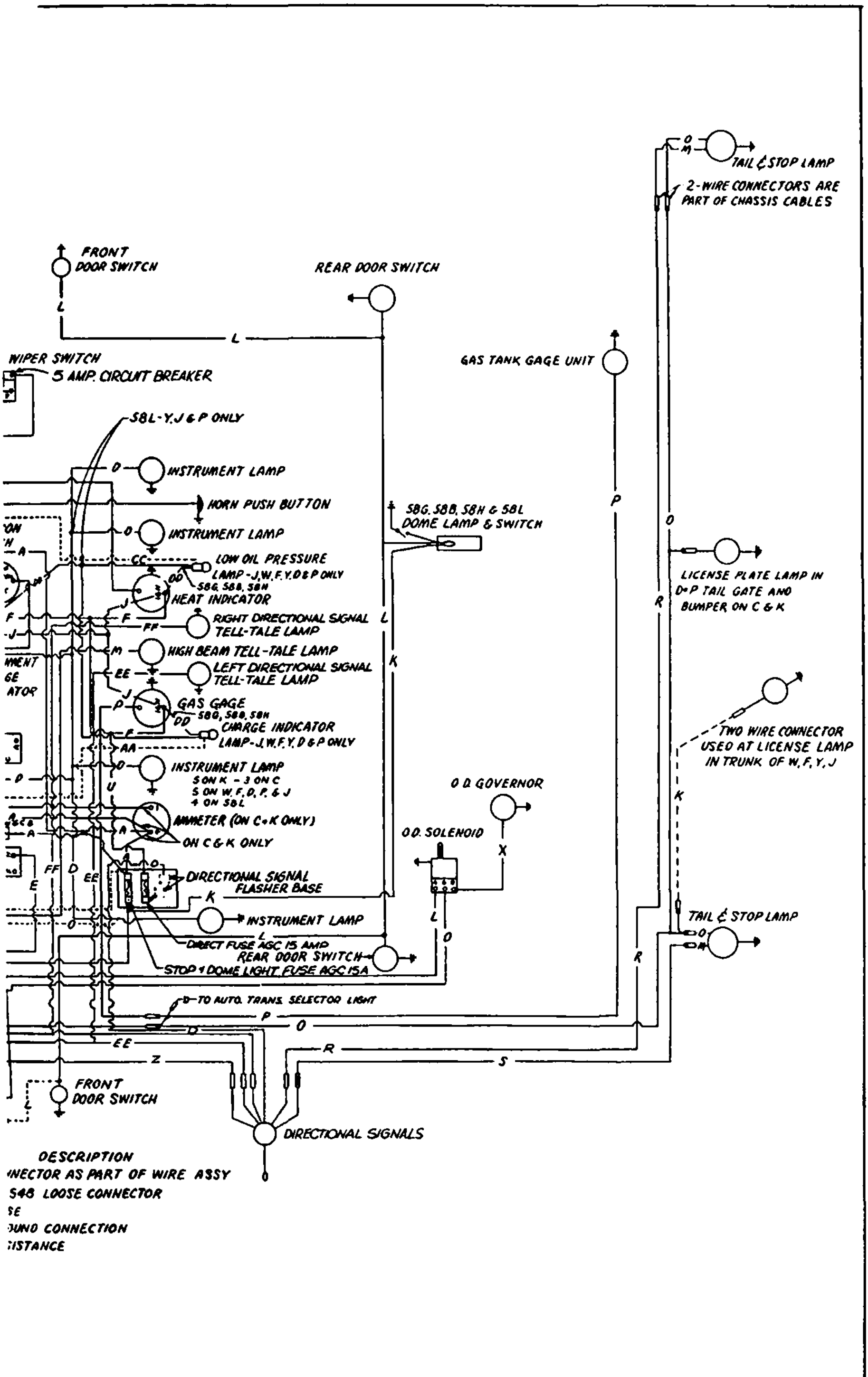


Fig. 7-1. Complete electrical



system of American-made car.

Courtesy of Studebaker-Packard Corp.

of very simple ones tied together, you won't have a bit of trouble understanding them.

Basically, each circuit consists of the device itself and the controls (switches), plus a wire leading to the battery and a return circuit to the other side (Fig. 7-2)—which is *always the metal frame of the car.* Remember that there are always two wires: a "hot" wire from the battery, and another "wire" which is the frame or body of the car. Previously, to get rid of a noise component we simply bypassed it to ground—either an actual earth ground or the frame of the device. Here, the frame or body of the car serves the same purpose. Any noise is bypassed to the frame or body, where it is absorbed and dissipated harmlessly as eddy currents. Since the system is DC (and low voltage, too), we can use any size of capacitor to bypass the AC noise components to ground without affecting the primary DC supply.

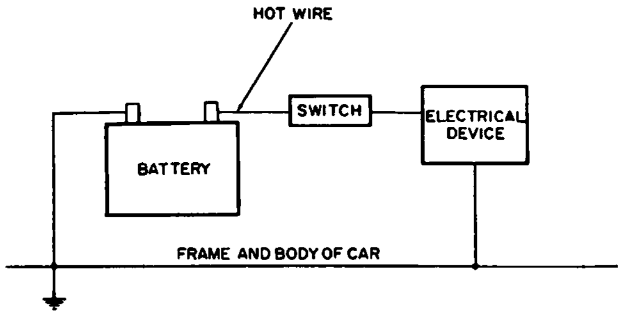


Fig. 7-2. Basic automotive electrical circuit.

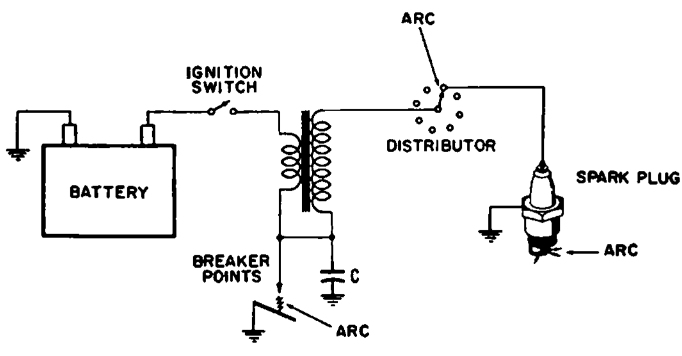


Fig. 7-3. Basic schematic of the automotive ignition system.

THE IGNITION SYSTEM

Of all noise sources in a car, the ignition system is the worst offender. This is due to the very high-voltage pulses generated and to their intermittent nature. Fig. 7-3 shows the circuit of a typical ignition system. Briefly, its operation is as follows: When the ignition switch is closed, battery voltage is applied to the ignition coil, which is simply a two-winding iron-core transformer with a very high step-up ratio. Current flow through the primary is controlled by a switch, called the breaker points, in the distributor. When the breaker points close, a pulse of current flows through the primary, charging capacitor C in Fig. 7-3. When the points break (open), the magnetic field in the coil collapses, inducing a very high-voltage pulse in the secondary. This action is aided by the discharge of the capacitor. The high-voltage pulse is distributed to the spark plugs through a rotary switch known as the distributor. At the plug, the pulse jumps the gap, causing an arc which fires the fuel charge in the cylinder.

As you can see, this system is full of noise-producing gadgets such as the arcs at the points and distributor, but mostly the high-voltage arc at the spark plugs. This can run as high as 20,000 volts or more. The whole system is a highly efficient noise generator which not only radiates noise into other wiring, but also couples it to the battery (Fig. 7-4).

Ignition noise, or plug noise as many technicians call it, is usually easy to detect. It is a sharp popping sound which is heard whenever the engine is running, whether the car is moving or not. The noise will vary with the speed of the engine. At low speeds (wider pulses) it will be louder; at higher rpm's, it will gradually blend into a roar. The number of pops per second is directly proportional to the engine speed.

Eliminating Ignition Noise

The noise must be eliminated without disrupting the operation of the ignition system. This is done by reducing the amplitude of the pulses slightly and bypassing them liberally, to keep them from feeding back

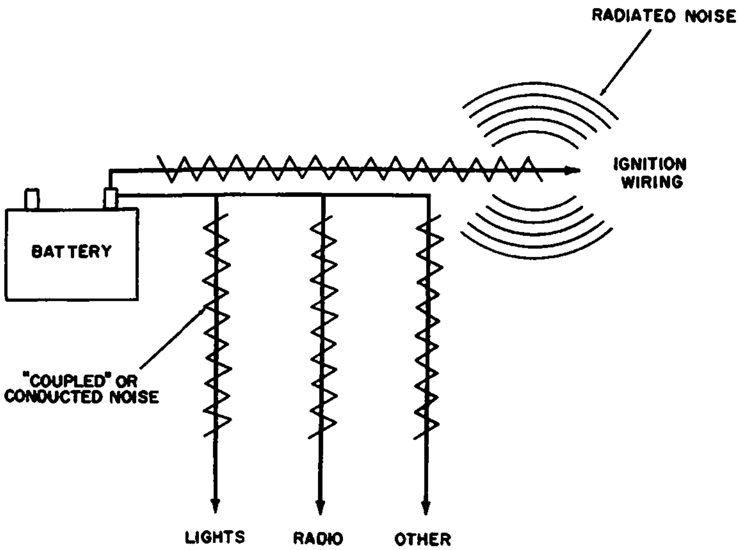


Fig. 7-4. Noise from the ignition system being radiated or conducted into other parts of the wiring.

Identifying Ignition Noise

Before you can eliminate a noise, you must first identify it! In auto-radio noise work this isn't always as easy as it sounds, because a lot of noises sound alike but originate from entirely different places.

into the power-supply wiring. The high-voltage pulse is the worst offender because of its tremendous amplitude. It has the waveform shown in Fig. 7-5A. Notice the similarity to the ringing oscillation in TV damper circuits, etc.—the gradual dying away of oscillations in an inductive circuit, with a fairly high *Q*. In the automobile electrical system, the coil secondary winding, etc., and the distributor capacitor form a high-*Q* circuit.

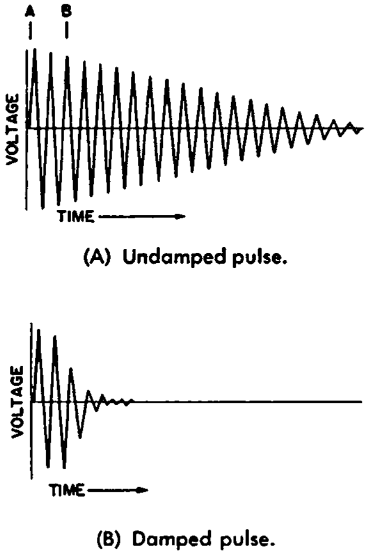


Fig. 7-5. Appearance of the ignition pulse voltage.

reduce the total amount of noise power and hence its ability to cause interference. To do so, we connect a resistor of about 10,000 ohms in series with the high-voltage circuit (Fig. 7-6). This resistor suppresses, or damps, the circuit to reduce its ringing time; as a result the pulse will appear as shown in Fig. 7-5B. The amplitude of the initial pulse is only slightly reduced, but the succeeding alternations are quickly damped. In most cars, only a single resistor connected at point A will be needed. If the ignition noise is very high, we also need a resistor at point B (on the spark plug).

In auto-radio noise work, these resistors are called suppressors. Most are carbon resistors built into insulating shells, with terminals to fit the specific application. Some suppressors are inductive—that is, RF chokes which are made in the same form and do the same job. Quite a few cars built since about 1958 use a special ignition wiring which is actually resistance wire.

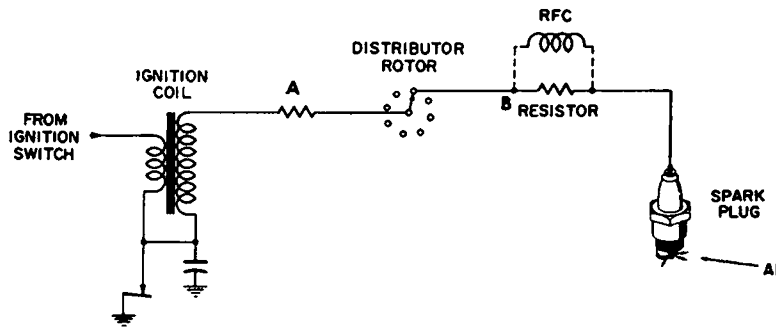


Fig. 7-6. Adding resistive suppression to damp pulses in the ignition system.

As small boys often say when being dressed for Sunday school: "A lot of this stuff ain't necessary!" We can fire the plug very well, using only the initial two or three pulses of high voltage between points A and B in Fig. 7-5A. The remainder of the pulse isn't needed. By cutting down on the pulse width, we can

Some of the different types of suppressors are pictured in Fig. 7-7. A "cable-type" suppressor, shown at the top of the illustration, is used mainly for distributor suppressors (although the plug-in type at the bottom is also used). To install a cable-type suppressor, simply cut the wire between the center contact

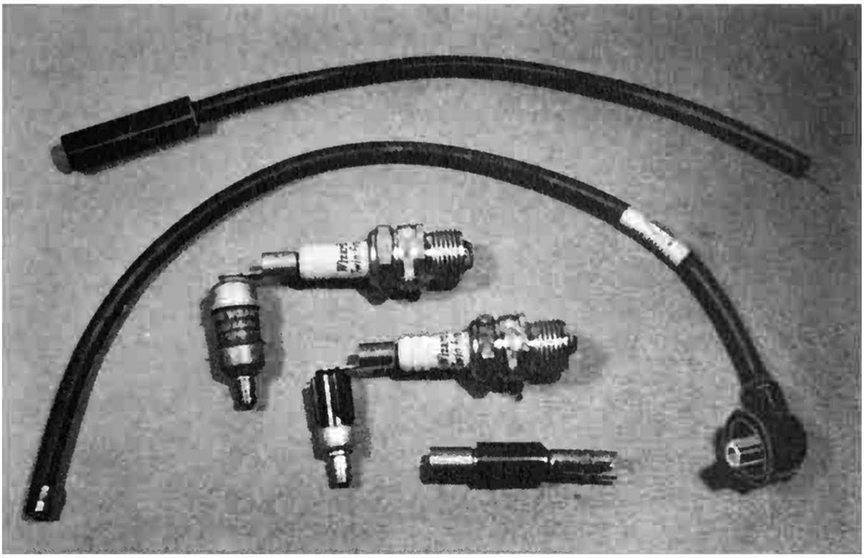


Fig. 7-7. Different types of suppressors.

of the distributor cap and the center terminal of the coil, somewhere near the center, and screw the ends of the wire directly into the suppressor. A special high-pitched screw is used which bites into the wire and pulls the insulation tightly into the ends of the insulated case. An expanded detail of one of this type suppressor is given in Fig. 7-8.

cable-type suppressor in Fig. 7-7. The suppressor attached to the top spark plug in Fig. 7-7 is the inductive type, and the one attached to the lower plug is the resistance type. These suppressors are simply slipped onto the terminal of the plug and the wiring inserted into the top of the suppressor. The suppressor at the bottom of Fig. 7-7 is the plug-in

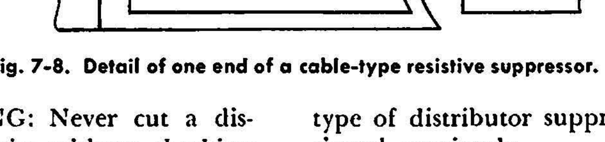


Fig. 7-8. Detail of one end of a cable-type resistive suppressor.

WARNING: Never cut a distributor wire without checking it first! If the word "Radio" is printed down its length, it is resistance wire and you already *have* a distributor suppressor!

The resistance-wire type of suppressor is pictured directly below the type of distributor suppressor mentioned previously.

Special spark plugs are also made in which the suppressor is built right into the plug (Fig. 7-9). The resistance wire or resistor plugs are very effective in reducing ignition noise. They can also be installed on older models.

Fig. 7-9. Spark plugs with built-in suppressor resistors.

Bypassing the Ignition Coil

We have succeeded in damping out some of the unnecessary energy from the high-voltage pulse to stop the radiation. Now we should try to keep the remaining noise from being fed back into the battery wiring on the other side of the ignition coil. We can do this by bypassing the primary side of the coil, as shown in Fig. 7-10. The connections must be exactly as shown. Because

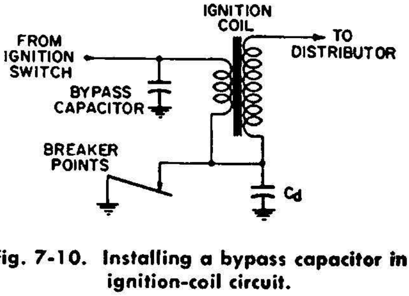


Fig. 7-10. Installing a bypass capacitor in ignition-coil circuit.

of the circuitry used, "distributor condenser" C_d must be matched to the coil; this determines the HV circuit time constant, which will vary from car to car. If an extra capacitor is connected across the points, the operation of the ignition system will be upset. So always be sure to connect the noise bypass capacitor to the switch side of the coil—never to the distributor side. Fig. 7-11 shows a correctly mounted capacitor. Almost all coils have provision for mounting the capacitor at this point.

GENERATOR NOISE

The next most common noise in auto radios is from the generator. All DC generators—auto or otherwise—use brushes (noises from carbon brushes and commutators were covered quite extensively in earlier chapters). The DC generator makes a random noise, usually called hash, which we get rid of by the same method as before—bypassing it to ground with a capacitor.

The capacitors are special units made to withstand the very hard service they get. They must be able

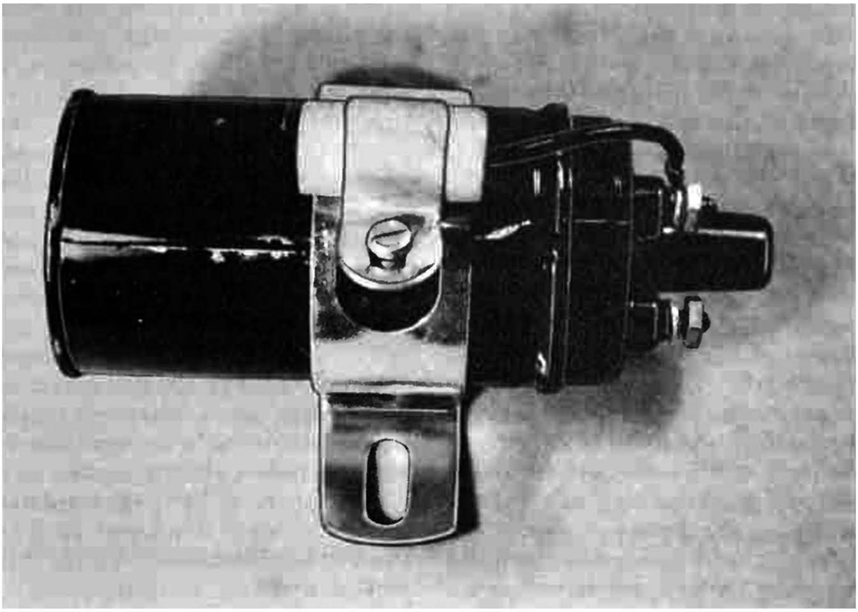


Fig. 7-11. Bypass capacitor mounted on ignition-coil bracket.

to bear up under heat, oil, moisture, vibration, and other abuses without breaking down. They are usually 0.5 mfd, 200-volt units in heavy metal cases fitted with a large mounting lug. The case and lug also serve as the ground return for the capacitor, the other lead being a well-insulated pigtail with a terminal lug. (See Fig. 7-12.)

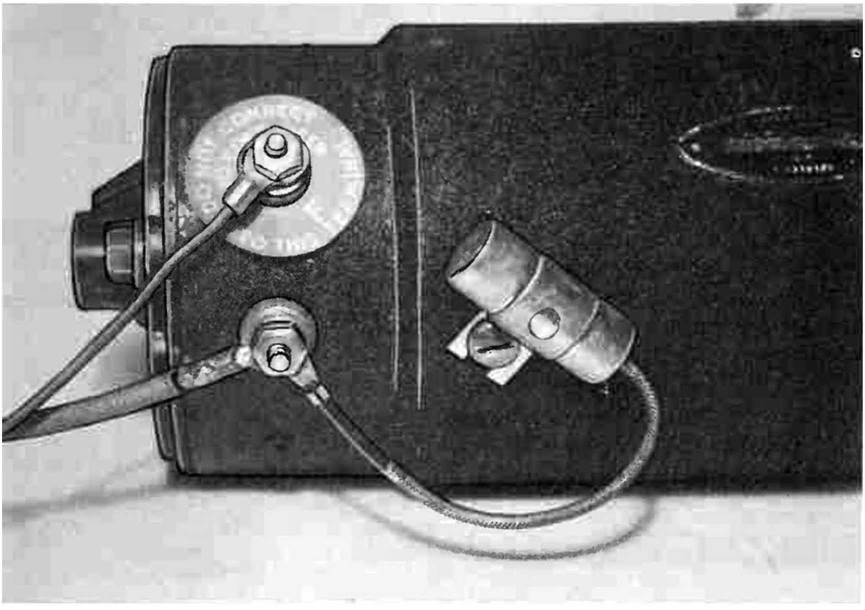


Fig. 7-12. Generator capacitor mounted on generator housing.

The generator manufacturers have provided an easy place for mounting this capacitor. As usual, we want to get it as close to the noise source as we can. So we mount it on the generator itself, where you'll find a screw to hold its mounting lug. The pigtail connection goes to the armature lead of the generator (Fig. 7-12).

Older cars used only the DC generator, plus a small relay called the cutout which automatically disconnected the generator when the motor wasn't running. Otherwise, the battery would have discharged through the generator. (Connect a rotating generator to a battery, and it charges the battery; connect the same generator, standing still, to the same battery and it becomes a *motor*! The cutout kept the generator from acting as a motor. Unless the generator was turning fast enough to charge the battery, the relay stayed open and kept the battery disconnected from the generator.)

Modern cars have a slightly more complicated system called a voltage-regulated generator. A voltage regulator, consisting of three relays, controls the charging action of the generator. The old system simply ran the generator wide open all the time. When the battery reached full charge, say during a long trip, the generator kept right on pumping. As a result, the voltage sometimes rose far above normal, burning out light bulbs or even worse. Because of the numerous electrical apparatus in a modern car, such a system simply wouldn't do: high voltage is very hard on radios, electric motors, and other apparatus. Voltage-regulated generators were developed to keep the voltage constant or within very narrow limits.

Fig. 7-13 shows the circuit of a typical system. The separate field winding on the generator, with its connection to the voltage regulator, controls the charging rate of the generator by adjusting its field cur-

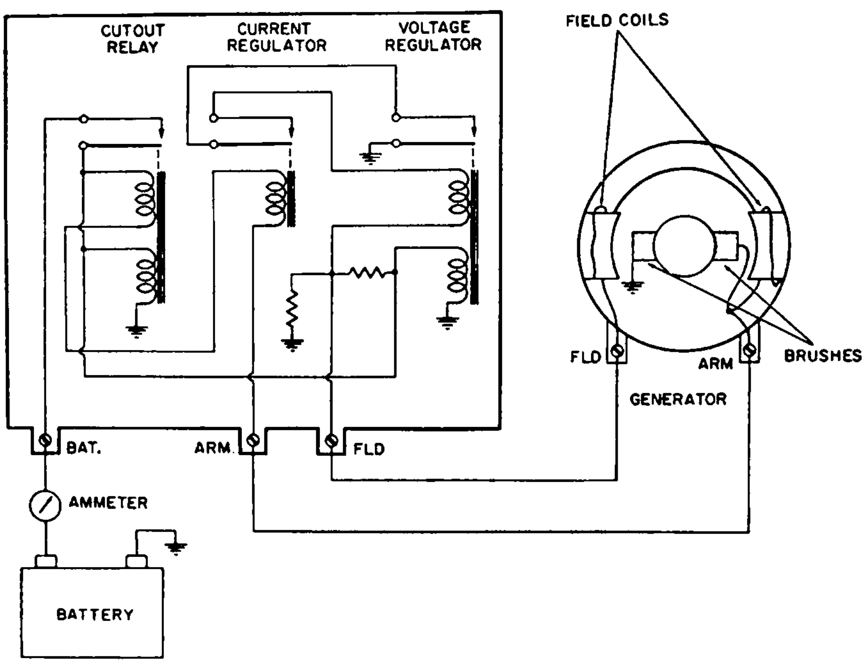


Fig. 7-13. A typical voltage-regulator circuit.

rent. One of the other relays is our old friend the cutout, and the other is a current relay.

To bypass noise in these systems, connect a capacitor to the generator case, as shown in Fig. 7-12. This puts the bypass directly across the output brush. Never connect a bypass to the field terminal: too much capacitance across the field relay upsets the time constant and thus interferes with the circuit action. Incidentally, the field wire is always much smaller than the armature wire. In addition, there is usually a red paper collar around the field terminal to warn you not to connect a bypass capacitor here.

Voltage-Regulator Noise

In addition to brush noise from the generator, now we have something else that makes noise—the rapidly opening and closing relay contacts in the regulator. This sounds much like spark-plug noise, so you'll have to listen closely. It is a popping noise, heard only while the engine is running—but the trained ear will detect the slight irregularity, compared with the continuous popping of plug noise. Also, voltage-regulator noise cannot be heard unless the engine is running fast enough for the generator to charge. To find it, slow the engine down until the ammeter indicates "no charge" (or the generator light glows); then speed up the engine very slowly until the generator cuts in. If no noise is present until the generator cuts in, the trouble is voltage-regulator noise. If noise is heard all the time, it is plug noise.

To eliminate voltage-regulator noise, connect a bypass capacitor at the battery terminal of the regulator, as shown in Fig. 7-14. Bad cases may need another on the generator terminal, although there already is one on the other end of the same wire, at the generator. However, the bypass at the voltage regulator is intended to keep noise orig-

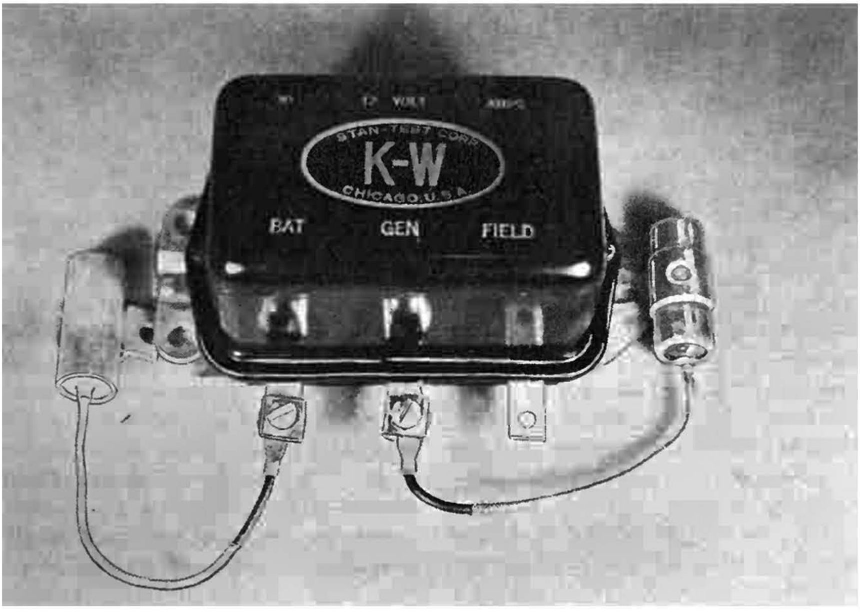


Fig. 7-14. Voltage regulator with bypasses connected to generator and battery terminals.

inating in the regulator from passing into the wiring harness. Bypasses are never connected to the field terminal. Special field-suppressor units are available, as we'll see in the next chapter; but for ordinary auto-radio work they are unnecessary.

FRONT-WHEEL NOISE

We may seem to be skipping around a little in presenting these noises, but many years of field experience have shown that they occur in this order—ignition, generator, and front wheels.

The front wheels, as they rotate, sometimes are momentarily insulated from the rest of the car by a thin film of grease. The tire builds up a static charge as it contacts the road. As the wheels continue turning they will at various times become electrically connected to the rest of the car and the static charge discharges into the body, producing a pulse of current heard as a "pop" in the radio. This is repeated at irregular intervals. Front-wheel noise is heard only on smooth roads and on dry days. The constant bouncing of the wheels on rough roads won't allow the wheel to remain "insulated" long enough to build up a static charge; and if it's raining, the water will short out the static charge before it builds up, of course.

This is a fairly easy noise to identify. For a positive test, run the car up to 20 or 30 miles per hour until the noise is heard. Then switch the engine off, but leave the radio on, and let the car coast. Gently apply the brakes to see if the noise stops. If so, it's definitely front-wheel noise because the brake drums have grounded it out.

To stop the noise, we've got to supply a constant contact between the wheels and body. We can do this by installing grounding springs inside the front-wheel dust caps (the "inside" hub caps). One type of grounding spring is shown in Fig. 7-15. The springs are pressed into the cap, so the large end contacts the cap and the small end contacts the small conical hole in the end of the front spindle, called the lathe center. Be sure this hole is free of grease before installing the spring. Now we have a positive contact at all times.

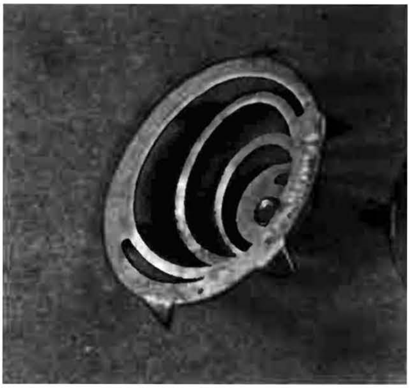


Fig. 7-15. A front-wheel grounding spring.

On rare occasions this noise is found even after the grounding springs have been installed. The noise is due to static buildup in the tires themselves. To cure it, blow the tires with a graphite powder, which forms a conductive layer inside the tire and prevents buildup of static charges.

INSTRUMENT NOISE

Most instruments in an automobile consist of a "transmitter" that measures whatever value is needed (fuel level, oil pressure, temperature, etc.), and an indicator on the dash. Fig. 7-16 shows the basic circuit of a fuel-level gauge. Being electrically operated, all instruments are potential sources of noise. Basically, instrument noises aren't too hard to cure, but the crowded construction of some modern cars can complicate the procedure.

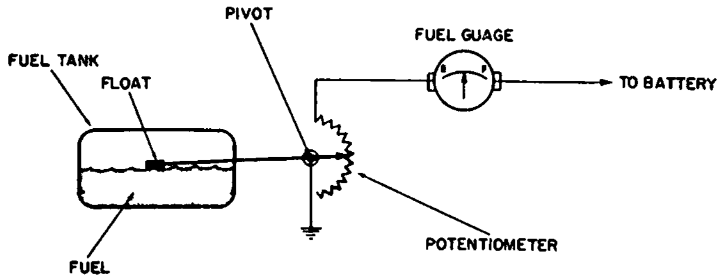


Fig. 7-16. Basic circuit of an electrically-operated fuel gauge.

In dealing with instrument noise, always remember the basic noise-elimination theorem: go directly to the source of the noise and apply corrective measures. Noise in the fuel gauge of Fig. 7-16, for instance, originates at the tank unit in the potentiometer. Hence, there would be very little improvement if a bypass capacitor were located on the more accessible dash indicator unit. The noise would have to flow all the way from the tank, via the wiring, to the bypass at the dash. On the way, it would inevitably be coupled into other wires and reach the radio. By putting the bypass at the tank unit, we've stopped the noise at its source.

Instrument noise is an irregular popping sound resembling front-wheel noise. However, it is worse on *unpaved* roads, is *not* affected by weather, and *can't* be stopped by applying the brakes. About the best test for it is to turn the ignition (and radio) on, but leave the engine off, and jar the car body by kicking the bumper or stamping on the floor. If this produces a noise in the radio, it is usually instrument noise. Because of the numerous instruments, it is sometimes a problem finding the one causing the trouble. However, if kicking the rear bumper makes the noise worse, it is likely to be coming from the fuel gauge; if jarring the dash or firewall makes more noise, then probably one of the engine-mounted instruments (oil pressure, temperature, etc.) is to blame. (Assuming, of course, the car has a front-mounted engine.) You can always use the process of elimination: disconnect the wire from each instrument under the dash, one at a time, until the noise stops.

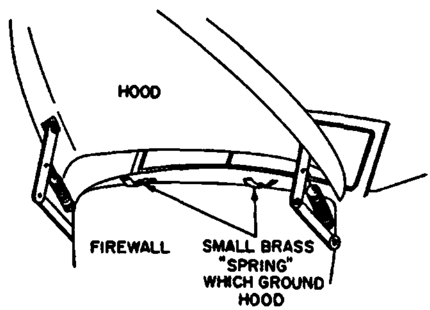
There is one exception to always bypassing to ground. Certain makes of cars (the defunct Kaiser, for instance) were equipped with an instrument voltage regulator—a small thermostat-like device located behind the instrument panel and connected in series with the voltage supply to the dash instruments. The "thermosnap" blade in series with the current makes and breaks rapidly enough to hold the voltage constant. (The current flowing through the bimetal blade heats it, causing it to warp and break contact; as it cools, it makes contact again.) Its main effect, however, was to produce a tremendous amount of radio noise! By some quirk of the circuitry; the usual bypassing directly to ground does not stop the noise; the only way is to connect about a 0.1-mfd or larger radio-type bypass capacitor directly *across* the terminals (and contact points) of the device. The radio bypass is used because there is no room inside the instrument cluster for the larger auto-radio type. Use spaghetti on the leads, and tie the capacitor in place with tape. Fortunately, these devices are rare today.

NOISE FROM OTHER ELECTRICAL EQUIPMENT

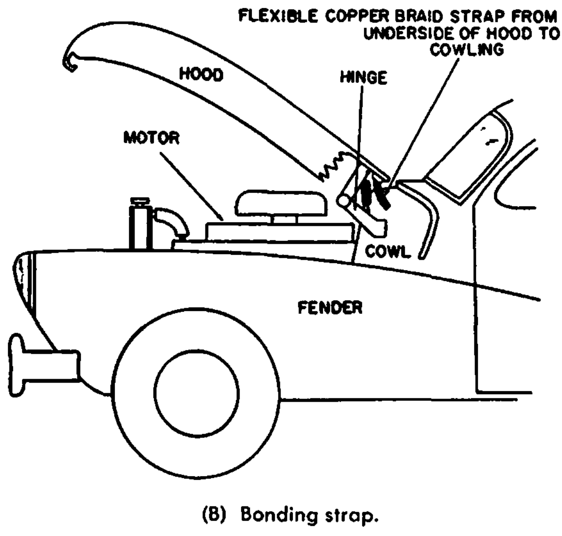
As we said a while back, anything connected to the power source is a potential noisemaker. Electric window-lift motors, for example, are all good prospects. Such noise is easy to identify because it will be heard only while the motors are in operation. But getting to them to apply bypasses turns out to be a different matter! Window-lift motors, for instance, require removal of the door upholstering for access. It might even be worthwhile to try bypassing the supply wiring at some accessible point, to see if the noise can be reduced slightly without having to tear the car apart. If these motors cause very severe radio noise, they are probably not working right and should be repaired by a qualified auto mechanic. Try to be there so you can install the radio bypassing before he puts the car back together again!

SHIELDING, BONDING, AND BODY NOISES

In older cars, body noises occur now and then because of poor electrical contact between different sections of the car body. Today's welded bodies seldom give such trouble. However, if you find a mysterious noise that will not respond to nor-



(A) Brass springs.



(B) Bonding strap.

Fig. 7-17. Methods of grounding the hood of an automobile.

mal treatment, try bonding the various parts of the body together. Points of likely trouble are the front fenders (the inner surfaces of which form part of the engine compartment), the tailpipe and muffler, and the hood.

Because the hood encloses the engine and thus forms a shield, you may have to bond it. Otherwise, unless it is making very good electrical contact when closed, some of the radiated noise in the engine compartment will leak out and be picked up by the antenna rod. To check while listening to the noise, insert a small screwdriver or knife blade between the edge of the hood and the cowling and twist gently, so the sharp edges of the blade will cut through the paint and ground the hood. If this helps at all, install grounding clips at the edge of the hood, as shown in Fig. 7-17A. These are small "C"-shaped brass clips mounted facing upward so the hood closes down tightly on them; the serrated edges will bite through the paint on the underside of the hood and ground it.

Bonding can also be applied at the hinge side. Fasten a piece of flat shielding braid not less than one-half inch wide to the underside of the hood and to a convenient place on the cowling (see Fig. 7-17B). Be sure the braid does not foul the hood hinges.

CORONA

Now and then you'll run into a very mysterious form of noise in auto radios. It is found only in hot, dry weather on paved roads, like wheel noise, but it has a sound all its own. Beginning with a slight increase in the hash, it gradually builds up, growing higher in pitch until it winds up as almost a shriek and drowns out the music; then it stops with a loud "pow"!

This noise is not due to a banshee, but to corona discharge from the tip of the antenna! While in motion an automobile, under just the right circumstances, will build up a heavy static charge. If the tiny metal ball on the tip of the antenna has been broken off, the discharge will take the form just described. (In fact, the proper name for this ball is "corona ball.") Incidentally, replacement balls can be purchased at radio-TV supply houses, but the best remedy is a new antenna.

ANTENNA TROUBLES

The importance of an auto-radio antenna is not fully understood, even by many auto-radio technicians! It is always a very short (compared with the wavelength on which it works) metal rod connected to the radio through a coaxial cable. The antenna is mounted on an insulating base which must hold it firmly in place, insulate it from the body, and make a perfect ground for the outer shield of the coaxial cable.

The rod and capacitance of the coaxial cable are part of the tuned circuits of the RF stage. Only by designing this circuit so the antenna is actually resonant over the standard broadcast band can any RF pickup be obtained at all out of so little an antenna. For best results, the antenna and lead-in cable must be in perfect condition at all times.

In addition to picking up the signal, the antenna must deliver it to the radio without allowing a lot of noise to creep in. This it does through the coaxial lead-in, the outer shield of which is firmly grounded at *both* ends. The lead-in must pass through the very strong field of radiated noise always present inside the car body. The noise pulses are picked up by the shield and flow harmlessly to ground at either end, as eddy currents in the solid (to RF) shield. The lead-in itself, which is the inner conductor, thus is not affected. However, if the shield becomes ungrounded at either end, standing waves of noise will be set up on the shield and transferred to the inner conductor.

Some antennas do not have the high-quality insulation necessary for the best performance. Cheap, damaged, or cracked insulators will allow moisture to seep in, creating a high-resistance leakage across the base of the antenna. Strangely enough, such a leak does not seem to affect the signal pickup too much (unless it becomes a dead short), but it will always increase the noise pickup. Therefore, if an auto radio grows noisier in wet weather, check the antenna for leakage.

Antenna Testing

There are three tests you should make on every antenna. Use a VOM and make resistance tests at the points shown in Fig. 7-18. The first test (1 in Fig. 7-18) is for continuity. With one test prod connected to the antenna rod and the other to the tip of the plug, you should get a reading (measured on the low range) of three to five ohms—not zero as you might expect. The reason for this is that the inner conductor is made of very fine wire in order to obtain the correct impedance for the coaxial cable. Measuring from the tip of the plug to ground (Test 2) should result in a completely open circuit on the highest ohmmeter range. In Test 3, from the shell of the plug to ground, we should read zero resistance on the lowest ohmmeter range.

Rear-Mounted Antennas

For some reason, the antenna in some of the later models is quite a distance from the radio—on the rear fenders, the trunk, etc. This brings on more complications. Now the

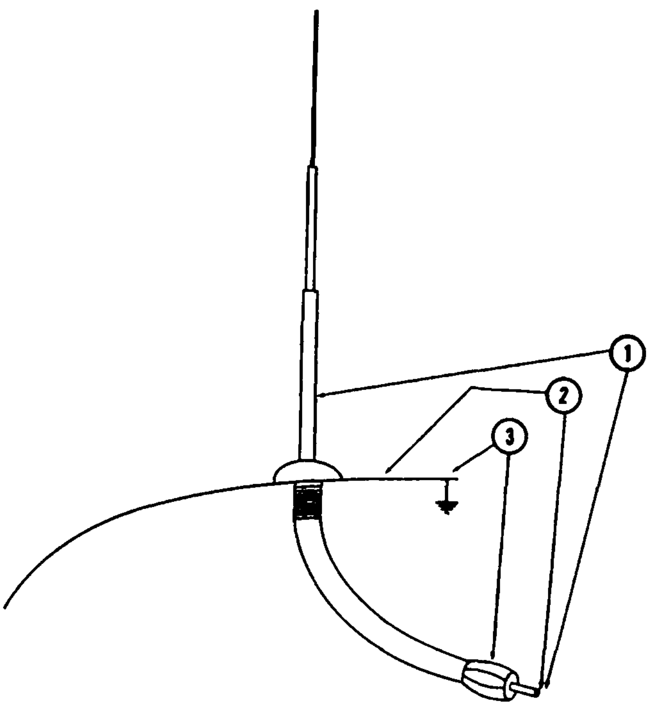


Fig. 7-18. The three tests for an automobile antenna.

radio designer must compensate for a tremendously high-capacitance lead-in (some as long as 20 feet!) compared with the normal 24- to 30-inch ones. The solution used by most designers is to add a series capacitance to effectively shorten the line and thus give more efficiency. Signal losses remain quite high, though. So, if you are testing the lead-in of one of these antennas for continuity, don't forget the series capacitor. It will make a simple continuity test impossible, of course.

The best check for lead-in continuity is to turn the antenna trimmer capacitor back and forth; if you can find a peak anywhere, the lead-in has continuity. A "flat" antenna trimmer means an open or leaky lead-in.

FALSE NOISES

Various interferences can give misleading clues as to their sources, and you've got to be on your toes all the time! A noise can imitate the characteristic sound of an entirely different noise and fool the unwary noise hunter. One well-remembered case will illustrate this point: I sat in a car behind my shop, listening to a terrific case of plug noise. Some twenty minutes later, after installing every kind of ignition-noise suppressor known to man, I could still hear the noise just as loud as ever! The car's engine had been allowed to idle, because plug noise is loudest at idling speed. Finally, I angrily slapped off the ignition switch, killing the engine and radio. The key went all the way over to the "accessory" position, turning the radio back on again, but leaving the engine off. Much to my surprise and mortification, the plug noise was there, just as loud as before!

Starting the engine again, I drove around the block. The radio was one of the most noise-free ones you've ever heard. But when the car returned to the back of the shop, so did the "plug noise." Eventually, the culprit was "smoked out"—it was a defective ventilating fan in the bakery next door! (Moral: never settle for a single test! By simply pressing the accelerator, I could have found out there was no relationship between the noise and the engine speed! This would have told me the noise was external.)

ALTERNATORS

In some cars and trucks, a new device has replaced the familiar DC generator. This is an AC generator called an alternator (Fig. 7-19). However, its purpose in the electrical system remains the same—to produce a DC current for charging the battery.

In a DC generator, each coil in the rotor produces a small AC pulse as it turns through a magnetic field. These pulses are actually rectified by the commutator and brushes, and then connected to the output the instant they're all flowing the same way. This provides the direct current. The field coils are stationary and are attached to the frame.

In an alternator, however, the *stator* windings are attached to the frame and the rotating part is the *field*. (Notice that the effect is the same: one set of coils stands still while the other turns.) However, now the output is AC. A set of silicon diodes rectifies this AC to make it suitable for charging the battery. The stator (output) windings are connected in a Y to give more pulses per rotation and to cut down on the filtering needed.

The voltage regulator is a single relay which cuts a resistor in and out of the field circuit. This changes the amount of field excitation and hence the output.

All we're concerned about is the

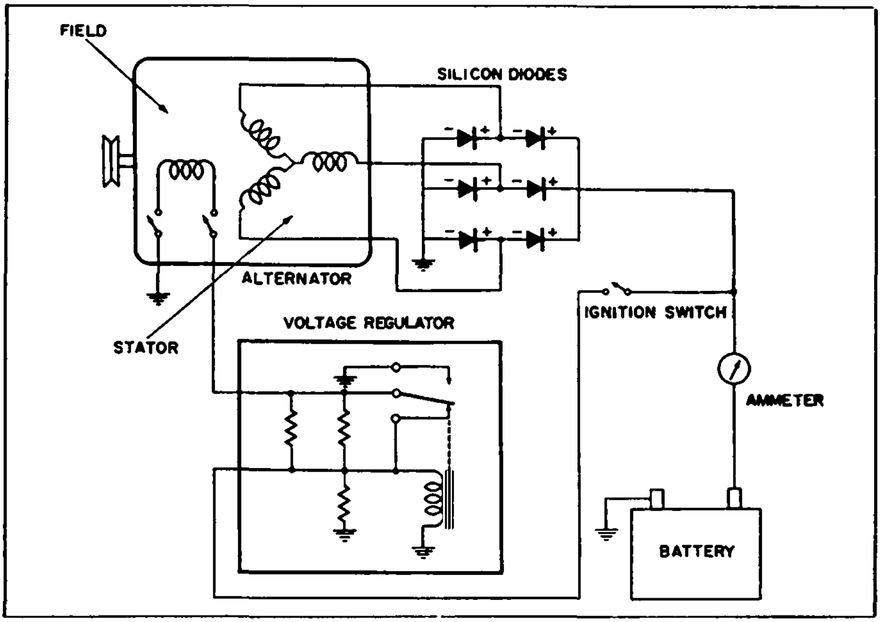


Fig. 7-19. Alternator-type automotive electrical system.

system's noise-making ability, which is considerably less than in conventional DC generators. The reason is that there is no continuous making and breaking of contacts on the commutator. Notice the symbol used in Fig. 7-19 for the field contacts. No commutator is shown; this symbol indicates slip rings (continuous bands of copper with no breaks, as in a commutator). The brushes merely slide around the slip rings, and in normal operation should create no noise at all. If a noise resembling generator noise is heard, check the brushes and clean the slip rings. A dirty spot on a slip ring will cause noise by changing the current each time a brush passes over it.

The voltage regulator will require a small bypass capacitor across the contact points; a 0.1-mfd unit will be sufficient. Defective diodes will also cause noise, especially if intermittent, but this trouble is very rare.

IMPORTED CARS AND U.S. COMPACTS

In general, the U.S.-built compact cars are exactly like their larger brethren in construction, design, and circuitry used. The same noise-elimination methods will also work on the smaller cars, since as a rule they have the same parts in the same places.

Foreign cars may turn up some surprises, especially the more exotic jobs. Here again, just remember they all have generators, spark plugs, voltage regulators, and so on—only in different places. Fortunately, the electrical system is often more accessible on the smaller cars than in the bigger ones with their overcrowded under-the-hood condition.

CHAPTER

8

Two-Way Mobile-Radio Systems

NOISE AND interference in a home radio or television is at worst only an annoyance. But in a two-way mobile-radio system it not only can cause trouble and expense, but can even endanger life. The two limiting factors in the range of a two-way system are the power output of the mobile transmitters and the amount of noise present. Most of this noise comes from the electrical system of the vehicle itself.

You must hold an FCC license to work on the transmitter. However, any competent technician can repair the receiver or perform noise-reduction work on the vehicle. At the last report, there were several hundred thousand systems licensed, with over *one million* transmitters! So, there's a worthwhile market.

GENERAL DESCRIPTION

The first two-way mobile-radio systems used AM. The frequencies allocated were a couple of channels just above the present broadcast band (1620 and 1720 kc, to be exact). The police were the main users. However, as soon as others found out how useful two-way mobile radio was, it began to grow in earnest! The two original channels were soon outgrown, and today there are two-way radio-equipped vehicles everywhere. Police, taxicabs, forest service, oil drillers, highway trucks, movie makers—the list is endless.

Because it is less susceptible to noise interference, frequency modulation (FM) soon became popular and now almost all mobile radios are FM. The systems were moved up into the 30- to 50-mc band, then into the 150-160 mc, and even into the 480- and 490-mc band. In fact, by the time you read this, still other bands may be in use! At first, 20-kc channels were allocated and the receivers used a 15-kc modulation swing. This gave a very good audio recovery (the amount of audio signal voltage obtainable from the modulation) and excellent noise rejection.

However, the tremendous expansion of two-way radio soon overcrowded these channels, and something had to be done to reduce the cross talk and interference from other stations. The FCC, in conjunction with leading radio manufacturers and users, developed a plan known as split-channel operation: the original 20-kc channels were "split" to allow three channels of 7.5 kc each, and the allowable modulation swing was reduced to only 5 kc (Fig. 8-1).

But this brought on more trouble! Frequency tolerances were cut down, requiring transmitters with much less drift, and other restrictions were imposed—for example, audio modulation was limited to 3 kc to prevent sideband splatter (sideband products

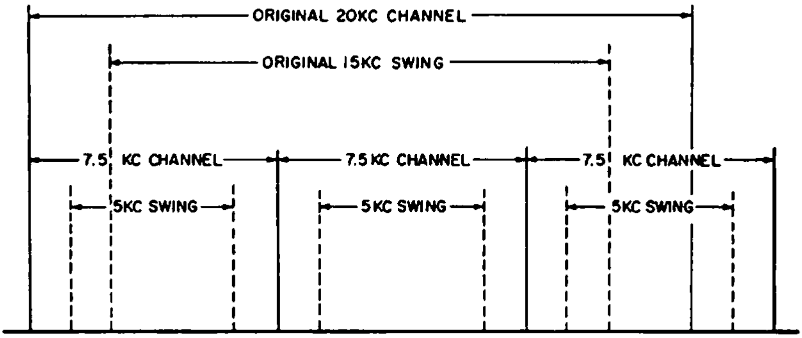
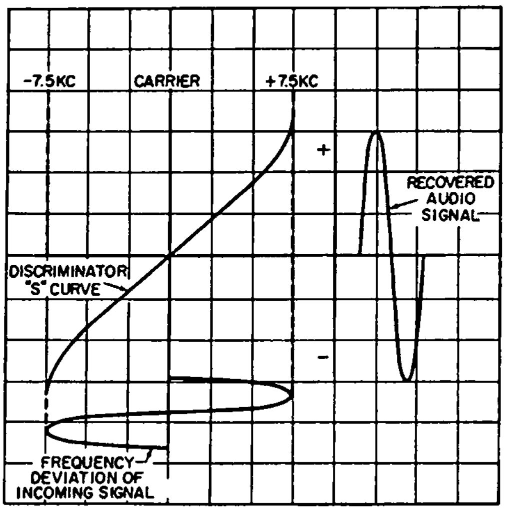
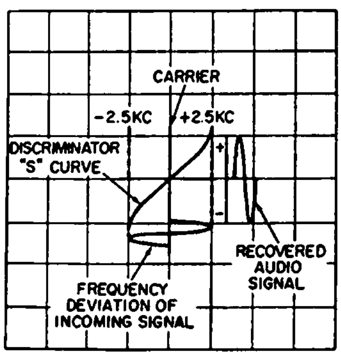


Fig. 8-1. Comparison of the original 20-kc channels with the narrow-band 7.5-kc channels.



(A) 20-kc channel system.



(B) 7.5-kc channel system.

Fig. 8-2. Effect of the narrow-band channels on the recovered audio signal.

interfering with adjacent channels). The reduction in modulation had far more serious consequences than any of the rest.

In FM radio the *amplitude* of the audio signal is directly proportional to the *frequency deviation*. (See Fig. 8-2.) Audio recovery in the first sets was fairly good; but with the new narrow channels, it was reduced by more than two-thirds. The same amount of noise was still present, so the signal-to-noise ratio fell off badly. This cut down the effective range of the radio-equipped cars, because the effective range is the range over which the base transmitter can be read clearly. Close to the base station, there is no difference: an FM receiver, in the presence of a strong RF signal, will "quiet." The RF signal amplitude is so high that the limiter stages in the receiver remove all traces of AM modulation (which is noise to an FM receiver!), and reception is clear as a bell. However, in the fringe areas (to borrow a term from TV), communication fell off so badly that places where the base station was clearly heard before were impossible to use for communication! The RF signals were about the same amplitude, but because the audio recovery was so much less, the signal-to-noise ratio made them unreadable.

In order to get the total range back to anything like what it was before, something had to be done about the noise. Of course, not too much could be done about atmospherics and other external noises. But something could be done with the worst offenders—the electrical systems of the cars and trucks carrying the mobile units! To tell the truth, at that time many two-way radios were 'installed" by simply being thrown into the vehicles and bolted down! Because of the excellent noise rejection of the receivers in wide-band systems, not even the most elementary noise-suppression equipment was installed. Fortunately, such slovenly work is a thing of the past. For successful operation in a split-channel system, the ambient noise level of the vehicle electrical system must be reduced far below that required for operation of a broadcast radio.

Noise generated by automobiles and trucks, especially from the ignition system, is much worse at high frequencies (30 mc on up into the lower TV channels) than at even the broadcast radio frequencies. The very sharp rise time of the ignition pulses gives a larger portion of noise in the VHF band. This will be verified by anyone listening to a shortwave receiver near a busy street, or watching TV in a fringe area near a highway! (At 30 megacycles or so, a sensitive receiver will pick up an unsuppressed ignition system over a mile away!) Therefore, noise-suppression equipment had to be developed which would give much lower levels, in order to reduce or eliminate the high-frequency noise as much as possible.

TESTING FM RECEIVERS FOR NOISE

We have a slightly different problem in checking an FM receiver for noise. In AM broadcast receivers the noise comes right on through, but FM receivers used in mobile units must be equipped with a squelch circuit to keep the speaker cut off except when a signal is being received. (See Fig. 8-3.) Some systems even use a special squelch circuit keyed by a supersonic tone, in addition to the standard squelch.

The first mobile radios didn't have a squelch circuit: the receivers simply ran wide open with a terrific roar. This was hard on the operators, who usually turned the gain down and consequently missed many calls.

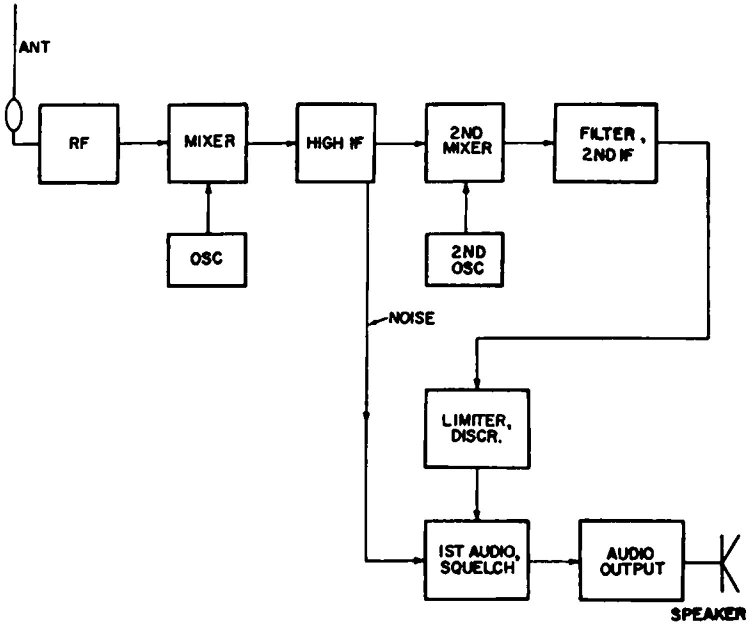


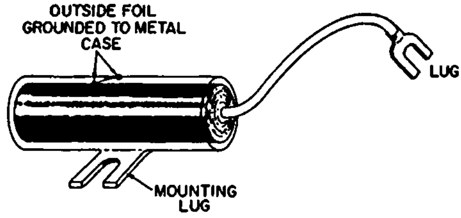
Fig. 8-3. Block diagram of a typical mobile FM receiver.

With squelch-equipped receivers, there is no sound (called *blow*) in the speaker unless a signal is being received.

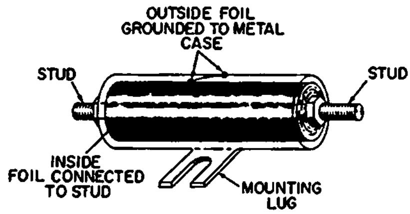
The basic squelch circuit is quite simple. A DC amplifier tube is adjusted to develop a high negative bias on the first audio-amplifier tube. The source of this bias, the actual noise in the receiver input, is amplified, rectified, and applied to the squelch tube. When a signal comes in, the receiver quiets and the noise voltage falls off. The squelch circuit then develops a positive bias which cancels the negative one, the first audio tube returns to its normal operating condition, and the signal is heard. In the tone-coded squelch, a very selective filter circuit is used so that voice signals alone will not operate the squelch; the keying tone must also be present before the squelch will open. The keying tone blocks all signals except those from the mobile unit's own base station and thus alleviates co-channel interference. With this system two taxicab companies, for example, can operate on the same frequency in a city, and each cab will receive only the calls from its own dispatcher. Provision for disabling a keying-tone squelch, so the receiver can be tested, is provided on the control head.

Now we have a problem. Simply "blowing" the squelch on an FM receiver will not allow us to hear ignition noise, etc.; an RF signal must also be present. This signal must be very weak; too strong a signal will quiet the receiver and block the noise, thus giving us a false reading.

There is a way to cope with this problem when the vehicle is in the shop. Turn the radio on and the volume full up, and shut off the squelch. Now turn on an RF signal generator and connect a short wire to the output to act as an antenna. Tune back and forth around the frequency of the receiver, using a



(A) Standard generator capacitor.



(B) Coaxial bypass capacitor.

Fig. 8-4. Comparison of a standard generator capacitor with a coaxial bypass capacitor.

400-cycle modulated AM signal, until you hear the squelch "break." The AM signal will come through the FM receiver at this short range and the 400-cycle modulation will be heard, allowing you to identify it. Turn the attenuator of the signal generator down until the signal is as weak as possible and still hold the squelch open. Now you have simulated the weak-signal conditions the receiver would encounter at a long distance from its base station, and the engine noise will be heard. The 400-cycle modulation can be turned off now, if you want to, leaving only the "blow" of the receiver.

Most shop RF signal generators will cover the mobile-radio frequency bands. If not, use a TV sweep generator without the sweep. If the signal generator covers the UHF TV channels, it will even work up into the 480-490 mc UHF mobile bands. All you need is just enough signal to break the squelch. If you cannot get it, run a longer wire from the shop to the car to increase the field strength at the receiver. Now we're ready to go to work on the noise!

We've got the same problem here as in the preceding chapter. The main difference will be in some of the equipment used. Basically, of course, it's the same, only constructed differently for greater efficiency in reducing VHF noises.

For example, the bypass capacitors will usually be of the coaxial type instead of the less expensive standard ones we've been using (Fig. 8-4). The capacitance remains the same—0.5 mfd—although a 0.1-mfd unit occasionally is found. A coaxial-type capacitor is compared with the standard bypass in Fig. 8-4. Coaxial simply means the conductor in the circuit being bypassed goes all the way *through* the case of the capacitor, on the inside foil, and comes out the other end. Connections are made at the studs on each end. The outside foil is connected to the case, which is fitted with the usual grounding-mounting lug. This construction gives a more efficient bypassing action.

In the last chapter we told you not to install a bypass on the field terminal of a voltage regulator. A special RC filter (Fig. 8-5) is used on the field in two-way radio work. On the outside, these look just like conventional bypass capacitors, but include a resistor in series with the capacitor to keep from upsetting the voltage-regulator action.

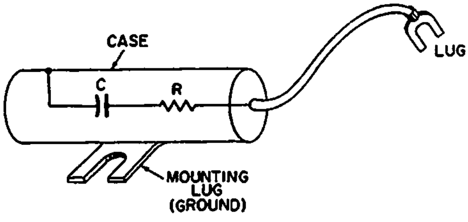
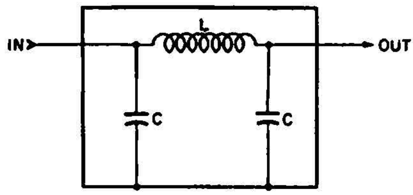


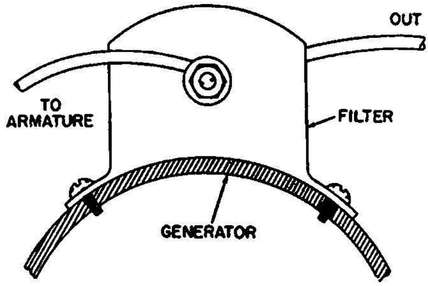
Fig. 8-5. A special RC filter for bypassing the voltage-regulator field connection.

Generator filtering is the same—with coaxial capacitors. Some vehicles use heavy-duty generators, and the heavier loads imposed on them makes them likely prospects for noise. Therefore, the generator filter in Fig. 8-6 will sometimes have to be used. It includes coils and capacitors, plus a heavy waterproof metal case and the usual mounting-grounding lugs for attaching it to the generator housing.

Let's go over a typical noise-finding procedure in a two-way radio. The first step is to install the minimum noise-suppression equipment—a resistive suppressor in the distributor coil lead, and a 0.5-mfd capacitor across the generator armature. Now make the operating test with the signal generator to see how quiet the vehicle is. (Incidentally, noises sound exactly the same on communications as on broadcast radios.) Be sure the hood is closed and latched. A large percentage of radiated noise in mobile radios is picked up through the antenna, and the hood is an integral part of the ignition-system shielding.



(A) Circuit.



(B) Shown mounted on generator housing.

Fig. 8-6. A special generator filter.

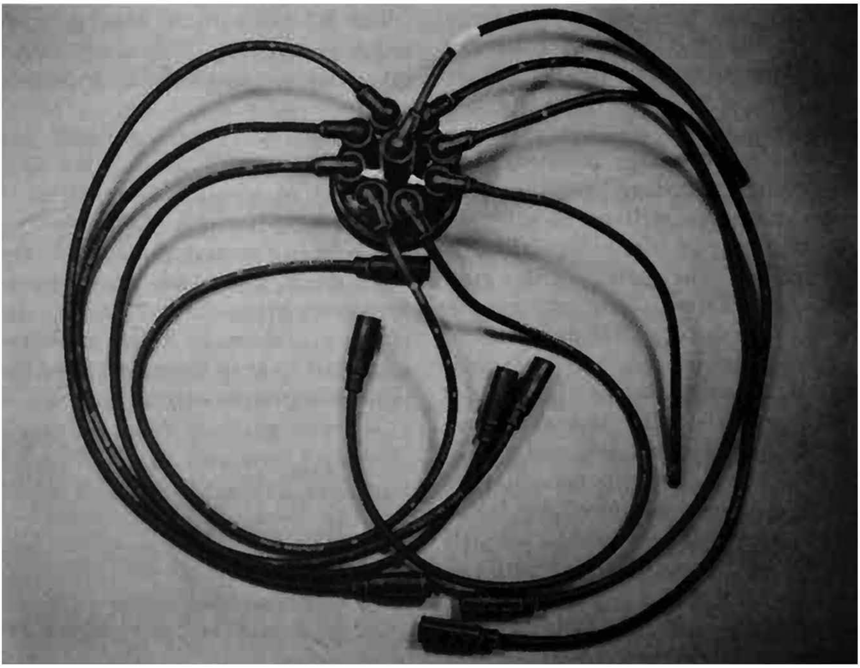


Fig. 8-7. A complete set of resistance-type ignition wiring.

If there is still too much ignition noise, the best bet is to remove the suppressor and install a complete set of resistance-type ignition wiring (Fig. 8-7), which can be purchased at any automobile agency. It is also factory equipment on quite a few cars now, so before cutting the ignition wiring to install suppressors, be sure to check. If marked "Radio," it is resistance wire and the suppressor is unnecessary. Resistor-type spark plugs are also available, but don't use both—the two together would probably cause trouble in the ignition system.

Other noises will respond to the same remedies listed in the previous chapter. Connect the generator and voltage-regulator filtering as shown in Fig. 8-8. A coaxial capacitor can also be used in the ignition-coil primary circuit, as seen in Fig. 8-9. A resistor spark plug is shown in Fig. 8-9.

Some cars, if exceptionally noisy, may require additional suppression devices. If so, refer to the following list of possible causes and install suppression as needed:

Ammeter: Bypass with a 0.5-mfd capacitor under the dash.
Ignition switch: Same as ammeter.

Headlight, taillight, and domelight leads: Bypass with 0.5-mfd capacitors.

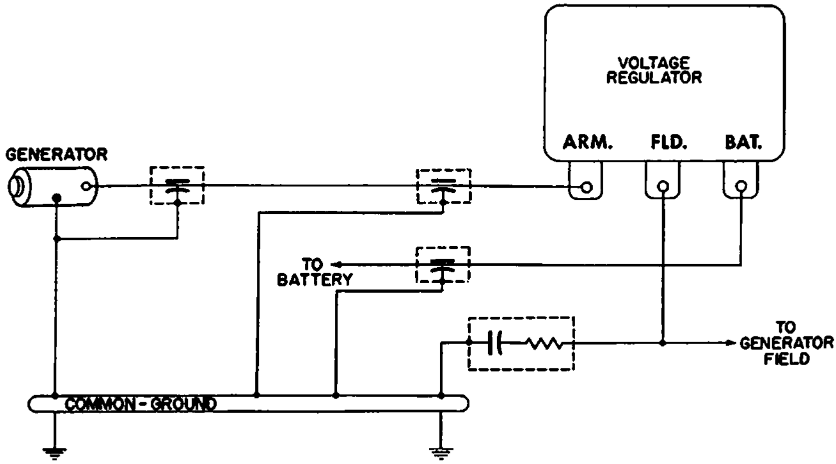


Fig. 8-8. Points where coaxial capacitors and the special field filter unit should be used for mobile-radio work.

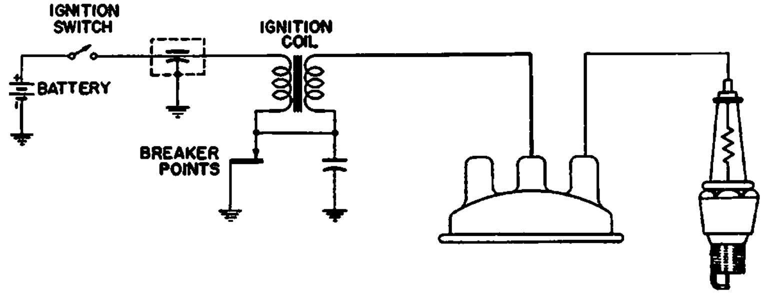


Fig. 8-9. A coaxial capacitor added in the primary side of the ignition coil.

Accessory wiring (electric windshield wipers, heater motors, window-lift motors, etc.): Bypass with 0.5-mfd capacitors.

Install hood-grounding wipers or bond the hood.

Install front-wheel grounding springs.

Connect the primary (battery) lead of the radio directly to the "hot" terminal of the battery instead of to the starter relay as is customary. A fully-charged battery will act as a very large capacitor (up to one *farad*!) and thus bypass directly to ground any noise riding the battery wiring. Be sure to coat the whole terminal with heavy grease, working it well underneath to prevent corrosion.

SHIELDED IGNITION SYSTEMS

For the car which must have the absolute minimum of electrical noise, specially-designed, completely-shielded wiring systems are available for ignition and other wiring. These systems are provided with filtering, in addition to the shielding.

Noise usually originates from one of two places—the ignition system (both the primary and the secondary sides) or the generator. Therefore, by confining the noise to these systems, we can reduce it to a level far below anything previously thought possible.

A shielded ignition system consists of a completely shielded and waterproof distributor cap, and special terminals for the shielded spark-plug wiring, as seen in Fig. 8-10. The spark-plug wiring has special fittings which not only make contact with the plug, but also provide a watertight positive ground connection at that end of the shielding braid. Fig. 8-11 shows the plug connector and a cutaway view of its internal construction. The wiring between the distributor and coil is also completely shielded, of course, and there is a shielding cover on the ignition coil itself (Fig. 8-12). A passthrough capacitive filter, on the primary side of the coil, keeps the noise from feeding into the other

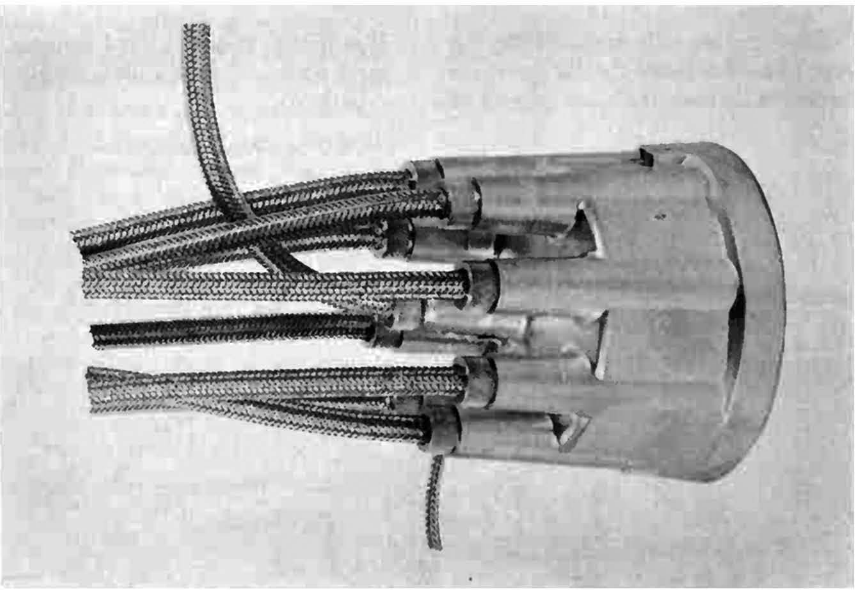


Fig. 8-10. A special shielded distributor cap with shielded spark-plug wiring.

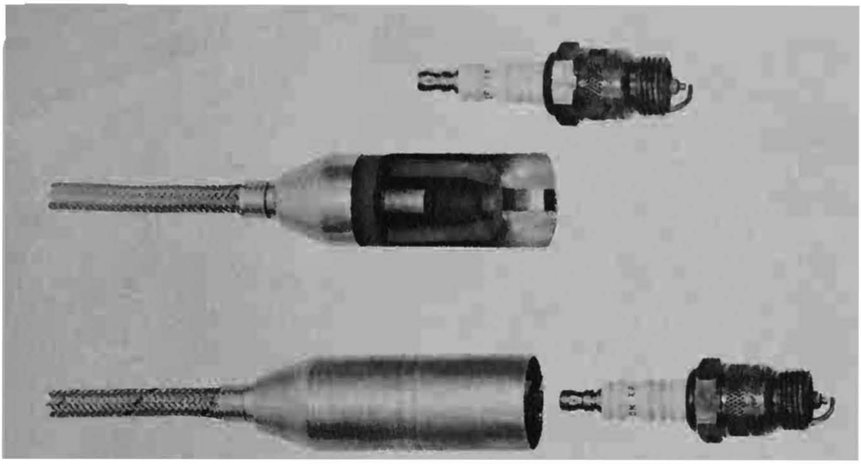


Fig. 8-11. Special shielded terminals for spark plugs.

Fig. 8-12. Shielding cover for the ignition coil.

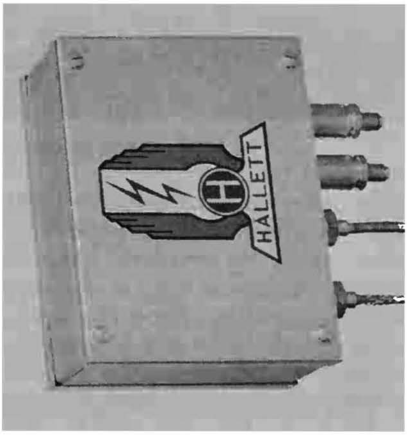


Fig. 8-13. Shielding cover for the voltage regulator.

wiring. This cap is for ignition coils with metal cases; if the case is plastic, a metal bottom shield must be added. The shielding is grounded wherever possible, and additional grounds are provided in the ignition-wiring harness clamps.

Shielded wiring is used between the generator and voltage regulator, and a shield completely encloses the voltage regulator as seen in Fig. 8-13. Passthrough capacitors in the leads of this cover complete the filtering. Access is gained to the voltage regulator by removing the four screws in the cover.

Fig. 8-14 shows the complete installation of this system. Notice the extra grounding obtained by using the ignition harness clamps. By the way, this shielding can be easily transferred to another car, especially if of the same make. This will reduce the over-all expense of the installation considerably, because only a new distributor cap will be needed as a rule.

The noise reduction attained with

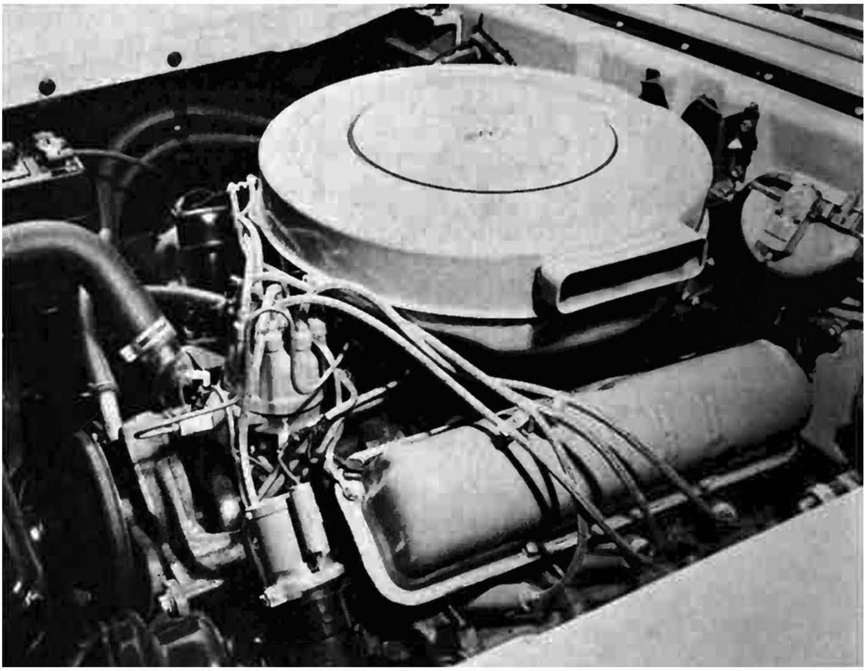


Fig. 8-14. Fully-shielded ignition system installed on a car.

a properly installed system of this type is remarkable, especially if either resistor-type spark plugs or resistive ignition wiring is also used with the shielding. Fig. 8-15 shows a set of typical test curves, made by placing a monitor radio receiver alongside the test vehicle (*hood open*) and measuring the radiated noise over the frequency range indicated on the chart. Notice the final result—the total noise level is prac-

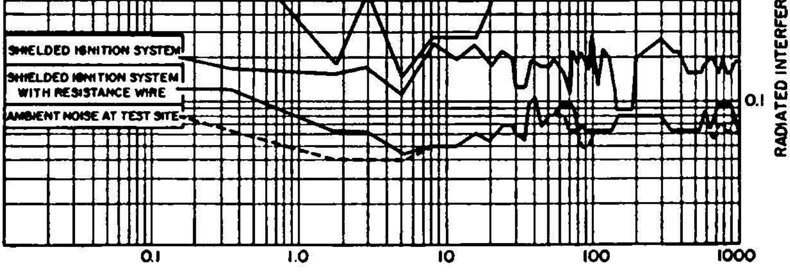


Fig. 8-15. Comparison of radiated noise from a shielded and an unshielded ignition system.

tically coincident with the ambient noise (the noise present when the engine is not running)!

RECEIVER ADJUSTMENTS

As a final touch-up, it is often possible to reduce the output noise in a receiver by adjusting its alignment slightly. Check the discriminator centering by tuning in a signal from the base-station transmitter. If this circuit is misadjusted, the noise level will be very high and the sound will be garbled.

To adjust, start the engine and feed a signal from a generator into the antenna. Very carefully touch up the second mixer coil by listening to the sound and watching a tuning meter. Don't reduce the meter reading too much because the sensitivity of the set must be kept high. The high IF's can also be checked the same way. Full instructions will be found in the manual covering the particular make of set; there are so many that it would be hopeless to try to discuss them all here.

NOISE IN BASE-STATION RECEIVER

Up to now we have dealt exclusively with noises from the electrical systems of the vehicles in which the mobile units were installed. The reason is that they cause most of the trouble. Now and then, however, noise will be found in a base-station receiver (although this is fairly uncommon, because its antenna is usually mounted on a tall tower and equipped with coaxial-cable lead-in to minimize noise pickup).

Noise in a base-station receiver is usually from power lines, motors, or other electrical apparatus. It is usually pulsed, producing large high-frequency components which are heard at all times on the base-station receiver, and can seriously interfere with communications.

To locate such noise sources, use the same methods outlined before for finding TV and other noises. One of the mobile units makes an excellent noise tracer. Drive around the area close to the base station until you find the place where the noise is loudest. Then take a portable BC radio and track it down. It will be very intense in BC radios, since it is loud enough to bother an FM receiver.

Remote-Controlled Base Stations

Many times the base-station antenna in a two-way radio system is three or four miles from the control point, on a hill or tall building. This is done so the antenna will be high enough above surrounding obstacles to give the system sufficient range. Telephone wires connect the receiver, transmitter, and antenna to a remote-control unit. All controlling is done by means of relays. Only audio-frequency signals are carried on the control lines, together with DC voltages to operate the relays.

In cases of interference, you'll have to find out where it is coming from. Is it high-frequency noise being picked up by the antenna? Or is it audio-frequency noise being picked up by the long telephone lines? One way to find out is to go to the remote receiver site, disconnect the control lines, and listen to the receiver. If the noise is still present, you have eliminated the remote unit. Noise picked up by the receiver is probably from power lines, defective "hardware," etc., as covered in Chapter 6. The power and light company will co-operate in looking for it.

Audio noise picked up on the control lines may be more difficult to trace, since the lines are often several miles in length. The best way to check this out is with an auto radio. Drive alongside the lines and listen for a similar noise. When it is heard, check the area for possible sources. One actual case of such a noise was caused by a tree branch which had fallen across the bare telephone line. Its other end was touching an AC power line, and there was just enough resistance in the bark to allow a bad AC hum to feed into the control lines! Telephone-company linemen will be glad to help out, since the control lines are almost always leased from the telephone company. With their help, the line can be "sectionalized." In other words, you can go to about the middle of the line and disconnect it. Then, by listening to each half with a test set, you'll be able to tell which segment is causing the noise. Further sectionalizing will let you pin down the noise source and eliminate it.

CHAPTER

9

Aircraft Radio

THE UNITED STATES has an amazing number of private airplanes, and it is increasing every day. A great many of them are equipped with at least a communications radio . . . and many are also equipped with radio compasses, VOR, and "beam-riding" receivers for navigation. We'll not try to cover the whole field of aircraft radio here, but confine ourselves to light planes and the smaller executive aircraft.

The amount of radio equipment in some of these planes will astonish you. For instance, a typical flying ambulance has 200-400 kc low-frequency receivers for flying the radio beams, 100-120 mc band VHF receivers and transmitters for air-ground and ground-air communication, a VOR (*V*isual Omni*R*ange) for navigation, and a radio compass. The latter covers the broadcast band and provides directional readings on any BC station within range. By taking two or more bearings, the pilot can locate his position with accuracy.

AIRCRAFT ENGINES

The typical engine in such planes is a seven- to nine-cylinder radial. You'll note one difference between aircraft and automobile engines: the aircraft generator, etc., are driven by gears instead of a fan belt. The equipment is mounted under the accessory cowling at the rear, as shown in Fig. 9-1. This cowling is removable to provide access to the

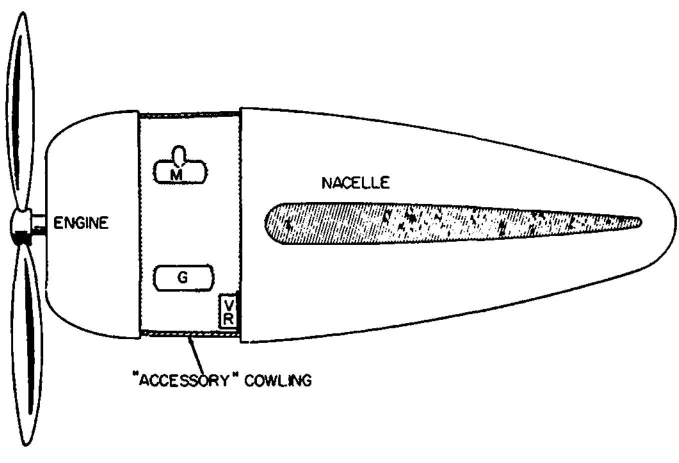


Fig. 9-1. Location of the generator, voltage regulator, and magneto on a typical aircraft engine.

equipment. Ignition is furnished by dual magnetos. An impulse booster increases the spark available while the engine is being cranked.

DC VOLTAGE SUPPLY SYSTEM

The DC voltage supply system of an aircraft is identical to that of an automobile, except that 24-volt systems are used in order to reduce the size and weight of the wiring and apparatus.

A DC generator controlled by a voltage regulator keeps the battery charged. The generator and regulator are the exact counterparts of those in an automobile and can be treated as such when hunting noise. Aircraft generators are usually fairly well loaded down, and the batteries are light in weight. Although the light weight reduces its capacity, the battery is actually a sort of floating load across the generator, which supplies most of the current.

When testing, never run the radios more than one or two minutes from the battery. Either keep the engine running or use an external battery cart. The latter is a heavy-duty battery on a small wheeled cart, with extension cables for connecting in place of the airplane battery.

There is one peculiarity of aircraft electrical systems: most of them have a Battery switch which must be closed to operate the radio or other electrical equipment. In some ships the Main switch must also be closed. (In some aircraft it is labeled the Master switch.) Some use a dual switch with Ship's Battery and External Battery positions. If there is no provision for disconnecting the battery, take off one of the battery cables and connect the external battery to it. (The simplest way to find out is to ask the owner or pilot how it is connected.)

AIRCRAFT RADIO EQUIPMENT

Almost all aircraft radio equipment is the plug-in type where all units are removable for service. The wiring connections are made through multiple contact plugs, and all wiring remains in the aircraft. Much of this equipment is rack mounted, either in the instrument panel or in a radio compartment (Fig. 9-2), and the wiring is connected to a socket on the back. The radio chassis slides into this rack on guides, and a plug fits into the socket to make all power, control, output, etc., connections. The chassis is held in place by screws or by the popular half-turn

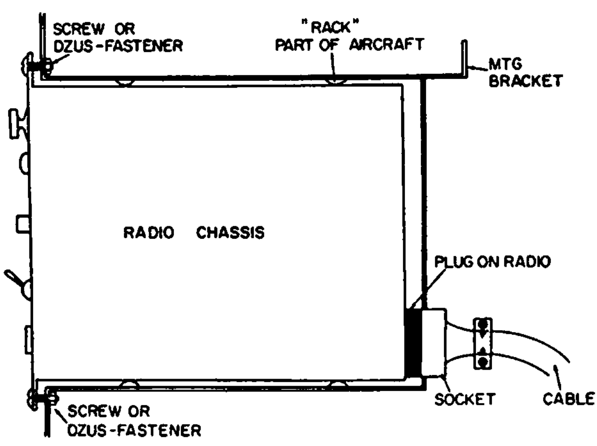


Fig. 9-2. Method of mounting aircraft radio equipment.

fasteners (*Dzus* fasteners) used throughout many aircraft.

ELECTRICAL NOISE IN AIRCRAFT RADIO

You'll find three types of noise in aircraft radio. Engine noise is exactly the same as in automobile radios and responds to the same cures. It was discussed in detail in an earlier chapter. Second is accessory noise, which includes all other electrical equipment on the plane. This noise can be bypassed directly at the source. Noise from gauges and instruments would come under either category. The third, and the one which can cause you the most trouble unless you're really alert, is vibration noise!

Because of the very high engine speeds needed, the whole airframe is subjected to a severe high-frequency vibration which can cause trouble if there are loose connections, dirty socket contacts, or similar troubles in the radio equipment. Therefore, in complaints of irregular static-like noise, make a thorough test of all equipment on the ground and with the engine *off* before trying anything else. Hammer the frame and fuselage with your fist while the radio volume is wide open, and clear up any noise before attempting anything else.

Checking for Engine Noise

Checking for engine noise is the same in an airplane as in an automobile, but with one exception—you'll have to tie the airplane down! Start the engine, and with the radio at normal volume, "rev" the engine up to cruising speeds (this point will be "red-lined" on the tachometer). If ignition noise shows up, run the engine on first one magneto and then the other. Ignition noise will almost always be found in one or the other, but seldom in both. If you do seem to find noise in both, check the antenna shielding and the radio bonding and grounding; this is more likely to be antenna trouble.

Many aircraft use shielded ignition systems like the one in Chapter 8. If noise is found here, check the shielding for loose grounds. The magnetos are fitted with conductive covers for shielding, and the most common cause of ignition noise is leakage from it. Clean the shielding carefully, washing off all grease and oil with carbon tetrachloride. Then replace the cover, being sure it is fastened tightly and the safety wires have been replaced on all screws.

Speaking of safety wires, perhaps it would be appropriate to explain just what they are and how they are used. Safety wires are used in aircraft to prevent the cables and the mounting bolts and screws from working loose during flight. Holes are provided in the screw heads and bolts and, after they have been tightened, a soft copper or brass wire is run through the holes and fastened to a nearby object (Fig. 9-3). A safety wire is also attached to all cable connectors and fastened to a nearby object. Always be sure to replace any safety wires, and if you use any new screws, be sure they can be safetied.

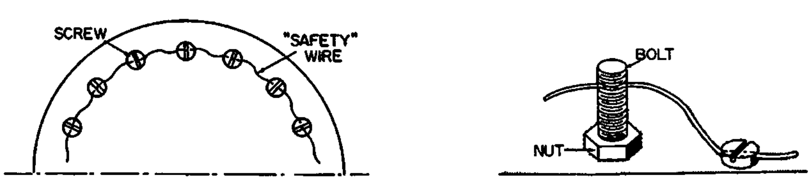


Fig. 9-3. Safety wiring of mounting bolts and screws.

Generator and Voltage-Regulator Noise

Generator and voltage-regulator noise will also be the same as in an automobile, and will respond to the same cures. When mounting capacitors on either unit, be very sure they are sturdily mounted and the bolts are safetied. Because of the terrific vibration and G stresses encountered in flight, all parts must be securely mounted to keep them from coming loose in flight.

On some ships you'll find a very convenient device for checking generator noise—a switch which cuts off the generator while the engine is running, in case it goes bad in flight. Simply turn the generator off if you suspect generator or VR noise; if the noise stops, then you're sure of it!

Static-Discharge Noise

Static-discharge noise is heard in flight. Although not really interference, it is often mistaken for such. It is a static discharge from the metal skin of the aircraft, caused by high-speed flight through dry air. One way to eliminate this noise is with static dischargers which are fastened to the trailing edges of the outer surface, such as the wing tips and rudder. The static charge gradually leaks off into the slipstream from these devices.

Interference in Instrument-Landing and Homing Systems

The airplane using radio-compass homing, or making a blind landing on instruments, is very vulnerable to interference, especially while on the glide path, or final approach. Any interference could cause the pilot to miscalculate and to crash. For this reason, both the FAA and FCC are understandably anxious to eliminate any such danger to the passengers or crew.

Instrument-landing systems are in the VHF bands for maximum immunity to normal atmospheric disturbances, and VOR equipment works in the 108-112 mc band for the same reason. Therefore, atmospherics don't bother these systems too much, but there is always the possibility that radiated RF interference will cause trouble.

Low-frequency equipment is more vulnerable, of course. A peculiar phenomenon occurred a while ago. Transport pilots using the low-frequency homers to find marker beacons and get into the correct landing patterns were annoyed by heterodyne beats and squeals in the receivers. What was more alarming, this caused the indicators to go wild! After some difficulty, the cause was finally located; it was radiation from the intermediate-frequency stages of transistorized portable BC radios carried by the passengers! These sets almost all use 265-kc IF's, and enough radiation was leaking out to upset the very sensitive homing-compass receivers. The FAA is thinking about barring such equipment aboard commercial airliners, as it should.

Some interference has been found even in the VHF range. Several radio-controlled garage-door opener transmitters near an airport were radiating entirely too much power. Although their fundamental was on 27.255 mc (their allocated frequency), the fourth harmonic of the transmitters was interfering with ILS equipment operating on 109 mc. This was also too close to some of the VOR frequencies.

Such transmitters are authorized to radiate only a very weak signal no farther than 50 to 100 feet. This particular equipment had excessively high output and, of course, no harmonic filtering in the antenna circuit. Ordinarily, it is possible to install such filtering in order to cut the transmitter power down to where the equipment will be acceptable. However, these garage-door openers had been made by a company which had not bothered to secure FCC approval! Needless to say, they now have such approval, plus much lower output and no harmonic radiation!

CHAPTER

10

Marine Radio

BOATING IS fast becoming one of the most popular sports, and small boats have increased tremendously in number the past few years. By small boats, we don't mean just row-boats, either! We mean powered craft, all the way from a 20-foot cabin cruiser up to some which can be classed as small yachts. Even the house trailer is getting into the act! One manufacturer is building a completely amphibious trailer. You drive up to the lake, back it into the water, crank up an engine in the trailer, and you have a houseboat!

There has been a corresponding increase in the amount of radio equipment designed for marine use. These include two-way communication equipment, entertainment radios, radios combined with direction finders, radio compasses, and even transistorized depth alarms which ring a bell when the water beneath the keel is shallower than a preset depth. And for commercial and sport fishermen, "fish finders" are available which work like sonar!

With all this electronic gear aboard, it is essential that the electrical system of the boat be silenced to prevent interference. Otherwise, radio noise might interfere with the radio direction-finding equipment or with emergency communications.

MARINE ENGINES

Marine engines are either the familiar outboards, which range from 3 up to 75 horsepower, or inboard engines, which go up to 200 or 300 horsepower in some of the large fishing boats and small yachts.

Inboard Engines

The inboard marine engine is exactly like its automotive counterpart, except it has no radiator because water is drawn from overboard. Most of them are housed in a well or compartment in the middle of the boat and are reasonably accessible.

Ignition systems are like those in an automobile and the same noise-reducing procedures can be used—resistor spark plugs, resistive ignition wiring, bypasses on the generator and voltage regulator, etc. The major difference is that the entire ignition system must be completely waterproof, and whatever noise-suppression equipment we install must never interfere with the waterproofing. For this reason, resistor spark plugs or resistive wiring should be used instead of plug-in or cable-type suppressors, because they can be made just as watertight as the original. A liberal application of waterproofing compound is also recommended on all connections.

Fully-shielded ignition systems similar to those for automobiles are also available for marine engines. These have the added advantage of being completely waterproof.

Outboard Engines

Outboard motors probably outnumber the inboard types by a large margin. They range from the tiny one-cylinder trolling motor to the six- or eight-cylinder racing types. Often, they are used in pairs to drive medium and large cruisers.

Almost all of them are equipped with magnetic ignition. Fig. 10-1 shows the magnetos and breaker points of a typical outboard motor. Notice the plastic-encased coils at the top and bottom. These are the ignition coils. Some of the larger outboards have electric ignition like an automobile's, and even electric starters. Magneto ignition systems can cause noise, the severity depending on the construction of the motor. If it has a solid metal cover over the spark plugs, not too much suppression may be required . . . the cover serves as a shield. There will be some noise pickup near the motor, but it often is not even noticeable forward where the radio equipment is located. Motors using plastic covers may need suppression, however.

In some magnetos the wiring is part of the coils and it is impossible to use resistance-type ignition wiring. Instead, resistor-type spark plugs will have to be used. (Separate suppressors like those used on cars would not be too durable.) To repeat: the ignition system must be as waterproof as possible, so always use resistance wire or resistor-plugs.

Fig. 10-1. Magneto and breaker points on a typical outboard motor.

LIGHTING GENERATORS

Some of the more elaborately equipped boats will have auxiliary engines to provide electric lights and power for a refrigerator and other electric apparatus. These engines are used mostly to charge a bank of 6-, 12-, 24-, and 32-volt batteries. The engine drives a heavy generator with a capacity of 30 on up to 100 amperes or even more.

Noise problems arise from the auxiliary engine's ignition system, which can be either shielded or suppressed like any other gasoline engine. Resistor spark plugs will probably eliminate almost all ignition noise. The generator is simply a large DC generator, exactly like a car generator except for its size. Hence, the same procedure of bypassing each brush with a large capacitor can be used. Also clean and polish the commutator. Standard LC filters may have to be installed in series with the main power wiring, between the battery bank and the load (or better still, between the generator and batteries).

Some systems employ a 110-volt, 60-cycle AC generator so that standard electrical appliances can be used afloat. An AC generator isn't inherently as noisy as the DC generator because the output is taken off by means of slip rings; the worst trouble here will be in the auxiliary engine itself.

OTHER ELECTRICAL EQUIPMENT

On the more luxurious boats, electric sail hoists or anchor winches may cause noise due to the brushes in their motors. Standard filtering procedures will take care of this. Install bypass capacitors at the motor, across the brushes. When the equipment is exposed, always be very sure the filters are completely waterproof if installed on the outside of the motor. If only bypass capacitors are installed on the inside, be careful to replace all waterproof gaskets, seals, etc., after reassembling the motor.

Some of the factory-built LC filters can be very useful in marine work; they are already completely sealed in tubular cases and hence are entirely waterproof. In addition, they can be installed in bulkheads (naval slang for the walls), special metal boxes, or on the motor itself.

RF INTERFERENCE: DISTRESS AND COMMUNICATION CHANNELS

Since 1958, the FCC has made it mandatory for boats carrying more than six passengers for hire to have radio receiving and transmitting equipment aboard, and the radio operators must maintain a watch over the distress and calling frequencies of 500 and 2182 kc, and also the ship calling frequency of 8364 kc.

Several cases of radiated interference have been found on these frequencies, quite a few due to "stuck" transmitters. This is caused by a keying relay contact, etc., becoming stuck and keeping the transmitter on the air without the operator's knowledge. The frequency is blocked for several miles in all directions, of course. The only way to locate this trouble is with direction-finding equipment. A minimum of two bearings is required to locate this, or any, interference source.

Other equipment can interfere with these frequencies; LF carrier-current systems have been picked up on them, as have industrial heaters and arc welders, etc. Once again, the DF receiver is the handiest tool.

CHAPTER

11

Unusual Noise and Interference

UP TO this point, we have been talking mainly about the effects of noise and interference on radios (both entertainment and communications types) and television. Now, let's take up the much more serious and sometimes dangerous effect that interference and noise can cause in the more delicate electronic apparatus in use today. Typical units would include electronic computers and controls, telemeters, electromedical and geophysical apparatus, and many others.

Most of them are very sensitive receivers, and a high ambient noise level can play havoc with the accuracy of their recordings. The result may cause severe property damage and endanger human life. For example, a rocket launching at Cape Canaveral was supposed to have been delayed for several hours while technicians located and repaired a faulty transmitter, in a taxicab radio system miles away, that was interfering with their telemetering receivers!

The most common cause of interference is exactly like what we have been discussing in the earlier chapters: fluorescent lights, defective motors, bad connections, improper shielding, radiating devices of all kinds, and so on. These can be located and quieted with conventional apparatus. However, special cases of unusual interference may require more drastic measures. Interference which is concentrated in a certain band of UHF frequencies, for example, may be impossible to locate with ordinary equipment.

Quite often it will be possible to locate the noise source by using the receiver being interfered with as a detector. Monitor its output, either

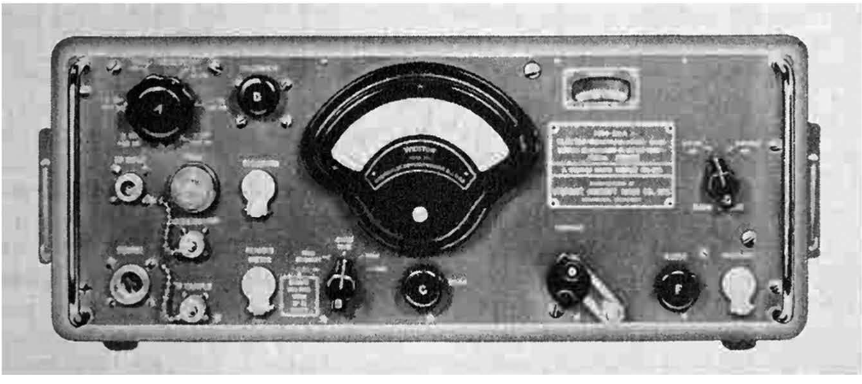


Fig. 11-1. A professional noise locator.

on a graph or oscilloscope, while turning on various items of electrical equipment in the vicinity one at a time, to see which one is responsible for the interference.

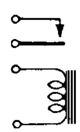
In very difficult cases, a professional noise locator like the one in Fig. 11-1 will have to be used. It is made in several models covering different parts of the radio-frequency spectrum. The unit shown has a range from 375 to 1,000 mc. Other models provide measurements from as low as *thirty cycles* to 10.7 *kilomegacycles*! These are very accurately calibrated, highly-sensitive RF microvoltmeters that can measure not only the frequency and amplitude of the noise, but also determine the bandwidth over which it is present. Recording voltmeters can be used with them so that a permanent record of the noise level can be kept. An oscilloscope can be connected to the output for a "panoramic" display—i.e., a sweep-frequency pattern of the entire band of frequencies being used. In this way, noise sources can be located within several megacycles of the frequency in use.

A variety of input devices are available for these instruments. A conventional dipole or a broad-band "bow-tie" can be used in the UHF ranges, or a directional loop antenna will provide bearings on the noise source. For other work, special shielded probes are used to pinpoint individual noise sources within the interfering apparatus. The sensitivity of the detector is adjustable over a very wide range, and additional pads are available to bring it down to whatever value is needed.

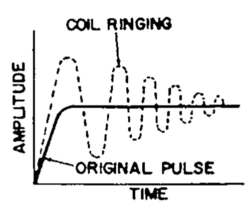
This detector is often used with directional antennas of various types to pinpoint the location of a noise or interference source. It can also be used as a field-intensity meter because it is capable of cancelling interference in the presence of a sine-wave RF signal and thus reading the actual field strength of the signal without the noise.

INTERFERENCE FROM INDUCTIVE CONTROLS

Many times the electrical apparatus is remote-controlled, necessitating a large number of relays, solenoids, and similar controls. Each of these controls has as its actuating mechanism a coil, which can be the source of a peculiar type of interference. Most relay coils are actuated by a sudden pulse of current. Under just the right circuit conditions, this current can cause the coil to "ring" (go into temporary oscillation). As a result, a pulse-type interference is generated which can be radiated or conducted into other nearby apparatus, upsetting their operation. (See Fig. 11-2.)



(A) A typical relay coil.



(B) The applied pulse and the ringing voltage.

Fig. 11-2. Ringing in a relay coil.

Such interference is caused by the unavoidable conditions in any circuit using inductance. All coils have inductance; they also have a certain distributed capacitance between any one turn of wire and all the other turns. There is also the DC resistance of the wire. The LC constant of the coil determines the frequency of the fundamental burst. The Q of the coil determines the number of cycles in the ringing waveform; high-Q coils, of course, will ring longer than low-Q coils, which tend to be more or less self-damping because of their low DC resistance.

This is really a design problem, usually taken care of when the equipment is built. However, now and then unavoidable interference will be found when apparatus made by different manufacturers is used together.

There are several ways of curing this kind of trouble. The simplest, of course, is to install line filters, both in the device causing the noise and in the one being interfered with. With adequate input shielding, this will often be the easiest way out. If it doesn't bring the interference down to an acceptable level, then we'll have to do something to the offending coils themselves. A lot of work may be required in disassembling the machines, etc.—which is the reason for suggesting the simplest way first.

The coil or coils causing the trouble must first be positively identified. This can be done by using the noise locator just described and a well-shielded probe to pinpoint the offender. Always remember the first rule of noise-suppression work: the filtering device must never interfere with the primary purpose of the circuit being filtered. For this reason be very careful, when applying corrective measures, that each piece of equipment still performs exactly as before.

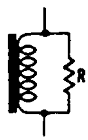
The worst headache is the sensitive relays, solenoids, etc., which must act very rapidly—many opening and closing several times per second. The actuating coils of such relays have a very fast drop-out time (the time in seconds or milliseconds required for the magnetic field of the coil to collapse and allow the armature of the relay to be released). Other relays will have a delayed release; they hold the armature down for a certain time after the exciting current has been interrupted. We'll have to be very careful, with the last ones, to keep from upsetting their time constants.

However, the picture is not as dark as we have been painting it. There are ways we can damp out the ringing in a coil without affecting its performance or changing its time constant too much.

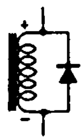
Remedies

The simplest method of damping a coil, shown in Fig. 11-3A, consists of shunting a resistor across it. The resistor, which is several times as large as the DC resistance of the windings, changes the Q of the coil and thus damps the reverse pulses quite efficiently. However, the lower amplitude of the pulses will slow down the re-energizing time of the relay. The magnetic field of the coil will have to be built up again after the resistor has damped it, and hence a few more milliseconds will be added to the re-energizing time.

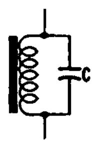
Another method is shown in Fig. 11-3B—a reversed diode connected across the coil. The effect is obvious—the diode does not conduct when the current is applied in the "normal" polarity, and the exciting current is permitted to flow through the coil. When the coil attempts to ring, however, the diode conducts heavily on the first half cycle of the reversed-polarity current and thus damps the coil rapidly. This gives excellent suppression; but it cannot be used where the relay must have a very fast reaction, because the magnetic field of the coil must have time to rebuild after being completely drained off by the diode.



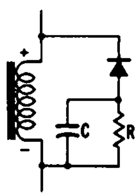
(A) Resistor across coil.



(B) Diode across coil.



(C) Capacitor across coil.



(D) Combination of diode and RC network across coil.

Fig. 11-3. Methods of damping inductances to prevent excessive ringing.

Another alternative is to use a shunt capacitor across the coil (Fig. 11-3C). By adding more capacitance, we can lower the natural resonant frequency of the coil enough to throw the fundamental out of range of the apparatus being interfered with. Most of the time, large low-voltage capacitors are used; however, in some VHF and UHF applications, a small capacitor may move the noise peak out of the bandpass of the receiving apparatus without slowing down the time constant of the relay too much.

In some cases, a combination of all three may be used, as shown in Fig. 11-3D. By making the time constant of the RC network very short, the release time of the coil will not be affected too much and the coil will be ready for service again.

If the circuitry makes it possible, other more common filters may clear up the trouble. For example, if the relay is energized by pure DC, it should be possible to install a rather "heavy" filter in the supply circuit, as shown in Fig. 11-4, and to increase the DC supply voltage to allow for any voltage drop in the filter.

Shielding can also help here. If space does not permit the entire re-

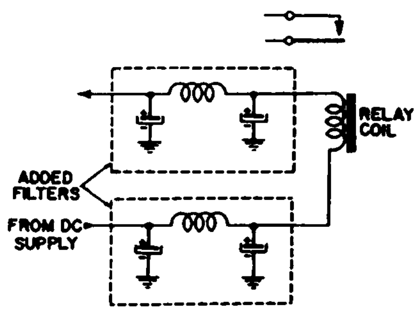


Fig. 11-4. Adding LC filters on both sides of radiating coil to eliminate interference.

lay assembly to be shielded, small homemade shields can be placed around the coil. In close quarters, wrap the coil with several turns of aluminum or other metallic foil, tie it tightly with string, and ground the foil by taping one end of a wire to it and attaching the other end to the chassis (Fig. 11-5).

Other circuits may offer more difficulties. If the coil happens to be

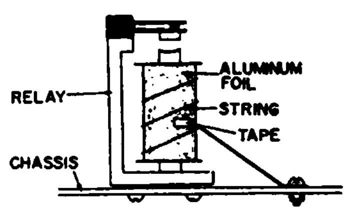


Fig. 11-5. Shielding a relay coil with foil to eliminate interference.

in the plate circuit of a vacuum tube, as so many are in this kind of apparatus, we are severely limited in the number of interference suppression devices we can use. However, we're still not entirely helpless. For example, if a coil used in the circuit of Fig. 11-6 is radiating interference, we can reduce it by taking the measures shown. Correctly applied, these should reduce the radiated pulse interference without affecting the performance of the stage. After all, there are still only two ways these interfering pulses can escape—by radiation, which can be cut down by shielding, and by conduction over the supply wiring, which can be reduced by proper bypassing.

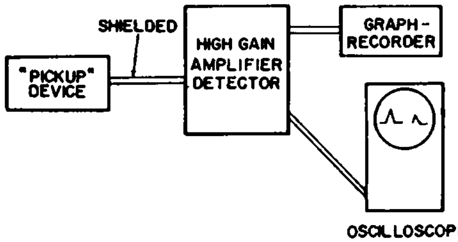


Fig. 11-7. Block diagram of a typical electromedical device.

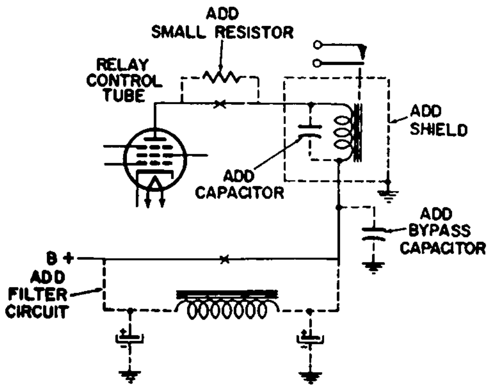


Fig. 11-6. Methods of reducing interference from a relay coil in the plate circuit of a vacuum tube.

ELECTRONIC MEDICAL APPARATUS

Modern hospitals use a tremendous number of electronic apparatus for both diagnosis and treatment. Such items as the electrocardiograph (abbreviated EKG) for recording heartbeats, and the electroencephalograph (abbreviated EEG) for measuring brain waves, can be easily upset by an excessively high electrical noise level. Basically, these and all similar instruments consist of a transducer or other pickup device which converts the quantity being measured into electrical signals. Fig. 11-7 is the block diagram of a typical electromedical device. The pickup is attached to the patient and its output is fed into a very high-gain amplifier. The detected output of the amplifier is then fed into a recorder which makes a permanent chart of the readings. Some are used with an oscilloscope so the waveforms can be examined at the same time.

Noise and interference can get into the input of such devices and cause false readings, misleading the diagnostician. This can be very dangerous. Therefore, all possible precautions must be taken to keep the area in which the equipment is used free of electrical noise and interference. The amplifiers in such equipment have a very wide range of response, often running from almost DC up to 100 kc. Therefore, they are sensitive to almost any frequency of noise. The room and building should be checked very carefully with radio detectors or one of the special interference locators described before. Normal sources of noise, such as fluorescent lights, motors, etc., must be quieted with filters, and all other electrical apparatus within range checked for noise radiation. Where the ambient noise level is very high and cannot be reduced economically, the equipment may have to be placed in a completely shielded room to keep out extraneous noise.

The equipment itself must be very carefully checked to insure that it is in perfect condition. Quite a few complaints of external interference have been cleared up by repairing the apparatus itself! Since these instruments require a very high sensitivity to respond to the minute currents generated by brain waves, etc., the input shielding must be absolutely perfect. Loose or ungrounded shields, loose connections in the pickup, and similar troubles, can cause false noise in the equipment. Check and clean all connections. Then test the apparatus for noise immunity by operating some kind of noise generator nearby, such as a noisy electric drill or an old-type electric razor. Make a test recording or observe the waveform on a scope, to see if the noise is being shielded out as it should be. Incidentally, it would be a very good idea to make a test recording, using no input, on each new piece of equipment when it is first installed. This will give you an idea of the normal noise level of the unit. If a great deal of this work is done, one of the many calibrated noise generators can be used for accuracy.

If some hospital equipment is among the worst at receiving noise, other units are among the worst in creating it! Among these are the older X-ray and diathermy machines. The champion noisemaker is the cautery, or "radio knife" as it is sometimes called, in Fig. 11-8. It

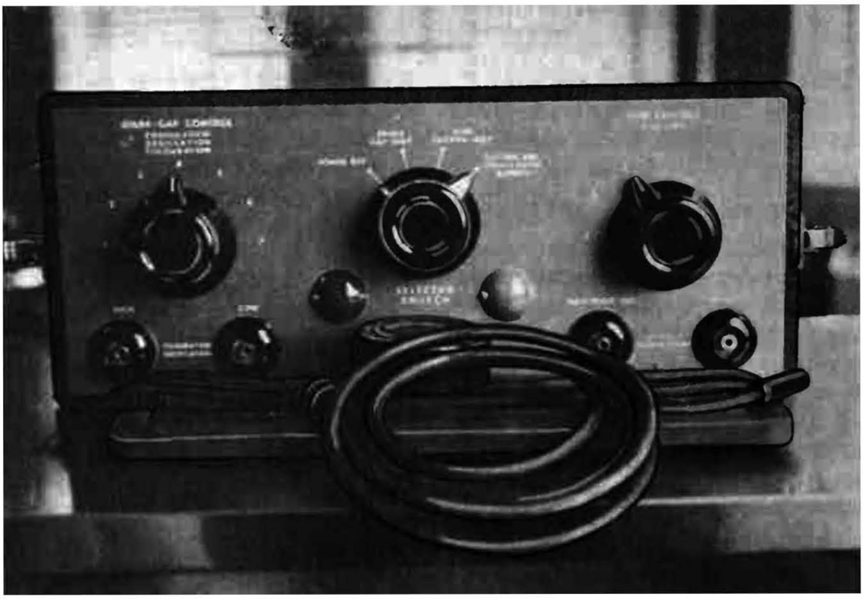


Fig. 11-8. A "radio knife," or cautery.

generates a high-frequency current which is controllable in amplitude and, to a certain extent, in frequency. It is used for cauterizing wounds and sometimes for cutting tissues without excessive bleeding. The latter is done by applying current through an electrode; a tiny arc sears the tissues as they are separated.

The basic schematic of a typical cautery is shown in Fig. 11-9. The step-up transformer, together with an electrically-driven set of contacts in series, forms a high-frequency arc between the points. This pulsating voltage is fed, through insulated cables, to the cutting or treatment electrode and to a return pad, or ground, placed under the patient. The current thus consists of a rapid series of high-frequency, high-voltage pulses. Their amplitude and frequency are regulated by changing the distance between the vibrating points, and hence, the length of the arc.

This is a rich source of RF interference, of course! Unfortunately, we can do little about it except recognize its source. The only way to completely eliminate the radiation would be to use the cautery in a fully shielded room. However, there is one small, alleviating feature—the unit generates interference only when being operated, which is for very short periods of time. Current flows for only a second or two, resulting in one or two short bursts of noise. Installation of an LC filter in the supply wiring, and complete grounding of the apparatus (necessary in any event for the protection of both patient and surgeon) will help shorten the range of the radiation, which ordinarily will not travel far beyond the operating room.

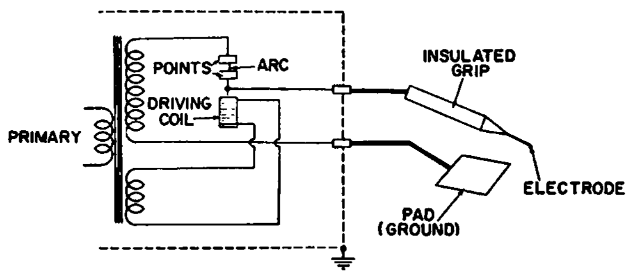


Fig. 11-9. Basic schematic of a "radio knife."

GEOPHYSICAL EQUIPMENT

Another place where absolute radio silence must be observed, at least as far as noise and interference are concerned, is in geophysical equipment. Such equipment is used to explore for oil deposits and other subterranean research. A lot of extremely sensitive recording equipment is used: recording seismographs, geophones (seismic detectors), and a large assortment of telemetering equipment. Two-way radio equipment is also employed for communication and for telemetering between the base and observation stations.

The trucks, cars, boats, and aircraft used must be noiseproofed to prevent radiation of ignition noise, which could interfere with the sensitive recording equipment and with communications. In addition, the generator at the main base must be absolutely "clean" as far as noise is concerned. The standard noise-reducing procedures and equipment outlined in earlier chapters will do the work, and LC filters should be used in all power-supply lines.

THE SHIELDED ROOM

Where a machine generates large amounts of radio-frequency or noise interference, or where very sensitive receiving equipment must be protected from random noises, it is necessary to enclose the equipment in a solid (to RF energy) shield. These are often called screened rooms because the most popular material for constructing them is copper window screening.

The purpose of the screening is the same as for any other shielding. The surface of the shield intercepts the energy and carries it off to ground in the form of eddy currents. The walls, floor, and ceiling must be completely covered with the conductive material, and all power lines and other conductors passing through the shielding must be furnished with filters. (Light fixtures can be hung on the outside to save filtering them.) Furthermore, all doors must be provided with wiping metallic contacts so they do not cause a break in the shielding. Fig. 11-10 shows a completely screened room.

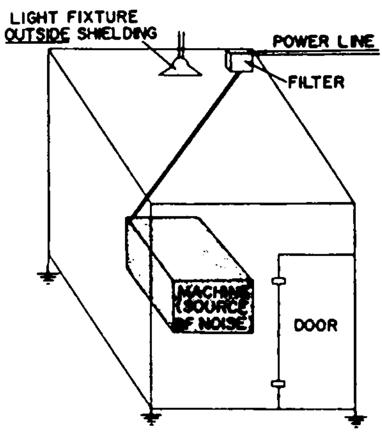


Fig. 11-10. Construction of a screen room.

Construction of a Screened Room

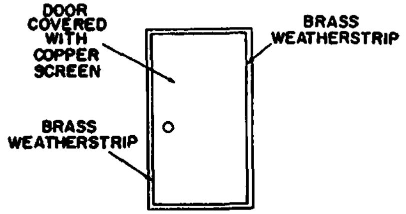
There are two types of screen rooms in general. One is where a machine must be shielded in a larger space, such as a factory floor, etc. The other is where the unit is installed in a small room. In the first type, a self-supporting framework of light timbers supports the screen. The floor can be covered with the screen, which in turn is covered with linoleum or other floor covering, or with solid sheet metal if more convenient.

The copper screen is soldered together at all joints to assure continuous shielding. Solder joints should be as close as possible, continuous soldering being best.

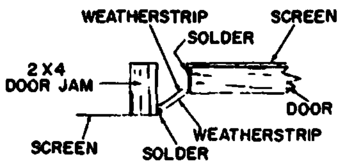
If the machine is in a small room of its own, the screening can be fastened to the walls and ceiling. Furring strips of wood will provide a place to nail the screen if the wall surface is masonry, etc. The top of the screening can be dropped below the ceiling and all lighting fixtures mounted on the outside to save using filters.

Details of the door construction are shown in Fig. 11-11. The edges of the door and the jambs are fitted with brass weatherstrip so they will make a tight contact when the door is closed. (The detailed drawing in Fig. 11-11B shows the door and jamb separated much farther than normal for clarity. The two weather strips should wipe tightly when the door is closed.) Copper screen on walls and door are soldered to the edge of the brass strips to make a good joint. The wiping action keeps the contacts clean.

All wiring entering the shield must pass through adequate filtering. An LC filter in a metal box should be used in each circuit, and the box connected to the shield itself. Where the machine is producing large amounts of radio-frequency



(A) The door.



(B) Detail of door edge.

Fig. 11-11. Construction of a screen room door.

energy, the filters can be tuned to the fundamental frequency for maximum efficiency. However, the standard brute-force filters will almost always be sufficient.

In severe cases, a dual screened room will have to be built, one inside the other. The two screens should be separated by at least ¾ inch or more and insulated from each other. Both the inner and the outer screens should be well grounded, and the inner-screen ground wires should be insulated where they pass through the outer screen. A ground rod at each corner of the room, connected to the screen by a heavy strap, will furnish the thorough grounding needed.

CHAPTER

12

The FCC and Its Role in Interference Complaints

THE FEDERAL Communications Commission (FCC) is the governmental agency charged with regulating all broadcasting and communication in the United States. In 1934, this agency had 20 offices, 7 monitoring stations, and 113 employees. That year it received 3,800 complaints of radio interference. In 1959 it had grown to 31 offices, 18 monitoring stations, and 80 mobile units, with a staff of 400. In that year it received 24,036 complaints of radio and TV interference!

With such an overwhelming load and limited staff, the FCC has aided in the formation of industrial and citizens' groups to handle as many local complaints as possible. There are 32 Cooperative Interference Committees (CIC), made up of engineers, executives, governmental officials, and others interested in the clearing up of mutual interference problems, and 525 Television Interference Committees (TVIC), made up of radio amateur operators, radio and TV technicians, broadcast radio-TV engineers, and others. Industrial groups have also been formed to aid in the design of such machines as plastic heaters, RF arc welders, etc., so they will cause as little interference as possible.

The TVIC groups handle all local interference complaints wherever possible. In some areas, a statewide organization has been formed and a headquarters set up in the state capital.

FCC MONITORING STATIONS

The FCC operates 18 monitoring stations in the United States. These stations are equipped with direction-finding equipment and receivers capable of covering almost all RF frequencies, as are the 80 mobile units of the field-engineering division. The stations and mobile units not only check radio and TV broadcast stations to make sure they adhere to the strict technical standards laid down by the FCC, but also track down interference of almost any kind. The locations of these stations are as follows:

Primary Monitoring Stations

Allegan, Michigan
Grand Island, Nebraska
Kingsville, Texas
Millis, Massachusetts
Santa Ana, California
Laurel, Maryland
Livermore, California
Portland, Oregon
Powder Springs, Georgia
Lanikai, Oahu, Hawaii

Secondary Monitoring Stations

Searsport, Maine
Spokane, Washington
Douglas, Arizona
Fort Lauderdale, Florida

Ambrose, Texas
Chillicothe, Ohio
Anchorage, Alaska
Fairbanks, Alaska

HOW TO REPORT A COMPLAINT OF INTERFERENCE

Obviously, a huge percentage of interference complaints are going to be caused by local conditions—defective electrical equipment, etc.—which can be located and cleared up easily by local technicians. Therefore, such cases should not be reported to the FCC until all resources have been exhausted locally.

The route for complaints to the FCC should always be: first, the local TVIC, then the state TVIC or CIC headquarters, and finally, *but only if these agencies cannot find the cause,* the FCC engineers. In this way, you'll avoid wasting the time of the FCC engineers—who have a very heavy workload at all times—on a case which should have been handled locally.

UNUSUAL CASES OF INTERFERENCE

Our deepest gratitude goes to the Federal Communications Commission for permission to reprint the following case histories. Taken from the FCC Field Engineering Reports, there are but a sample of the oddities the FCC engineers turn up . . . all in a day's work.

Interference in Aircraft Communication Systems

An inadequately shielded arc welder in Detroit caused a near-accident at a local airport when its released energy blotted out an important call of an approaching aircraft. Luckily, no damage was done, and after the offending welder was tracked down, it was properly shielded.

A Minnesota airfield reported disruption to aircraft communication over a radius of 50 or more miles. Thanks to bearings taken by a mobile unit, FCC engineers found the culprit to be a common electric doorbell half a mile from the airport. Its transformer contained a temperature-control strip with contacts which had become so pitted that the connection alternately went on and off. The interference stopped when the bell was silenced.

A recent long-distance interference case developed when an aeronautical service at Honolulu, Hawaii, reported that strong signals were blotting out its radio messages between air and ground. The FCC direction-finder net was alerted and fixed the source, not locally, but some 5,000 miles away—at a port on the east coast of the United States! The trouble proved to be a defective ground transmitter of another airline. Unusual propagation conditions caused the signal to span the continent and part of the Pacific Ocean to Hawaii.

An Air Force base in Colorado complained of interruptions to its air-to-ground communications. FCC engineers found it was due to radiations from an old-type radio-controlled garage-door opener at a nearby private residence where the garage doors were labeled "His" and "Hers." The difficulty was removed after the couple installed a remote-control system that could be licensed in the Citizens Radio Service.

The reason for complaint of an airport in Bellingham, Washington, was finally pinned on arc welders used in a local shipyard, which took measures to eliminate their effect on aviation radio communication.

An airlines office in Chicago reported serious interference on a frequency used by its planes. Direction-finder bearings indicated it came from a certain area in Minnesota. A mobile unit narrowed it down to a factory at Grand Rapids, Michigan, and further pinpointed it to an industrial heating device. The company promptly took corrective measures.

"Hillbilly" music which plagued radio communications at a Tennessee airport was emanating from a homemade record player nine miles away.

Interference to the International Airport at Boston, it was discovered, came from a broken cable in contact with a covering metal pipe.

Interference in Broadcast Radio Reception

A Maryland resident complained of severe interference, both to radio and TV reception, from 9:15 P.M. to 6 A.M. It had been going on for three months and the power company was unable to locate the trouble. The complainant was requested to recheck all electrical equipment in her home. Two days later she reported she had found the culprit—an old electric blanket!

In Fairbanks, Alaska, a broadcast station experienced jamming on its remote pickup frequency. An FCC mobile unit traveled the streets, going from door to door, until finally professional rather than personal preference caused it to stop in front of a tavern. Here a neon sign was turned on, but the gas in it was not illuminated and caused radiation. The tavern owner "signed off" and called a repairman.

An illegal but humorous operation was uncovered in a Chicago suburb. Four youths, using a makeshift "station" composed of parts of a castoff theater sound system and the power supply of an old TV receiver, not only broadcast recorded music and commercials (free), but were conducting "man-on-the-street" interviews as well. However, one of the persons interviewed on the sidewalk was an FCC field engineer who, in response to the opening questions, announced he was there to close down the station. There was a sudden sign-off announcement by the "ex-manager." A visit to the "studio" revealed a posted schedule of stiff penalties for violating the station's rules. They ranged from "goofing names on the news—3¢" to "messing up commercials—5¢."

There are cases of carrier-current or wired broadcast systems interfering with radio communication services. In one instance a so-called "college campus" system was radiating five miles from the school. The Commission's field staff has long tried to acquaint educational institutions with the availability and advantages of economical, low-powered, noncommercial educational FM broadcast operation.

When a California family went on vacation, it forgot to turn off the household broadcast receiver. Not only that, but something went wrong with the neglected set. Possibly because of loneliness, it started to retransmit the programs of a local broadcast station. It did so in a manner that played havoc with reception by land mobile radiotelephone stations up to 33 miles away. Insertion of a new tube and a turn of the Off knob eliminated the trouble.

This case involved complaint by a woman that a neighborhood amateur station was interfering with the operation of a radio phonograph. The amateur was elderly and in poor health. His principal interest was his "ham" station, which several fellow amateurs constructed and serviced for him. The amateur's sister informed the inquiring engineer that her brother had suffered a heart attack after a series of arguments with the complainant. Therefore, tests were made under the guise of a routine station inspection. No cause for interference was found in the amateur equipment.

At the complainant's home, interference was observed in the all-wave receiver, only when it was in the phonograph position. The antenna consisted of a short insulated wire wrapped around a line cord of a very "messy" electric system. When the antenna was unwrapped from the line cord and the line plug reversed, the interference ceased.

Some time later, however, another report was received from the same complainant. This time the agitated lady claimed that whenever she put her hand near the radio-phonograph pickup to change records, the amateur's voice would break through. This phonomenon, she said, was making her nervous and affecting her health. The investigating engineer discovered that the latest apparition was due to pickup in the phono-pickup leads. So he devised a wavetrap which eliminated the woman's "haunt," and the amateur continued to operate his station which, according to him, "makes life worth living."

The Commission wishes all interference cases could be resolved as satisfactorily and harmoniously!

In another case, near Havre de Grace, Maryland, both radio and TV reception on a broad scale was disrupted by a loud buzz. The Maryland CIC group traced it to a defective electric fence on a local farm. By following the advice of CIC experts, the owner was able to remove the intruding noise.

While monitoring for interference in Portland, Oregon, a mobile unit observed a strange signal which it traced to an apartment house. Here it was found to be due to a homemade short-wave receiver which had been discarded for two years. But, unknown to the owner, the power cord was still plugged in and the switch was on. This combined fire and interference hazard was remedied, but the owner is still trying to determine how much it cost him on his electric bill.

Interference in TV Reception

Complaints of interference, which gave a Massachusetts city "pictureless TV" on one channel, were traced to test equipment in a local radio tube plant—one of the complainant's!

In Worcester, Massachusetts, interference to reception on a certain TV channel was found to come from an oscillating AM receiver in the neighborhood. On the other hand, interference to AM broadcast reception in two Vermont communities originated with two wired TV distribution systems.

An investigation extending over many months was required to solve an intermittent TV interference problem in Marion, Massachusetts. The cause finally proved to be spark-type discharges in the antenna system of a military installation in that area.

An Indiana housewife blamed a neighbor's amateur operation for her distorted TV picture. She was not satisfied when an FCC field inquiry indicated that her receiver, rather than the "ham," was at fault. So she wrote to President Eisenhower. However, a second visit by an engineer of the Chicago office showed that the disturbance had been eliminated. The method used was unique. On the day when the lady of the house (described by her husband as the "dominant member of the family") was away, the helpful amateur, with the consent of the woman's husband but without her knowledge, installed a wave trap and a line filter in her set to make up for its poor interference-rejection capabilities.

Complaint was received of poor TV visibility by 60 families sharing a master TV receiving antenna on a Connecticut apartment building. Inquiry revealed that the trouble extended over an area containing 500 receivers. An FCC engineer found it was caused by a defective flashing neon sign in the window of a local finance company. The manager (not because of financing any of the sets involved) immediately turned the sign off and arranged to have it serviced.

During sunspot and other seasonal disturbances, the Commission is swamped with complaints of TV interference and reports of abnormal TV reception. At such times some TV signals occasionally span the continent. Nothing can be done about it; this is an abnormal condition due to reflections by the ionosphere—a layer of ionized air far above the earth's surface, above which radio waves normally do not go.

Manufacturers and users of industrial heating equipment are going to great lengths to curb interference from this type of apparatus, which has become important to many manufacturing processes. One firm, harassed by continuing complaints of interference, decided to correct the situation itself, since a commercial firm indicated it would take months to provide the necessary shielding. So plant personnel constructed a shielded room 70 by 30 by 15 feet at a cost of $3,000, and an outside engineer certified that it complied with the FCC interference safeguards. To make doubly sure, however, the plant's own engineer installed a meter in his office to check the radiation.

Numerous complaints of interference to TV reception came from a city in upper New York state. The complainants believed that amateurs, diathermy equipment, or station operation was at fault. But a Buffalo mobile unit traced the onerous signal to a local private residence. Here, on-and-off tests showed radiation from a booster amplifier, which went into strong oscillation when it was left on after the TV set was turned off. The owner promised, in the future, to turn off both his booster and receiver simultaneously.

A resident of Chicago complained about persistent annoyance to his and other TV receivers in the neighborhood. He was surprised to be told, after investigation, that the source was an electronic door-opening device on his own garage!

Inquiry into disruption of TV reception in a California community showed that technicians in an adjacent research laboratory had forgotten to turn off some transmitting equipment they were testing.

Interference to TV reception in a California city was first blamed on an obsolete diathermy machine. The latter was replaced with approved equipment. However, complaints continued and a new search led to an oscillating TV booster. This was also remedied. A short time later a letter was received from the local chamber of commerce, thanking the Los Angeles FCC office on behalf of "hundreds of persons whose TV enjoyment was impaired and who are most grateful for the prompt attention."

A TV store in Massachusetts complained that prolonged interference —for several hours at a time—was hurting its business because it was unable to properly demonstrate TV receivers to prospective customers. After some questioning, the FCC engineer asked if a TV booster was being used. When the answer was in the affirmative, he suggested the complainant turn off the booster. The annoyance stopped immediately. The store owner was voluble in his thanks. Time for solving this complaint—eight minutes.

A new TV station in San Diego, California, was blamed for spoiling reception from other stations. Inquiry showed the fault was receiver overloading through the use of high-gain antennas employed by viewers to extend their reception to Los Angeles. The receiver owners were instructed on how a quarter-wave stub or a commercial wave trap could remedy their trouble.

Disruption of TV service to an area of several blocks at Pitcairn, Pennsylvania, was traced by an FCC engineer to a defective thermostat on a gas heating unit in one of the homes. The local TVI committee induced the owner to have it repaired.

The owner of an industrial plant in New York went to great lengths to satisfy a New Jersey woman who was blaming TV interference on an electronic heater in his establishment.

Initial investigation revealed that during the World Series an employee of the plant had plugged a radio receiver into an electric outlet inside the room shielding the heater, and had placed the receiver on the outside for the benefit of his fellow baseball fans. Because the door of the heater room was left slightly open for the cord to pass through, some of the radio-frequency energy escaped. However, before the FCC investigator arrived on the scene, the plant management had discovered the door ajar, closed it, and cautioned the employee responsible.

But the New Jersey TV fan still complained of interference traceable to the plant. So the factory owner shut off his heater temporarily while he added shielding to the woman's TV receiver, installed a line filter for it, and even replaced her TV antenna with a better one.

This is an example of unusual cooperation from a user of non-communications electronic equipment.

Distortion of TV pictures in Danville, Virginia, was ended when a TV booster on the roof of a fire station was discovered to still be on, even though the receiver was off.

Residents near Santa Rosa, California, were plagued with TV interference. FCC engineers and cooperating electric company troubleshooters found the cause—faulty controls for ventilating the brooder house of a local chicken ranch. The owners replaced the defective devices.

In Pennsylvania a local official complained to the Commission and to his Congressman about interruption of his TV reception by a community antenna TV system. Inquiry pinned a double guilt—on cable radiation by the community TV system and on the complaining official's own defective TV receiver. Both parties promised corrective action.

A "popping" sound which blacked out TV reception over a four-block area in Denver was first blamed by a set owner on neighborhood amateur-radio operation. But investigation showed that it came from the complainant's own TV receiver. It had been "souped up" with higher voltage to take care of a larger picture tube, with resultant breakdown of equipment. The abashed owner agreed to remedy his set to satisfy his neighbors.

A TV repair shop in Kentucky reported that his entire community was experiencing severe interference on Channel 12. By using a mobile unit equipped with a field-strength meter, an FCC engineer traced the trouble to an amplifier used by a TV viewer to bring programs in over a very long lead-in line. The amplifier, in continuous operation, oscillated and acted like a small transmitter.

When TV fans at Port Jefferson, New York, complained that passing railroad locomotives were ruining their pictures, the New York field office and the railroad company collaborated in demonstrating, with the help of a locomotive loaned for the purpose, that this was not the cause. From that point it was traced to a defective insulator on an electric light pole.

Some cases of interference to TV reception are due to old-style electric light bulbs. They became such a problem in one community that the local electric power company, co-operating with local TV dealers, offered to replace free any outmoded bulbs turned in by the public.

Sixty families in three New York City apartment houses were annoyed by both radio and TV interference. Pooling their observations, they noted that the trouble always started after a certain tenant had returned home. An FCC engineer then determined that the source was in the suspect's apartment. Friendly entry with a police officer found the man using an old sparking-commutator motor. He said he did so to retaliate against a neighbor whose refrigerator, he thought, was ruining his AM reception. He desisted upon warning, whereupon broadcast reception returned to normal for everybody concerned.

Interference to TV reception in a section of Puerto Rico was traced to a poor connection at a nearby aeronautical beacon. In reverse, interference to an aviation station in the United States was found to come from a faulty transmitter at an FM broadcast station.

Interference in Other Communications Systems

A case of heater interference affected a marine distress frequency. It was in the form of 100 pulses a minute, indicating industrial heating of very small objects. It was traced to a factory in Washington state that was using 10-kilowatt applications on roller bearings at the rate of 100 per minute. Here, too, the management co-operated to remove the interfering "beats."

"Rock-and-roll" music invaded a marine rescue frequency to give operators an additional headache. The Millis, Massachusetts, monitoring station found it was caused by an overmodulated emission of a broadcast station. When notified, the broadcast station promptly suppressed it—the overmodulation, not the "jive."

When police and broadcast signals doubled up on a frequency used by an industrial radio station in Waterboro, South Carolina, a trap installed at the complainant's receiver removed the undesired signals.

Here is one for the birds! Complaint of interference to a Texas police radio system resulted in a floor-by-floor search of a 12-story hotel several blocks away. The woman occupant was kind enough to interrupt her bath in order to dress and allow the FCC and police representatives to enter and search out the trouble. It was found to be a defective TV receiver which had been left on. The woman explained that she usually did that for the enjoyment of her birds—a parakeet and a canary. Lady, birds, and police all seemed happy when a minor adjustment stopped the set from oscillating.

An international communication carrier complained of interference to radio messages en route from New York to Frankfurt, Germany. Both the German and British monitoring services had been unable to identify the source. FCC monitoring observations and direction-finding bearings placed it as coming from a commercial telegraph transmitter of another company in New York. Identification of spurious signals is often more difficult than the layman may think—or understand.

During recent floods, the Connecticut state police asked the FCC's Boston district office to inquire into interference to the state forestry radio system. From the information furnished, the Boston office felt that the trouble was in the forest service's own equipment, and suggested a check of that service's transmitters throughout the state. It detected one transmitter in continuous operation. This was due to flood waters actuating the relay, which remained closed after the waters had receded.

More widespread interference, reported by a gas pipeline company, was affecting communication between its facilities in three states—Texas, Louisiana, and Mississippi. At an FCC field engineer's suggestion, one of the company's planes took off and headed in a certain direction. As it approached a company installation 40 miles distant, the interfering signal became stronger. The plant there was requested to look at its main transmitter. The main switch had unintentionally been left on.

Interference to a marine calling and distress frequency, reported by a Coast Guard station in Washington state, was traced to an electric fence on an inland farm. The owner agreed to stop operating the fence charger until it could be repaired.

Intrusion on a radio frequency used by the Civil Air Patrol in Tulsa, Oklahoma, was due to an overly-healthy signal emitted by an improvised "health machine" in a Tulsa household. Below a sun lamp and two layers of colored glass, two jugs of water were in the process of being "vitamized" by radiation. The owner agreed that his health would not be impaired if he obtained his vitamins by other means.

The New Jersey Turnpike reported that interference was disrupting a portion of its highway radio network. Mobile detection units tracked it down to a telephone company transmitter in Philadelphia. The latter's defective resistor was replaced.

The British monitoring service requested FCC assistance in identifying a station spoiling reception at London of transmissions from Nairobi, Kenya, in East Africa. The Commission's monitoring observations and long-range direction-finder bearings showed that the interference came from a United States military station at Tripoli, North Africa. As a result of its contact with the military in Washington, D.C., the Commission was able to advise the British agency that the trouble would be eliminated as soon as a substitute frequency could be obtained for the Tripoli station.

When the transmitter of a Eau Claire, Wisconsin, nonbroadcast station did not operate properly and caused harmonic radiations, investigation revealed that squirrels had gained entrance to the remote apparatus and dined off the transmission line, chewing up a couple of filters for chasers.

Police of one Maryland county were troubled by erratic performance of its radio communication system. An FCC mobile unit traced it to a tailor shop in Baltimore. After an electric system which operates the pressing machine was repaired, no further antics resulted.

Interference to Internal Revenue Service domestic communication was identified by FCC monitors as originating from a station in Rio de Janeiro, over 4,000 miles away.

The Chillicothe, Ohio, monitoring station received complaints by an electronic firm about interruptions of its communication in the citizens band. The wayward transmissions were deciphered to be taxicab dispatching messages. However, they were not accompanied by call signals or other identification. Direction finders fixed their origin in Bermuda. Since citizen frequencies are used on a shared basis, with no interference protection, there was no justification for complaining to the British authorities.

The Pennsylvania, North Carolina, and Wyoming state-police radio systems complained of severe interference. Bearings obtained by FCC direction finders led overseas to a Berlin, Germany, radio station. The angle of the Berlin station's directional antenna was accommodatingly changed, but the interference appeared to be a transistory prank due to high sunspot activity. Likewise, passing interference to certain domestic radio communication channels has been caused by wayward video signals from British TV Channels 1 and 2 in the 40-mc band.

When an international telegraph carrier complained of multiple interference on its circuit to Saudi Arabia, the FCC net found that it was caused by 10 different radio stations scattered throughout the world.

A taxicab radio control station in Buffalo, New York, was not entertained by hearing local broadcast programs on the frequency it uses for dispatching cabs. Search led to a small clock-radio receiver which was radiating a strong signal over the neighborhood. A cure was effected by replacing the output tube in the radio.

That interference can span great distances is illustrated by the following:

The Coast Guard requested FCC assistance in locating signals blotting out ship communication. Bearings showed that they came from far-Pacific waters. When the Coast Guard contacted Japan, it learned that the signals were from a vessel in distress in the Philippine Sea.

Miscellaneous Cases

Interference is sometimes experienced by FCC monitoring stations. For example, tests of the direction finder at the new Douglas, Arizona, monitoring station were so handicapped. The origin was traced to a nearby power line—whereupon the co-operative power company installed new insulators and drove ground rods to a depth of 20 feet. This did the trick.

Disruption of service by a land radar installation near Long Beach, California, pointed to radar operation on a U.S. Navy vessel in the harbor. Naval personnel insisted that the ship's radar was not in operation. But mobile bearings showed that the boat's radar transmitter was on, despite the fact that its radar antenna was not rotating.

Another distance-spanning interference offender is the old-model diathermy machine. Its unshielded emissions can skip and jump over wide areas to bother regular radio services, particularly those on which safety of life and property depend. However, most of these machines are being brought into compliance with the FCC rules, and new machines release their excess energy on a special frequency provided for that purpose.

Not long ago an FCC inspector boarded a motor vessel at a California marina. The uncooperative owner ordered the inspector off the boat. When the latter stopped on the float to write his official report, he was followed by the boat owner and, in a resulting altercation, somehow found himself—literally—in deep water. Not having a pen that would write under water, he had to swim for shore to complete his report. As a result, the FCC is taking administrative action against the boat owner—this time through the mails.

This case typifies one reason the FCC wants its field inspectors brought under a Federal law which makes it a criminal offense to assault certain Government inspectors. FCC field men have no such protection at present, so the Commission has proposed covering legislation.

Another device which Commission field men inspected was an "electronic bug killer." It was supposed to emit a ray which so affected the antenna of insects that they would be driven away. The demonstration indicated no release of energy, but only sound which was calculated to greatly annoy the bugs.

The FCC monitoring station at Fairbanks, Alaska, was troubled with power-line interference. By taking bearings with improvised mobile equipment, it traced the source to power-line poles about a mile away, where the insulators had been shot away by erratic hunters.

Strong signals which prevented reception of mobile telephone calls at a Dallas, Texas, exchange were discovered to be high-frequency oscillation from a TV receiver about 500 feet from the telephone company's receiving antenna.

Complaint was made by a contractor on an Air Force project at Roosevelt Field, New York, that development of a radio telemetering circuit was being delayed by interference which was increasing the cost approximately $1,000 a day. The troublesome signal was traced by an FCC mobile unit to nearby radar equipment. Replacement of a defective tube in the latter was the simple cure.

The Veterans Administration at Boston complained that interference was rendering an electronic medical recorder inoperative. An FCC engineer found that the machine was not adequately shielded from the clinic's own diathermy machine. The latter was operating properly. Diathermy interference is no longer a major problem because such machines are now approved to control excess radiation.

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