IRE TRANSACTIONS

ON BROADCASTING

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Reprinted from Part 7 of the 1960 IRE INTERNATIONAL CONVENTION RECORD

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IRE TRANSACTIONS ®

on Broadcasting

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REPORT ON WORLD RADIO CONFERENCE
GENEVA, SWITZERLAND, 1959

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SUMMARY - A report on the world radio conference held in Geneva, Switzerland, during the last four months of 1959 is presented. The Conference was held under auspices of the International Telecommunication Union, the specialized agency of the United Nations which deals with radio and other telecommunication matters at international level. The organization of the conference is described, to show the mechanism by which engineers and telecommunication administrators from many nations work together to produce what amounts to international legislation in a highly technical field. The four principal work areas of the conference were: Radio spectrum allocations; frequency management techniques; definition of technical terms and establishment of technical standards; and operating regulations in the aeronautical and maritime radio services. Major decisions of interest to engineers in the United States are summarized, including new terminology which engineers will be expected to learn gradually in the years ahead.

Introduction

The International Telecommunication Union (ITU), which had its beginnings as a regional organization in Europe nearly 100 years ago, corresponds in a very rough sort of way at international level with the Federal Communications Commission at national level. Both attempt to regulate as necessary the telecommunications activities within their cognizance. There are approximately 100 members and associated members of the ITU, which is the specialized agency of the United Nations which deals with telecommunication matters. The Union is established and its functions are determined by a treaty called the International Telecommunication Convention. This Convention ordinarily is revised at five-year intervals. Annexed to the basic Convention are three sets of technical Regulations. These are the Telephone Regulations, the Telegraph Regulations, and the Radio Regulations. The purpose of this paper is discussion of the Radio Regulations.

The Radio Regulations last were revised at Atlantic City in 1947. Although they are supposed to be revised each five years, on the same time schedule as the Convention, 12 years elapsed before the members of the Union could agree that the time was appropriate to undertake revision. The means for revision is an Ordinary Administrative Radio Conference. The procedure for convening such a Conference, together with its rules of procedure and its basic agenda are specified in the Convention. The Convention allows so much latitude, however, that delegations to the Conference are at liberty to make any additions, deletions, or modifications in the Radio Regulations which they deem to be appropriate and on which general agreement can be reached.

The Radio Conference convened in August of 1959 and adjourned on December 21 after working continuously for more than four months. It produced a new set of Radio Regulations, almost twice the length of the old. It consists of a document with 300 pages of text, with which there are associated 26 appendices, 15 Conference Resolutions, and 36 Conference Recommendations, bringing the total number of pages to well over 500. It will be printed by the International Telecommunication Union in the near future in the five official languages, which are Chinese, Russian, Spanish, French, and English. In case of dispute, the French text is to be considered the authentic version. In addition to the five official languages of the ITU, pertinent parts of the Regulations will be translated into more than 40 languages, if the 1947 Regulations are to be taken as a guide.

Organization of the Conference

More than 600 delegates and advisers were in attendance at the Conference. In order for so many experts to work profitably, it was necessary to divide into groups and sub-groups. This was accomplished by establishing eight Committees.

Committee 1 was the Steering Committee. It was composed of the heads of the other seven Committees, together with a few officials of the ITU.

Committee 2 was the Credentials Committee. It dealt with the credentials of each delegation present and the right of each delegation to participate in the work of the Conference and to sign the Final Acts of the Conference. Since this was a technical meeting of engineers and telecommunication administrators, international political problems tended to be minimal, but such problems as there were gravitated toward this Committee.

Committee 3 dealt with Conference finances and budgeting.

Committee 4 dealt with one of the major work areas of the Conference, the revision of the International Table of Frequency Allocations and all text material relating directly thereto. Participation by all delegations in the work of this Committee was extensive. Approximately half of the United States delegation concentrated its work here. Before the Committee finished its work, it had established approximately 35 Working Groups and Sub-Working Groups to deal with different parts of the spectrum and particular problems which arose during the conduct of negotiations.

Committee 5 was established to deal with international frequency registration procedure and international frequency lists and frequency plans. Although very little glamour was associated with the work of this Committee, it dealt with the most complex single problem in international radio regulation, which is to reach agreement on the rights to protection from harmful interference for the radio operations of one nation as against another.

Committee 6 was the Technical Committee organized to be responsible for all definitions appearing in the Regulations, the classification of emissions, the specification of minimum frequency tolerances and spurious emissions, and international monitoring and procedures to be followed between Administrations in cases of harmful interference.

Committee 7 was organized to deal with the operating regulations which take up approximately half of the text material in the new Regulations. Its area of responsibility was operating matters relating to the aeronautical mobile and the maritime mobile radio services.

Committee 8 was the Drafting Committee. Any international conference of size inevitably requires such a committee as this. Its job is to take the output of the other committees, and edit and arrange the material to produce a finished product for adoption by the plenary sessions of the Conference. Since it cannot function until the other committees produce agreed documents, it normally operates only during the latter part of the Conference and then generally on a crash basis. This Conference was no exception.

I now have told you that the Conference organized its work by establishing eight Committees, four of which were responsible for the four main work areas of the Conference. To review, these work areas were: Frequency allocations; frequency management procedures; technical regulations; and operating regulations.

The Work of the Conference

The big question, of course, is what the Conference accomplished. You might think that with large delegations from both sides of the Iron Curtain not much could be accomplished, but this was not the case. The Table of Frequency Allocations was reviewed, modified, and extended upward from 10,500 Mc/s to 40,000 Mc/s. International frequency management procedures were revised, and the authority of the international body dealing with problems arising from individual radio station frequency assignments was strengthened. The number of agreed definitions of technical terms was approximately doubled. Several changes in technical terminology were made, of which we shall hear more in the years to come. Problems which had arisen during the past 12 years while using the old operating regulations in the maritime and aeronautical services were studied, and the old procedures were revised and refined in an attempt to eliminate the recurrence of such problems in the future.

Frequency Allocations. At international level, the first frequency allocation Table in recognizable form was adopted at Washington, D. C., in 1927. At that time the upper limit of the Table was 23 Mc/s, noting that the band 23 to 60 Mc/s was sub-allocated for amateur and experimental use. At the next Radio Conference in 1932 at Madrid, the upper limit was raised from 23 to 28 Mc/s, with the remainder of the spectrum up to 60 Mc/s still allocated to amateur and experimental radio services. At the 1938 Radio Conference in Cairo, the upper limit was raised to 200 Mc/s. At the Atlantic City Conference in 1947 the Table was extended to 10,500 Mc/s. At the Geneva 1959 Conference, the upper limit was raised to 40,000 Mc/s (40 Gc/s).

If one studies the allocation Tables which have been adopted by Radio Conferences since 1927, the most striking thing, aside from new developments in the state of the radio art, is the ever-increasing detail which appears in the international regulations. Since electromagnetic radiation has no respect for national boundaries and since the world scientific community continues to exchange technical information at a rapid rate, we can expect this trend to continue toward more and more international technical regulation. At the present time, the principal difference between an international Table of Frequency Allocations and a national Table is that the latter is more specific. For example, a given part of the spectrum may be available internationally to two or more radio services, but be available nationally for use by only one of these services.

In all international Tables prior to the adoption of the Geneva Table last year, wherever two or more radio services were allocated the same block of radio spectrum space, they had equal rights, one as against the other. Geneva has changed this. Without going into detail, a new service priority system has been established, and allocators should become familiar with the expressions "primary service", "permitted service", "secondary service", "additional service", and "alternative service".

The United States is one of the major users of the radio spectrum on a world-wide basis. Any change in frequency allocations in the bands below approximately 30 Mc/s which are useful for long-distance communications purposes would have substantial effects upon existing operations. This was the case after the Atlantic City Conference, when, among other changes, the high frequency broadcasting bands were expanded at the expense of the fixed services. It took several years before the necessary adjustments could be completed, and, in fact, adjustments still are taking place as we go through the various phases of the 11-year solar cycle. Therefore, the United States delegation and a number of other delegations felt that no substantial change should be made in frequency allocations below 30 Mc/s. Still other delegations, however, proposed that the high frequency broadcasting bands should be substantially expanded. Additionally, we very quickly learned that many delegations from new and developing countries had placed satisfaction of their national aspirations for spectrum space in the broadcasting bands high on their lists of priority objectives. It was with great difficulty, therefore, and after much deliberation, that the Conference finally concluded that no substantial allocation change should be made below 30 Mc/s. Instead, primary reliance is to be placed on improved frequency management techniques so that new high frequency broadcast operations can be accommodated in the existing bands allocated for that purpose without listeners to the new stations being subjected to harmful interference from existing operations. It will require the utmost of good will and cooperation to achieve this objective.

Very few allocation changes were made which affect the broadcasting industry in this Region of the world. The present AM or "standard" broadcasting band, which now has its lower limit at 540 kc/s, was extended downward to 530 kc/s, with a number of limitations imposed on the use of the new channel, including maximum power of 250 watts and something less than primary status due to sharing with other radio services. On the basis of representations by the Delegation from the Federal Republic of Germany, the band 11,700 to 12,700 Mc/s has been allocated on a world-wide basis for broadcasting. In this Region of the world, the allocation is shared with the fixed and mobile services other than the aeronautical mobile service. The German development, on which there is as yet practically no information, looks toward a large number of local broadcast outlets as a means of settling the European television program distribution problem. Although the U. S. delegation agreed to this allocation, there is as yet no information to indicate that the experimental technique has any application to the domestic television problems of the U. S. A. There is no U. S. allocation of this band to broadcasting at this time.

The air transport industry of the world cannot exist without a complex network of communications channels to support its operations. As the world air transport industry grows, its demands for a larger share of the total available radio spectrum space grow likewise. At the Geneva Conference, the aeronautical mobile service band at 118 to 132 Mc/s was extended upward to 136 Mc/s in all parts of the world except this hemisphere. In this area, the extension was upward by 3 Mc/s to 135 instead of 4 Mc/s to 136.

Geneva adopted a new allocations policy for navigational aids. Heretofore, the parts of the spectrum set aside for radionavigation use have been shared between devices used both for navigation and non-navigation purposes. The United States delegation proposed and the rest of the world agreed that the radionavigation bands should be split up or sub-allocated to get rid of the non-navigational devices. Accordingly, these bands have been subdivided between the radionavigation service and a new service called the radiolocation service. These two services together comprise what now will be known as the radiodetermination service.

Frequency allocations for long-range aids to navigation caused considerable disagreement. The final result was liberalized allocations in the frequency bands useful to the British Decca system of navigation and also in the bands useful for the U. S. supported Loran systems of navigation. Neither allocation is all that its proponents could wish.

The Conference established frequency bands for space research, but not for the exploitation thereof. To further this research, two new radio services called the "space service" and the "earth-space service" were defined, and bands of frequencies for their use were designated. In general, these bands are shared with radio services which already were using the spectrum space in question. A tentative date of 1963 has been set for a specialized world radio conference to consider, in the light of developments in the space research program up to that time, what further changes should be made. The bands of frequencies involved run all the way from 10 Mc/s to 31,000 Mc/s. Two very practical difficulties in obtaining recognition for space research requirements were that only a few countries are engaged actively in major space research programs, and that the Delegation of the U. S. S. R. felt that according international allocation status to frequencies for space use was premature.

The spectrum requirements of the science of radio astronomy also were recognized for the first time by the Geneva Radio Conference. The U. S. originally believed that protection of particular observation sites was sufficient and that recognition of radio astronomy requirements in an allocation table was unnecessary. It quickly became apparent, however, that the delegations of many other countries did not share this view. Accordingly, the U. S. changed its position in mid-Conference, and thereafter supported allocation recognition of radio astronomy requirements. The net result was to designate 19 bands, most of which are in approximate octave relationship throughout the radio spectrum. They begin at 2.5 Mc/s and extend upward to 31,000 Mc/s. All but one of the bands are shared with other radio services, which, in general, have the primary rights. These bands, therefore, are not nearly so useful as radio astronomers would like them to be. The ultimate objective of radio astronomers is understood to be approximately 1 percent of the radio spectrum free and clear of all electromagnetic radiations other than those which are received from extraterrestrial sources.

In the near future, we shall have new standard frequency service. The Conference established the frequency 20 kc/s as a worldwide standard frequency. It is understood that the United States Bureau of Standards is proceeding rapidly with plans to utilize this frequency for standard frequency and time service transmissions. Additionally, the Conference recognized that other frequencies below 70 kc/s also are useful for this purpose. The Soviet Union has stated that it plans to use 25 and 50 kc/s. The U. S. may use 60 kc/s as a high accuracy supplement to the 20 kc/s standard.

Limited provision was made for stations using the ionospheric scatter technique. All of the bands recognized for this purpose fall between 30 and 40 Mc/s. United States proposals to use bands higher than 40 Mc/s were rejected due, among other things, to European television broadcasting which begins at 41 Mc/s. The Delegation of the U. S. S. R. expressed great interest in the ionospheric scatter allocations and advocated a much more liberal allocation than that which was adopted.

The Conference recognized a continuing trend toward congestion in the high frequency part of the radio spectrum which will make this part of the spectrum progressively less useful. The Conference directed, therefore, that there be set up an international Panel of Experts to make detailed studies and recommendations on this problem. It also urged that, in the meanwhile, all Administrations take whatever steps might be necessary to reduce pressure on this part of the spectrum by consolidating lightly loaded circuits, sharing circuits, and exploiting communication techniques other than high frequency radio.

Operating Regulations. The Operating Regulations are of concern primarily to persons active in operation of the aeronautical mobile and maritime mobile radio services. This part of the Regulations was reviewed completely, and many changes were made, including provisions relating to: Radio station identification procedures; "service" documents published by the ITU; station operator certificates; station licenses; distress, safety, and operating procedures; and working conditions in the mobile service.

An important change in the operating regulations from the United States viewpoint was a substantial readjustment in the sub-allocation of the bands of frequencies in the HF part of the radio spectrum which are allocated exclusively to the maritime mobile service. Specifically, the bands allocated for passenger ship telegraphy have been rather drastically revised. Portions of these bands have been reallocated to: Double sideband radio telephone calling; single sideband marine telephony; and high-speed telegraphy, facsimile, and special transmission systems.

Technical Regulations. The Geneva Conference adopted a new Table of Frequency Tolerances, based on International Radio Consultative Committee recommendations. It will come into effect gradually. In the majority of cases, the new tolerances are no more strict than those already in effect in this country. The Federal Communications Commission currently is reviewing its Regulations to see what changes will be necessary. No announcement has as yet been made. If one is made, all parties will have an opportunity to comment before final action is taken.

For the first time, the Radio Regulations now include minimum specifications for the reduction of spurious radiation. The standards adopted are in general a reflection of current good engineering practice in this country.

In radio terminology, a number of changes have been made. Because such expressions as "very high frequency", "ultra high frequency", and "super high frequency" have little meaning when translated into a number of other languages or are difficult to translate, it has been decided that the nomenclature for frequency bands will be expressed in Arabic numerals. Thus, the VHF band from 30 to 300 Mc/s becomes Band 8 in the new system. If you write 300 Mc/s out in cycles, that is, the figure 300,000,000, and then count the zeros in what you have written, you will find that there are eight zeros. Although you can express it as a formula, this is the most simple way I know to determine the band number. The ultra high frequency range becomes Band 9, and the super high frequency range becomes Band 10.

Another change in terminology is adoption of "gigacycles" to mean one billion cycles and "teracycles" to mean one trillion cycles. For example, henceforth any frequency higher than 3,000 Mc/s should be expressed in gigacycles. Thus, 3,000 Mc/s becomes 3 Gc/s.

Still another change in terminology is the use of the word "Hertz" as a substitute for cycles per second (c/s). In most parts of the world where English is not the principal language, the use of Hertz and its multiples, "kHz", "MHz", and "GHz", becomes standard, based on the French text.

During the past 20 years there have been a number of phonetic alphabets. The Phonetic Alphabet and Figure Code recommended by the International Civil Aviation Organization (ICAO) was adopted by the Geneva Radio Conference, for general use in radiotelephony.

Frequency Registration and Management Procedures. The work of the International Frequency Registration Board (IFRB) and the International Frequency List which it produces is a very complex subject. The Conference actions in this area of its work well may prove to have more long-term significance than any other action taken. At the present time, the International Frequency List compiled by the ITU includes many individual frequency listings which are not used. Thus, when a country notifies the International Frequency Registration Board of a new operation, the IFRB's engineering examination, since it is based on the entries already in the List, may show that there is a probability of harmful interference being caused to the old assignment. It frequently happens that the new assignment, in the circumstances I have just described, will work quite satisfactorily and cause harmful interference to no one, because the prior listings were not actually in use. The Geneva Radio Conference devoted a major part of its work to this problem and other problems of a similar nature. It has adopted the basic idea that the International Frequency List should be a record of actual frequency usage and that assignments which are never used or which become inactive should be deleted. To this end, the powers of the International Frequency Registration Board have been somewhat expanded. It does not have the enforcement powers of a Federal regulatory agency or a court of law, but it has been given authority to investigate by all means at its disposal any entry in the List which seems to be of dubious validity, and to invite Administrations to submit appropriate amendments to their listings.

As a condition of entrusting additional powers to the IFRB, the delegations present at Geneva were nearly unanimous in believing that the Board should be made as nearly as possible a truly independent body of international experts. In furtherance of this objective, a number of changes have been made in the manner in which the members of the Board are chosen and in the operating procedures and rules which the Board follows in the conduct of its operations.

The Board is composed of 11 members elected as individuals and representative of all geographic areas of the world. It receives nearly half of the entire ITU budget.

Conclusion

There were actions of significance in each of the four work areas of the Conference: Frequency allocations; frequency management; technical regulations; and operating regulations. The results of the Conference were somewhat more consonant with U. S. aspirations than had been expected.

There are no major changes in frequency allocations, but everyone interested in frequencies above 10,000 Mc/s should examine the new Table of Frequency Allocations carefully. The adoption of new terminology, intended primarily to facilitate understanding between people using different languages, should eventually be of benefit to all.

The next Ordinary Administrative Radio Conference is expected to be convened somewhere in Switzerland in 1965, world conditions permitting. 1965 is the 100th anniversary of the founding of the ITU. Meanwhile, however, there is the job of securing ratification of the Final Acts of the Geneva Conference, taking necessary follow-up actions at national level, and, most important and difficult of all, becoming familiar in some detail with a complicated set of new regulations.

FUTURE POSSIBILITIES FOR FILM ROOM MECHANIZATION

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Summary

New equipment is proposed for simplifying the telecasting of slides and film. All 2"x2" slides currently in use are carried in one magazine. They are aired by momentary projection onto a storage tube which is then read out continuously while the slide is changed.

Instantaneous start of a film projector is accomplished by starting the parts having high inertia — motor and sound flywheel — before engaging the film; and running in this condition until show time.

A cartridge-loaded film projector for short segments carries sound on magnetic tape. Both tape and film are automatically cued to starting position.

Introduction

In recent years there have been many advances in mechanization of broadcasting operations. In television, most of the effort to date has centered around preset switching systems. The success of the various programmed switching systems suggests that mechanization of other phases of telecasting is desirable. I would like to discuss some of the possibilities in two of our major program source categories: films, and slides.

2" x 2" Slide Handling

Several good slide projectors are currently available, but most suffer from one common limitation. Slides must be shown alternately from two projectors, or two drums or other slide-carriers. This requires that they be inserted alternately into these two carriers, which in turn makes it difficult to re-use a single slide in a given series, or to add or delete slides.

As a new approach, auppose that all current slides are stored in a magazine such as that used in some of the more elaborate home slide projectors. Each slide is assigned a number, and the mechanism so designed that slides can be selected by number and shown in any chosen sequence. Due to the time required to change slides, a single projector of this type is unsatisfactory. There are at least two approaches which offer possibilities.

For the first, suppose that the selected slide is projected onto a storage tube such as was demonstrated at this convention last year by Westinghouse. For those who did not see it, a brief description is in order. It resembles a vidicon — an extremely "sticky" one. A picture flashed on its screen momentarily is retained until erased. The nature of the image retention, however, is entirely different from the familiar stickiness at low light levels. In effect the image is re-written on the target by the same beam which scans it for readout— sixty times per second. Fig. 1 illustrates some of the characteristics of this tube.

Erasure is accomplished by pulsing one of the applied voltages, or by flooding the screen briefly with a bright light, or by a combination of both.

Let us see how such a tube can be employed in projecting slides. Fig. 2 is a graph of the cycle of operations. The vertical-ruled strip at the top symbolizes the slide magazine. Three slides in sequence are shown going through the cycle : Magazine to projection gate, wait in gate until air time, flash onto storage tube, return to magazine. Just prior to each exposure an erase pulse clears off the previous image.

The timing of this cycle of operations is critical at two places. To make the scene change on the air completely invisible, it must be possible to erase the storage tube during vertical re-trace time. By careful pulse-shaping and/or high speed electronic light flashes, this appears to be feasible.

The second critical timing is that required to return one slide to the magazine and bring the succeeding slide into showing position, shown in Fig. 2 as "Magazine Cycling Time". This time must be no greater than the minimum time of showing of any one slide. At least one projector now on the market approaches this so closely that this is no problem.

In addition to the Westinghouse storage vidicon, there are available other types of storage tubes which can also be adapted to this application.

The second approach to improved slide handling also employs a single magazine containing all current slides. Two projectors, each essentially conventional, receive slides from this one magazine. The cycle of operations for this arrangement is shown in Fig. 3.

While one slide is being shown via film camera A, the slide chosen to follow it is drawn from the magazine into projector B. The first slide is returned to the magazine as soon as its showing is completed, and the next slide in the sequence is drawn from the magazine into projector A; etc. This cycle resembles that used in video relay switching systems which employ A and B banks of relays.

Both of these slide-handling systems are completely mechanical; both accomplish the same result on the air. The first utilizes a storage tube not yet proven in exactly this application. The second requires a dual projector a little more complex than those now offered the professional user. I believe that both approaches can be developed into highly satisfactory systems.

16mm Film Handling

Instantaneous-Start Projector

Improvements in the handling of film are probably more beneficial than improvements in the handling of slides. One of the recognized limitations in existing projectors is start time. It would be ideal if the film could be started as quickly as an audio tape machine. This would simplify switching, whether performed manually or by some form of mechanized preset switcher, since the present "START" and "SHOW" buttons could be combined in the single "SHOW" button. I believe this goal can be realized.

The time required to start present projectors is mainly that needed to bring the sound drum and flywheel up to speed, and to stabilize their speed. This sound drum is normally driven by the pull of the film wrapped around it. Once stable operating conditions have been reached, this is a very satisfactory drive — but it is not the best way to start the rotation. Since we wish to duplicate the quick start of the audio tape machine, suppose we copy some of its techniques.

In addition to "OFF" and "RUN", this projector will have a "STANDBY" mode, to which the operator switches after threading. In this condition the film is supported a slight distance from the sound drum, and the drum and flywheel are driven at normal operating speed. "Showing" imvolves starting the sprockets, which pull the film into contact with the sound drum, and removal of the external driving power to the drum and flywheel. The only elements which need to be accelerated quickly are the driving sprockets and a short length of film. The massive components — flywheel and motor armature — are already turning.

So much for the film sound track. But can we quickly start the film through the picture gate ? The answer is a definite "Yes", since it is started and stopped 24 times a second anyway. The motor is already running, as described above. So are the claws of the intermittent, with one difference. An additional linhage holds the claws from engaging the film, without interfering with their vertical movement. (A claw-type intermittent is assumed, but that is not essential to the principle.)

A projector having instantaneous start could, if desired, be threaded with the first frame of the picture stationary in the gate. During standby time this frame could be previewed by the switcher. More likely, with such a projector, the "switcher" would be a machine with no interest in viewing anything more exciting than perforations in cards or tape.

A projector which can be started instantaneously can also be stopped just as quickly. This feature is almost as advantageous as the instantaneous start. It simplifies the use of automatic cueing devices, permits inserts in a feature film without loss of continuity, provides greater flexibility in splicing different films together for sequential showing at different times, automatically runs off film leader, tec.

Cartridge-Loaded Projector

An instantaneous-starting projector does not solve all film problems. Someone is still required to load the film in the projector. For feature-length films, the time thus required is proportionately small. It is quite a significant proportion of the running time, however, for those 8- and 20- and 60-second spots. For these short film clips; especially for those which are re-run many times, it would be convenient if the telecaster had the same flexibility that has recently been provided for sound — cartridge-loaded projectors.

For silent film, cartridge loading is not new, having been employed prior even to the advant of 16mm film. The sound track, though, poses a problem. To simplify this, I propose to record the sound separately, on an endless loop of magnetic tape. Film and tape are in separate compartments of the same cartridge. Cue marks on the film and the tape insure their starting in synchronism. For a one-minute spot creepage is insufficient to destroy lip-sync. reproduction. Fig. 4 is a mock-up of such a cartridge. The machine for reproducing such a cartridge would start instantaneously, of course, much the same as the quick-start projector for feature films just described.

By reproducing the sound and the picture from separate media, both the cartridge and the reproducing machine are greatly simplified. The film (picture) portion is designed for precise film registration and focus, and the tape (sound) portion for constant speed.

Such a cartridge and reproducing machine should be carefully planned. Initially it will be necessary for the telecaster to load the short film segments into empty cartridges, having first dubbed the sound from the film to the tape already in the cartridge. This dictates that the cartridge be easy to load. If such a cartridge receives wide acceptance, this step may ultimately be eliminated. Possibly the most important feature is reliability. For this reason, as well as to avoid scratching the film, I do not favor a continuous loop of the film portion of the cartridge. Automatic rewind following showing, initiated and terminated by suitable cue marks is preferable, with the film gate open.

Looking farther into the future, one can envision mechanical handling of the cartridges much as slides are handled. The cartridge should therefore be such that very simple motions align the optical path, engage the separate film and tape transports including the film intermittent, and position the tape against the sound playback head. The mock-up pictured in Fig. 4 incorporates these features. The mirror receives light from the condenser and directs it through the film in the gate. The intermittent claws engage the film through the slot in the faceplate. A gear at the front engages a similar gear in the projector for both film take-up and rewind. A coarse-pitched gear is shown, having one tooth per frame of film, to minimize the chance of loop loss by keeping the constant-speed sprocket and the intermittent in step.

Just behind the film portion of the composite cartridge can be seen the front of the continuous-loop sound cartridge, with the tape visible through the openings for capstan and head.

Magnetic sound in a film cartridge offers an additional advantage. Picture material prepared for nation-wide distribution can have sound recorded as desired by local distributors. The quick-loading feature would give the Program Director added flexibility in many areas; for example, a film showing a blizzard to accompany such a weather prediction.

All of these advances in mechanization can be acheived with today's know-how. If they appeal to you, the users; and if you make your desires known — I am confident that the manufacturers will make the equipment available.

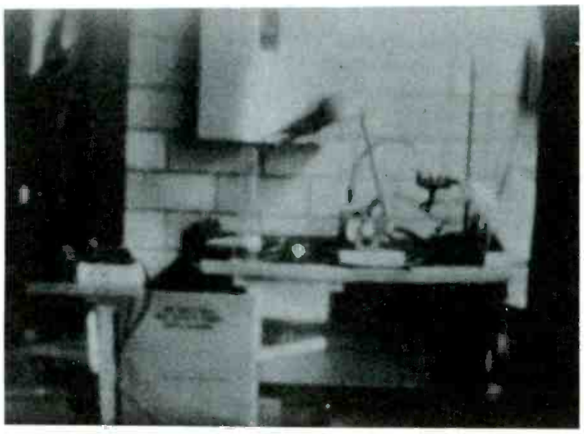

Fig. 1. Laboratory scene stored on Westinghouse Permachon, one minute after exposure. The resolution on the monitor was greater than in this photograph. Resolution of 600 lines with 8 shades of gray can be maintained for approximately five minutes. Toward the end of longer storage times, contrast and resolution deteriorate.

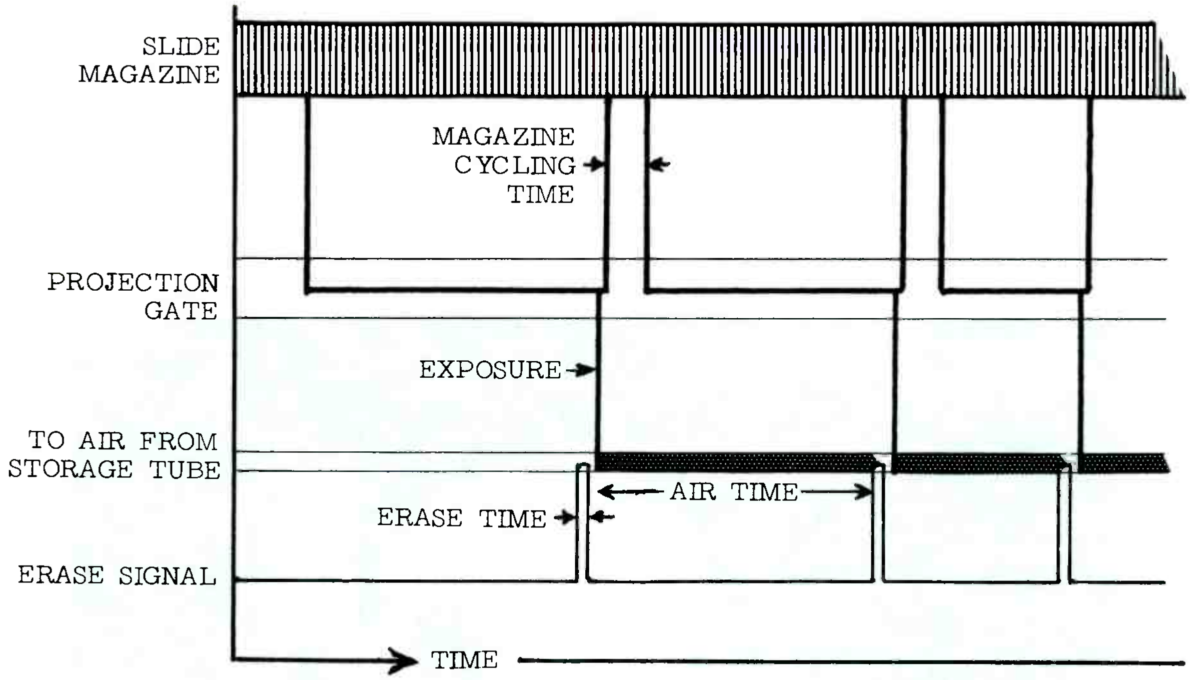

Fig. 2. Mechanized slide-handling cycle employing picture storage tube. Heavy vertical lines below the slide magazine represent slides. Three in sequence are shown being cycled from the magazine to the projection gate where they wait until air time. Airing is accomplished by flashing the picture onto the storage tube immediately following erasure, which is synchronized with a vertical blanking period. After exposure, each slide is returned to the slide magazine and the succeeding slide is placed in showing position, where it waits for its turn on the air.

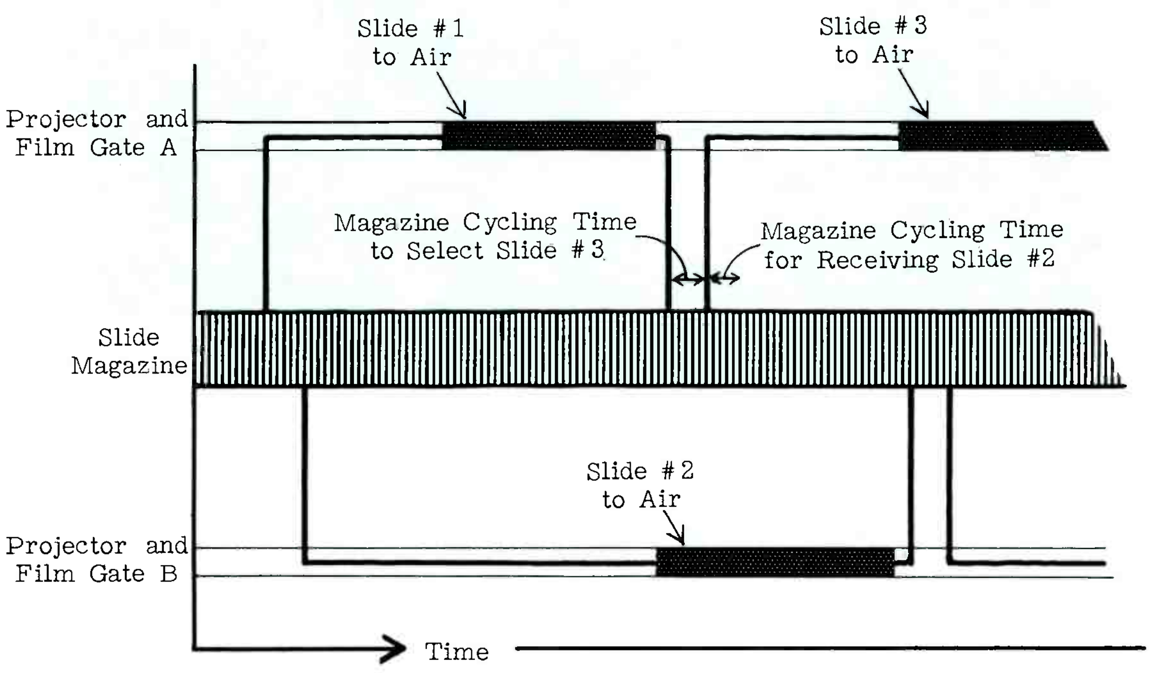

Fig. 3. Mechanized slide-handling cycle employing two slide projectors fed from one magazine. Heavy vertical lines from the slide magazine to the two projectors represent slides. The cycle of operations resembles that now used in many stations with one significant difference: Since all slides are stored in a magazine common to the two projectors, any slide may follow any other, and may be re-used at any time, without human handling.

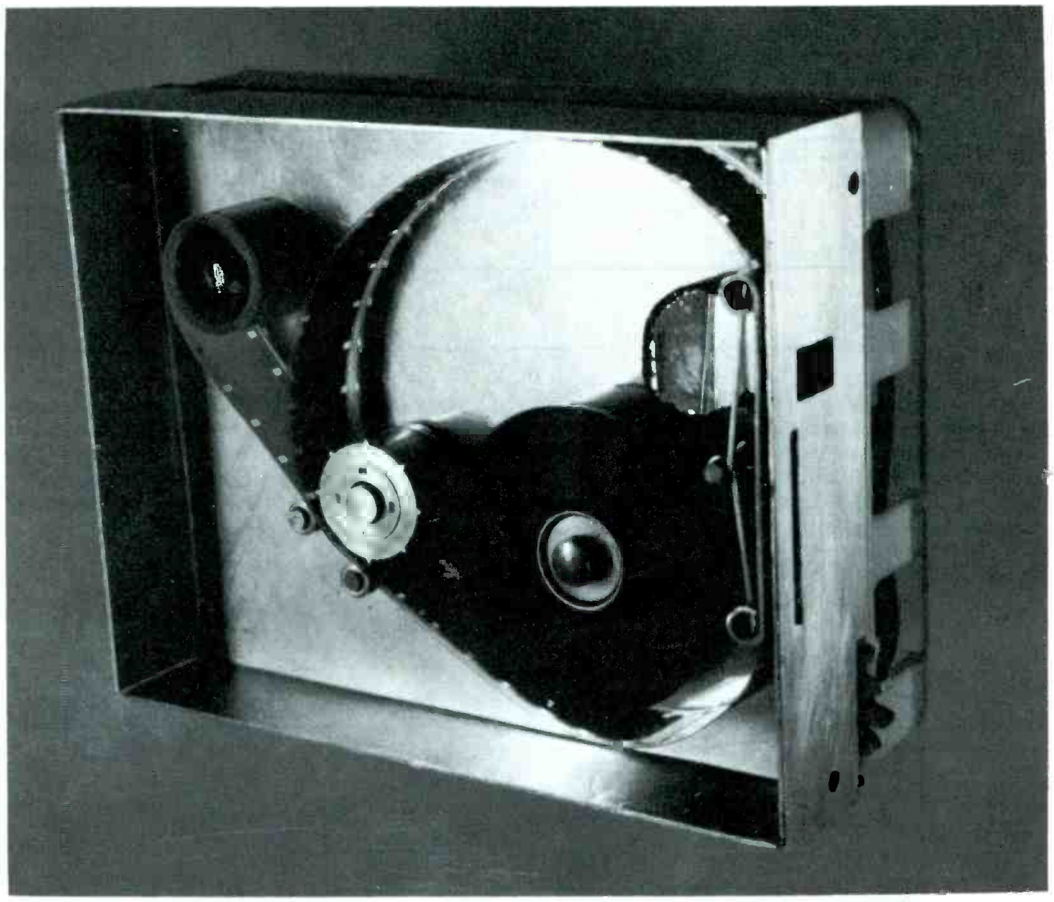

Fig. 4. Cartridge for quick-loading film projector. Sound and picture are reproduced from separate media, the sound from a continuous loop of 1/4 inch magnetic tape in the rear portion of the composite cartridge. The front portion carries 16 mm silent film. Separating picture and sound makes cartridge loading feasible.

DIRECTIONAL ANTENNAS FOR TELEVISION BROADCASTING

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Summary

Desirable operating characteristics and other requirements of directional transmitting antennas suitable for television broadcasting are considered. Basic limitations on directivity are imposed by long-distance propagation phenomena and reflections of signals into the weak-signal zones. Previous experience with directional antennas used for television broadcasting is reviewed. A number of appropriate antenna types are suggested.

Introduction

The use of directional antennas in the AM broadcast service to protect the service areas of cochannel stations has become widely accepted and generally used. At the present time, similar practices for television broadcasting in the United States are not authorized by the Federal Communications Commission. However, in a Notice of Proposed Rule Making, Docket No. 13340, issued by the Federal Communications Commission on January 7, 1960, comments are invited concerning limited use of directional antennas to permit new television stations to be assigned at substandard spacings. It is suggested that the ratio of maximum to minimum radiation in the horizontal plane shall not exceed 20 decibels.

Any antenna intended for television broadcasting should meet certain electrical performance requirements. Some of these are:

(1) The impedance of the antenna should match that of the feed system over the entire transmission channel so that reflections along long lengths of transmission lines, or other wave-transmission media, may be held to a very small value for all frequencies within the television channel.

(2) The antenna itself should radiate substantially all the energy delivered to it by the transmission system.

(3) Both horizontal and vertical field-strength patterns should remain stable for all frequencies within the channel.

(4) The antenna, including its transmission line, should have a high inherent power-handling capacity.

(5) The antenna should perform satisfactorily under all weather conditions.

(6) The design should be such that, after fabrication and initial test by the manufacturer, the antenna may be erected at the station site and be ready to operate with certainty without further field test.

Directional antennas for AM broadcasting use two or more vertical radiators with the currents in the radiators carefully controlled in phase and magnitude to achieve a desired radiation pattern by phase addition or cancellation. Similar techniques could be used in television broadcasting. However, the engineering costs would be high and the feed arrangements complex, largely because of the much larger bandwidth used. The shorter wavelengths used in television broadcasting make possible physical structures which could not be considered for AM broadcasting. In addition, we may draw on a wealth of experience in developing directional antennas for radar and other purposes.

Directional Antenna Structures

A structure which made use of a combination of a shielding curtain and a multiplicity of radiating elements to shape the radiation pattern was developed by D. W. Peterson and the author in 1941. This antenna, shown in Fig. 1, was built entirely of metal and with no insulators and covered the band of frequencies from 100 to 110 megacycles. The horizontal radiation pattern is illustrated in Fig. 2. For more than 280 degrees of azimuth angle, the horizontal radiation pattern is at least 34 decibels below the maximum of the pattern. Proper design of shielding curtains may easily achieve the value of 20 decibels suggested by the FCC.

A combination of axial slots in the

surface of a vertical cylinder offers an attractive solution to the directional antenna problem, since a variety of patterns may be obtained, the structure is simple, and mathematical analysis[1-6] may be undertaken with confidence. Fig. 3 shows the measured horizontal radiation patterns for a single vertical slot cut in the surface of a vertical cylinder for a number of diameters of the cylinder. The dashed curve for a cylinder whose diameter is 0.223 wavelength was computed from the formula:

$$E_\theta = K \sum_{n=0}^{n=\infty} \frac{a_n j^n \cos n\theta}{J_n'\left(\frac{kD}{2}\right) - j N_n'\left(\frac{kD}{2}\right)} \qquad (1)$$

where $a_o = \frac{1}{2}$

$a_n = \frac{\sin (n\beta)}{n\beta}$

β = one-half the radian measure of the arc subtended by the slot

λ = the free-space wavelength

$k = 2\pi/\lambda$

D = the diameter of the cylinder

J_n' = the first derivative of the Bessel function of the first kind

N_n' = the first derivative of the Bessel function of the second kind

When the cylinder diameter is 0.223 wavelength, $\frac{kD}{2}$ equals 0.7 and equation (1) reduces to

$$E_\theta = K \Big[(-0.1238 - 0.693\cos\theta - 0.003\cos 2\theta + 0.015\cos 3\theta) + j(0.416 + 0.196\cos\theta - 0.135\cos 2\theta + 0.0013\cos 4\theta)\Big] \qquad (2)$$

Multiple slots around the cylinder surface may be used to produce a variety of patterns. For instance, two slots cut in the cylinder may be fed in phase with each other to produce the measured results shown in Fig. 4.

When the two slots are fed in phase opposition, the horizontal radiation pattern becomes a cosine function, for all practical purposes, as shown in Fig. 5. Then only the terms of equation (1) for odd values of n are retained, and equation (2), for the particular diameter in question, becomes

$$E = K \Big[(-0.693+j0.196)\cos\theta + 0.015\cos 3\theta\Big] \qquad (3)$$

This pair of slots, when fed in phase opposition, may be combined with a second similar pair oriented on the cylinder face at ninety degrees to the first pair and fed in phase quadrature with the first pair to obtain a circular radiation pattern, thus making use of the Turnstile principle.[7]

A wide variety of directional patterns may be obtained by a combination of slots spaced around the circumference of the cylinder, particularly when the relative phases of the exciting means are varied.

G. B. MacKimmie, RCA Victor Co. Ltd. in Montreal, has made use of the single-slot arrangement shown in Fig. 3 in developing a Wavestack antenna which has been widely used for television broadcasting in Canada. Fig. 6 shows a Wavestack antenna at Ottawa where two slots are arranged in a vertical row to obtain some vertical directivity. The cylinder itself is used as a waveguide feed to the antenna system. The waveguide operates in the TE_{11} mode. Since the cutoff frequency for a simple cylinder of the size used here is higher than the operating frequency, a metal web is inserted in the cylinder to reduce the cutoff frequency. Fig. 7 demonstrates the manner in which this web alters the field within the waveguide to accomplish the desired result.

A twelve-slot Wavestack antenna with high power-gain is shown in Fig. 8. This particular antenna utilizes the cylinder as the complete supporting structure and waveguide feed. Fig. 9 shows another twelve-slot high-gain directive Wavestack antenna mounted on a conventional tower and fed with a transmission line.

TASO Directional Antenna Committee Experiments

During 1959, the TASO Directional Antenna Committee conducted careful and significant experiments at Television Station WKY-TV in Oklahoma City and at Television Station WBZ-TV in Boston. In both locations, the transmitting antennas were Turnstiles equipped with power-dividing networks to obtain the directional patterns. The WKY-TV antenna was rotatable and a reference antenna was installed above the normal transmitting antenna. It was fully demonstrated that the operational pattern of the directional antenna could be accurately established by field measurements using either the reference antenna or rotational techniques. It was also fully established that the operational pattern after installation of the antenna was in very close agreement with the patterns previously measured at the RCA antenna test site.

Observations at distant points, for both installations, indicated that time averages of the received signals were in accord with the operational pattern with suppressions up to 20 decibels.

At WKY-TV, the effect of ghosting was apparent in the null areas. Reflections from the main beam of the antenna back into the null with suppressions of 20 decibels caused ghosts that were comparable to the direct signal.

Conclusion

Suppressions of the order of 20 decibels, as suggested by the FCC, are well within the range of present engineering knowledge and skills of the antenna art. Slotted cylinder antennas offer excellent possibilities for meeting the criteria stated earlier in this paper. Well-designed structures of this type, carefully tested on a well-equipped antenna test site, preclude the luxury of a reference antenna at the final installation.

Ghosting in the null zone offers the greatest hazard to the use of directional antennas with deep nulls. It is imperative that the transmitting site should be so selected that the suppressed direction is toward the area of the lowest population density.

In certain atypical cases, greater suppression than the suggested 20 decibel value, even to the extent shown in Fig. 2, may be perfectly possible.

The theoretical work of Staras[8] indicates that, in addition to ghosting in the null areas, scatter propagation phenomena may limit the depth of the null which may be effectively used as well as serve as a guide in estimating the effects of rapidly increasing patterns on either side of the null.

Acknowledgment

The experimental data displayed in Figs. 3, 4, and 5 were obtained from O. M. Woodward, Jr., RCA Laboratories.

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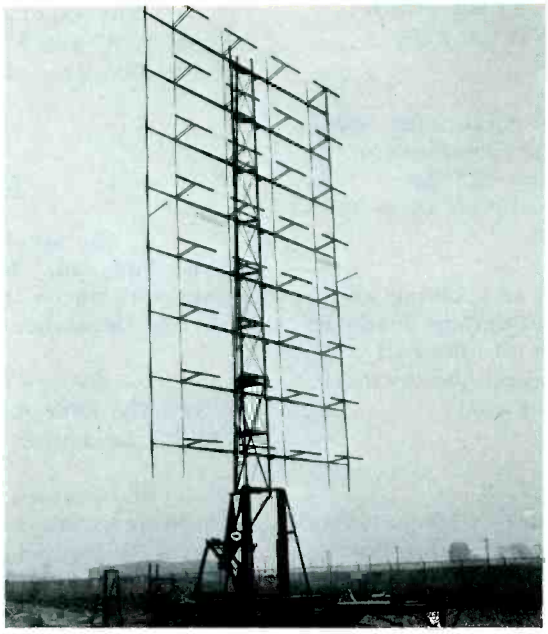

Fig. 1. A directive all-metal transmitting antenna for frequencies between 100 and 110 megacycles.

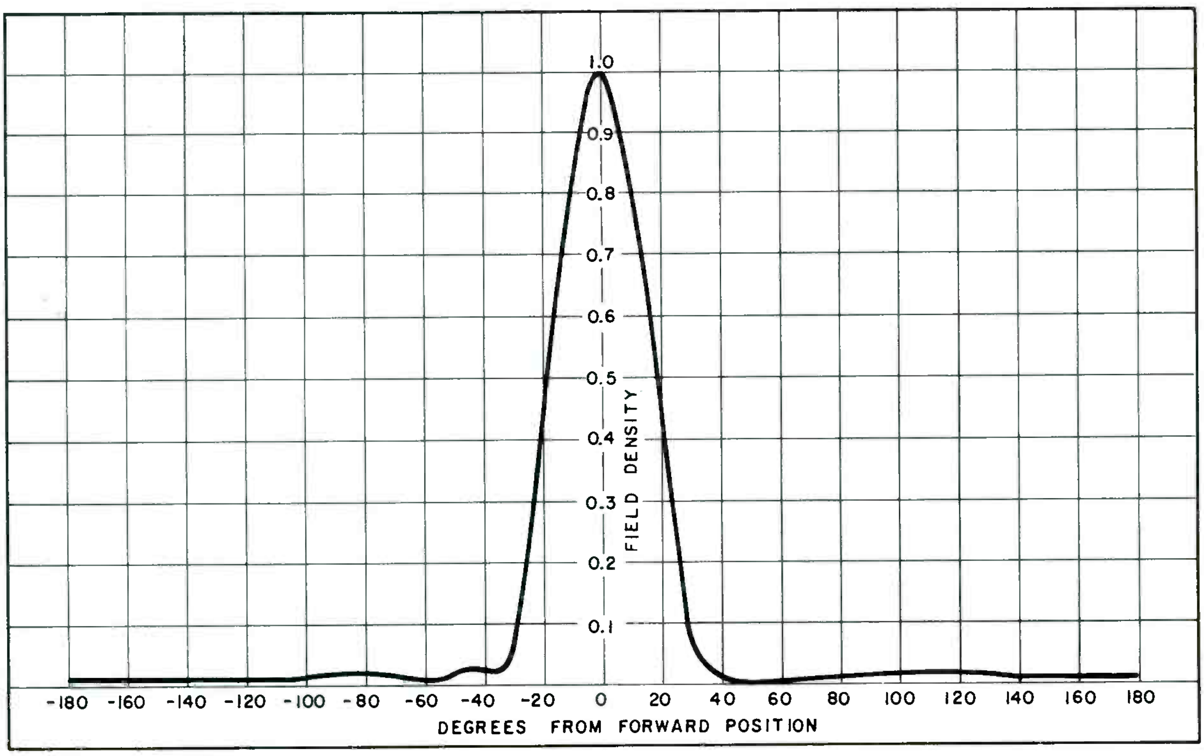

Fig. 2. The horizontal plane field-intensity pattern of the antenna shown in Fig. 1.

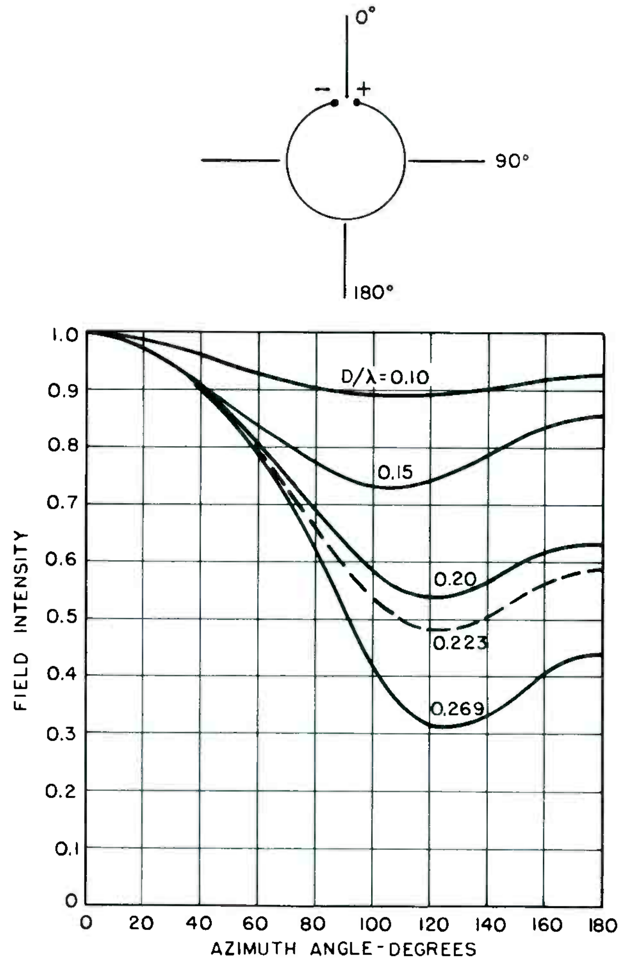

Fig. 3. Measured horizontal radiation patterns of single slots in a cylinder. The dashed curve is calculated from eq. (1).

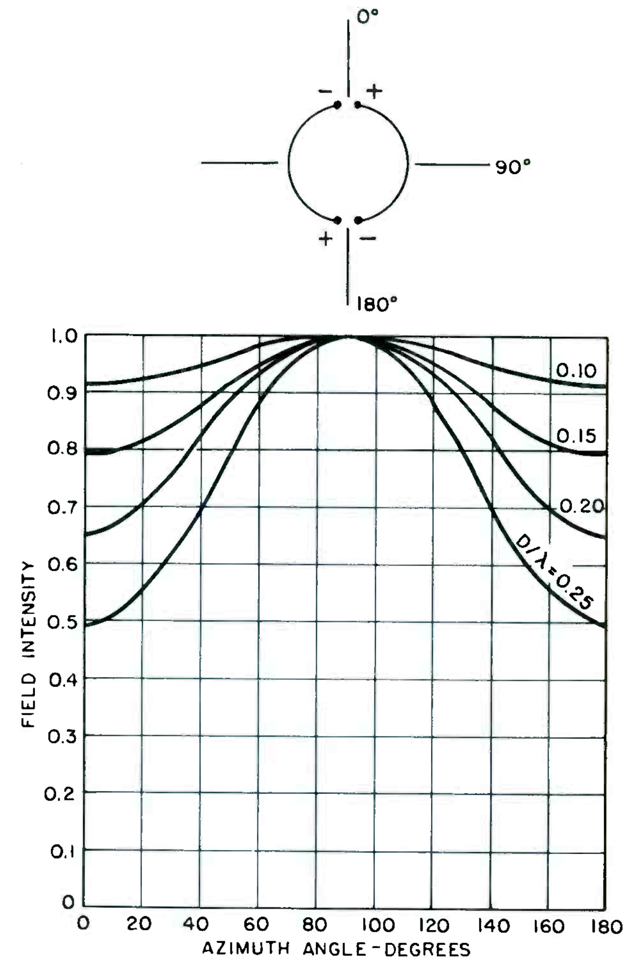

Fig. 4. Measured horizontal radiation pattern of two slots fed in phase.

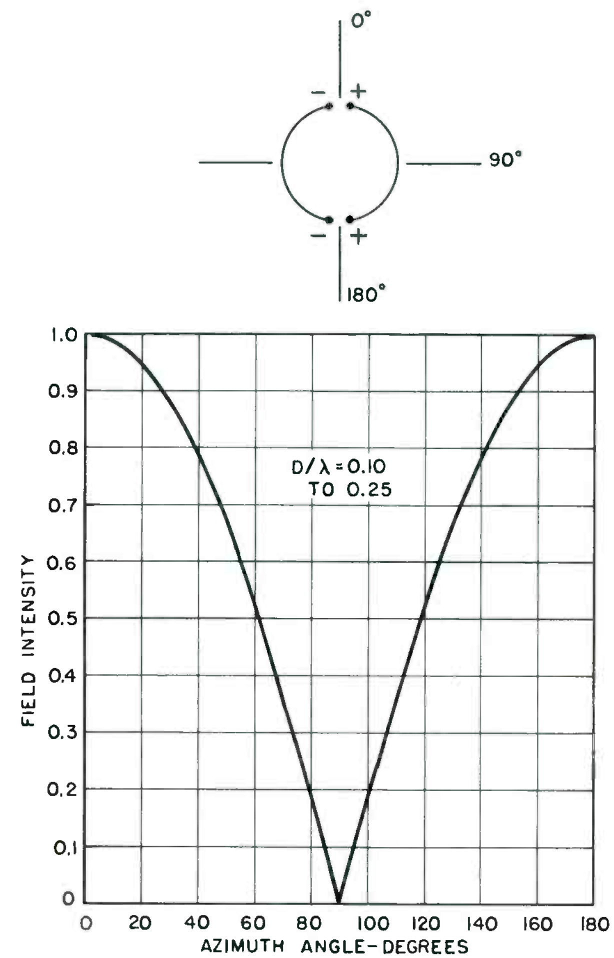

Fig. 5. Measured horizontal radiation pattern of two slots fed in phase opposition.

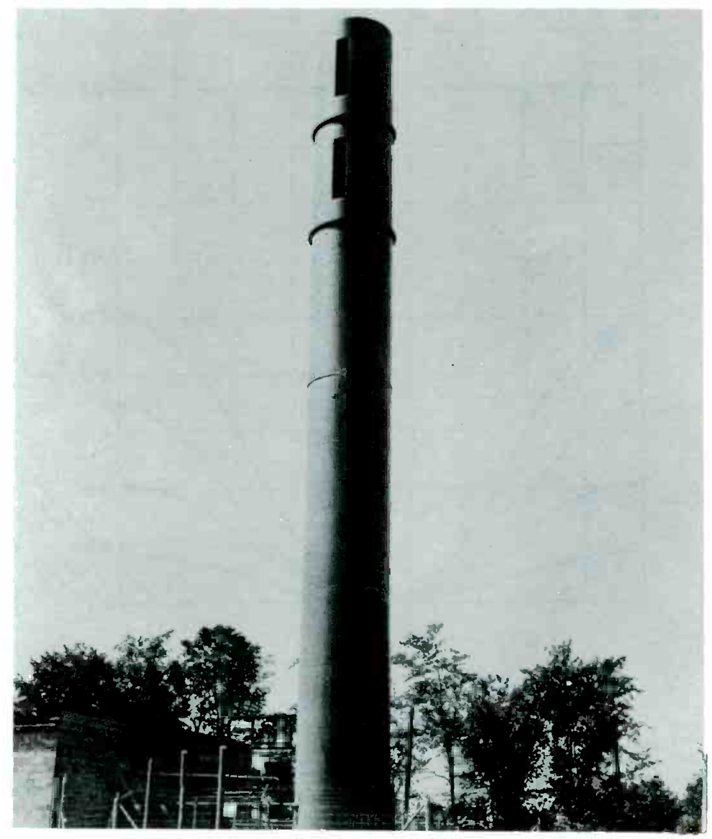

Fig. 6. A two-slot Wavestack directional television broadcasting antenna at Ottawa, Ontario.

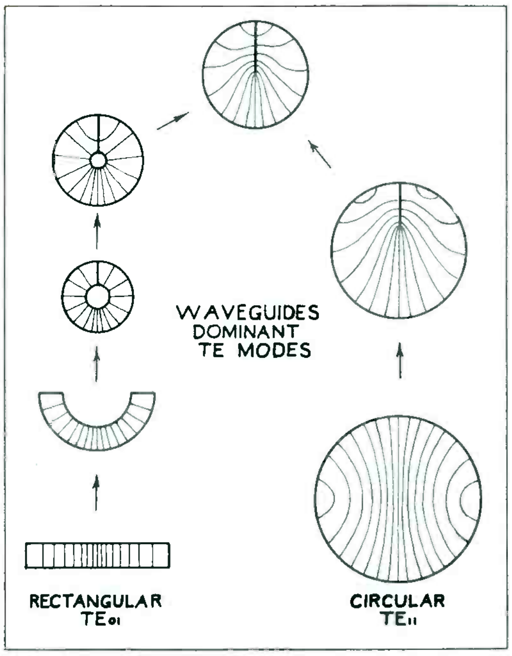

Fig. 7. The waveguide feed method used in the Wavestack antenna.

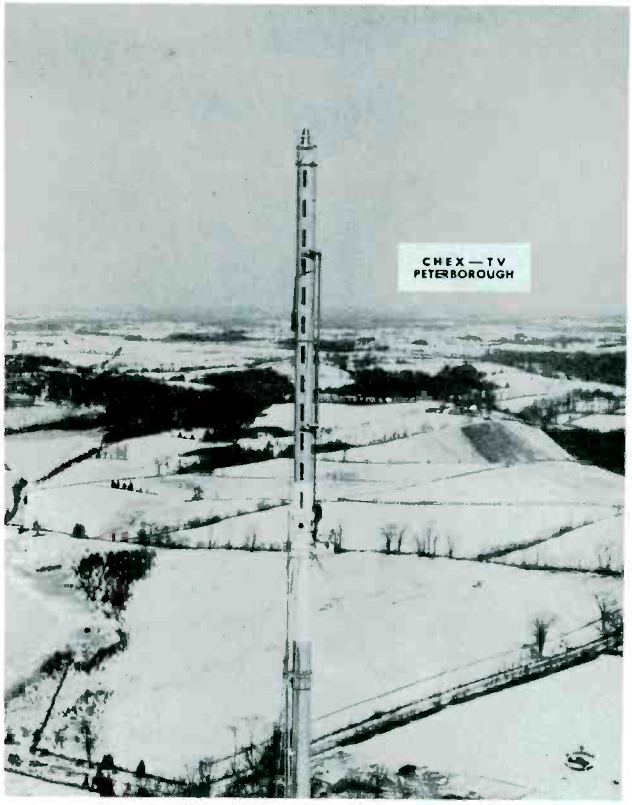

Fig. 8. A high-gain Wavestack antenna with wave-guide feed at Peterborough, Ontario.

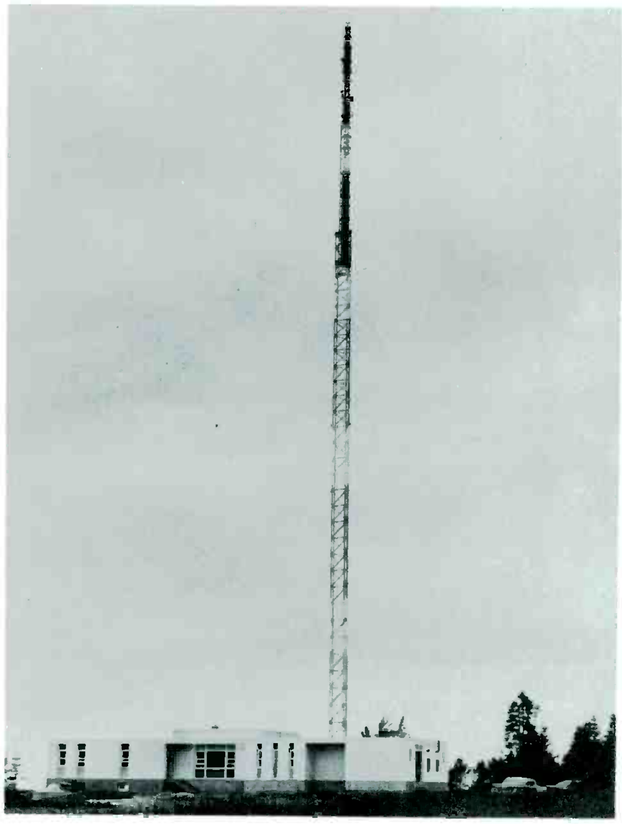

Fig. 9. A high-gain Wavestack antenna mounted on a conventional tower at Matane, Quebec.

SERVICE AREA OF AN AIRBORNE TELEVISION NETWORK

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Abstract

An educational television network using UHF transmissions from aircraft has been suggested as a means to provide improved classroom instruction to schools throughout the country. Initial airborne tests will begin in 1960. As a step in the evaluation of such a network, calculations have been made which describe the coverage from an airborne station in the presence of interference from other stations. The results should be useful in determining the equipment and channel requirements of a nation-wide network. These requirements will be compared with those necessary to provide equivalent coverage from ground-based UHF stations.

SOME ENGINEERING ASPECTS OF VIDEO TAPE RECORDING PRODUCTION

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In 1956, the Ampex Corporation demonstrated the first commercially available video tape recorder. The importance of this demonstration was quickly apparent by the fact that within a very few hours Ampex had received orders for in excess of 80 of these units. Until the day of this demonstration, the group of engineers involved with its development had considered it fundamentally a replacement for kinescope films which were then used by the networks for time delay. Many broadcasters present at this demonstration visualized the use of electronic production of programs using magnetic tape as its storage medium and ordered video tape recorders for this purpose. Many of these broadcasters saw the possibility of economies by more efficient use of crews. Some of them envisioned television programs which were being lost on one-time showings that now could become syndicated tapes. In general, the television industry as we knew it entered an entirely new phase.

In Hollywood, many things happened simultaneously. One of the first groups to feel the full impact of video tape was the film laboratories which previously had been processing the millions of feet per year of time delay kinescope films. In Hollywood, our industry, which should be considered a combination of both film and television, is made up of many unions and guilds. The feeling that tape would somehow replace film entirely caused these various guilds to take a restrictive approach with regard to any usage of electronic production and tape. This caused a virtual stalemate resulting in a delay in the use of video tape.

Los Angeles, as the third largest market, has seven television broadcast stations which are generally considered major production activities. At the present time, there are at least eleven video tape production units in Hollywood. Three of these are associated with the networks, four of them with independent broadcast stations, and the balance are completely independent of any previous television activity. They have found many advantages to electronic production methods; however, there are good reasons why video tape will never completely replace film. As these points became clearer throughout the last two years, much of the upheaval subsided. There has been a continued growth in the use of the electronic method and the production people are finding that their contributions are still valuable and necessary whether they work in film or video tape.

The thousands of square feet of stage space presently allocated to electronic production appear to be consistently active. The Times Mirror Broadcasting Company, which owns KTTV, has two syndicated programs that are financially successful. This company received its first video tape machine in March of 1958 and immediately started the preparation of syndicated programming as well as the production of commercials. Our experience has not shown a saving in money by using video tape but rather an increase in costs, coupled to a favorable increase in income. KTTV believes that the greatest advantage of video tape, exclusive of time delay, is in the production of commercials. The economic advantages to the sponsor, accompanied by a greater flexibility of production should result in more entertaining commercials.

In order to discuss the production techniques as they are developing today, it is necessary to include all of the elements. These can be divided into five general categories: pre-production planning, physical production, post-production processing, distribution and exhibition. As a producer of video tape, it is necessary to understand at least partially all of these divisions. Even though video tape has many advantages, there are still productions which cannot be done as economically with tape as with film and I believe it is important that video tape not be sold as an economic cure-all or a bogey man which will eventually drive film from the business. Video tape, as well as the television system in general, has limitations which cannot be overcome. However, television-VTR productions can offer much variety now excluded either economically or technically from the viewer's screen, and, consequently, from the sponsor's pocket book. The use of magnetic tape as a recording medium or "load for the camera" means that we utilize our basic television production techniques. However, our live television producers now find that with video tape they are not restricted by a time clock, availability of talent and many other creative integrations which were impossible with an all electronic system which had no adequate storage medium.

Today, video tape production techniques are moving toward many of the proven methods of film. Indeed, one of the problems facing tape production is that we may end up with a system which becomes even more cumbersome than film, and, consequently, will lose its economic advantage.

Video tape and the electronic production of programs have required that the television engineer assume a broader responsibility for the end product. Engineering assistance is valuable from the introduction of the storyboard through to the reproduction on the home receiver. The storyboard, as you know, is a script coupled with a series of still sketches which provide a visual concept of what the writer and producer wish to create. At this point, adequate engineering advice saves time and money as the director plans his lighting, camera angles, his electronic transitions and overall flow of production. We have found it advantageous to actually pre-plan and pre-set each camera shot of an important commercial before an attempt is made to even rehearse the runthrough of the entire segment. In the shooting of an entire scene as a continuous flow of action, it is possible to be on a camera as little as three or four seconds. In the pressure of speed, poor lighting or a bad camera angle may be missed until later in the calm of the screening room where it stands out to the detriment of the entire segment. It is possible without taking too much time to individually look at each shot. In a program such as DIVORCE COURT, which is purposely shot like a "live" program with the entire hour produced in a continuous fashion, this is not necessarily true. In this case, of course, you have many ad-lib shots and the importance of individual camera cuts is less than for a one-minute commercial. In the case of the one-minute commercial, you will probably have as few as eight to fifteen different shots. In this case, each one should be analyzed individually. KTTV has produced a single one-minute commercial which has required as much as two days' stage time. Conversely, commercials have been produced eight or ten per hour. The ability to encompass such a wide category of commercial quality in itself proves the tremendous flexibility of video tape techniques.

Technically, the quality requirements of our business have increased since we have been required to "face ourselves in the morning." When a crew can the next day sit and view the product several times, the small flaws begin to stand out and the engineer feels the need for better quality, and, most important, can now determine what he should have done.

The producer is learning the importance of adequate engineering advice and it becomes equally important that the engineering group be capable of supplying this information in terms which the producer can understand and will accept. In Hollywood, we are finding more and more film-indoctrinated producers and directors using video tape. This fact alone has required integration of live television and film techniques. Many things are requested and expected of the engineer which are difficult and time consuming and which, until recently, due to a one-time showing, would have been economically prohibitive.

The major engineering aspects of video tape production from a purely technical standpoint still remain those of grey scale, signal to noise and resolution. The improvement in pickup tubes as well as electronics in general is leading to an improvement of all three of these technical factors, and, consequently, an increase in our overall production quality. The improvement in the lenses and tube sensitivity are allowing a consequent improvement in the quality of lighting which in the past would not have been possible. The announcement recently of cameras using a 4½ inch image orthicon tube with a special target mesh will provide another step forward. Cameras using this tube, because of its greater sensitivity and larger target area, will allow a higher resolution, lower noise picture. The target mesh which eliminates the "redistribution effect" provides a longer and more linear grey scale, giving us an opportunity to provide a type of lighting that will attract more and more producers. In addition to the fundamental factors of grey scale, noise and resolution, engineering can presently provide other electronic devices which are useful production tools. The "special effects system," for instance, is very useful for providing a variety of transitions as well as keyed optical effects which results in economy as well as creative artistry. These effects in film from simple transitions to matte opticals can be extremely expensive. Using a keyed generator allows us, in many instances, to use a photograph for a background rather than the construction of what might well be an expensive setting.

The use of remote locations is still an important factor in electronic productions. At least four of the video tape producers in Hollywood are equipped with units containing video tape machines as well as cameras, film and other television equipment. The ability to take your production unit to location areas can provide a variety of settings which could not be produced by any other method. There is a unit presently being constructed which will be capable of doing video tape productions anywhere in the world. It will consist of a caravan of three 45-foot trucks; one to contain color cameras and control equipment, the second to contain color video tape recorders and film projection machines, the third to produce adequate power by self-powered generators as well as containing shop space for maintenance and construction.

There are two factors in video tape production which inevitably arise in any discussion. These are animation and editing.

Animation has always been a valuable tool in the presentation of products and programs. The ability to do frame-by-frame action is necessary to complete our production system. Since the beginning, several proposals to expose the tape frame-by-frame have been made. However, in each case, these proved to be inordinately complicated from a technical standpoint. KTTV conducted a study of this problem from a non-technical standpoint and found that the cost of animation is almost completely in the original artwork. The medium upon which the still frame action is handled is a relatively insignificant factor. Therefore, it seems that the best way to handle animation on video tape is to use film frame-by-frame and transfer the continuous motion to video tape. We presently use film for many integrations into our video tape production and find that the loss in transfer is insignificant.

Editing is one of the most important parts of our post-production processing. In a film, at the conclusion of physical production, the producer has many bits and pieces of film which contain various scenes or individual shots. These are now turned over to a film editor, who literally splices together the final product. In video tape production, we have a multiple advantage. Not only is it possible to do post-production splice type editing, but, with the proper pre-production planning, most of this editing is done in the control room at the time of physical production. We once again have the importance of our pre-production planning and the necessity of the engineer to provide the necessary elements. Post-production editing in video tape is actually a relatively cumbersome method as compared to film. The tape itself is difficult physically to handle and even the best of splices are somewhat less than perfect. After the editor locates the point at which he desires to splice, then "develops" the tape, finds his edit pulse and makes his cut, he still is not sure of control track continuity. A few degrees of control track displacement can cause an annoying motion within the frame of the picture even though it does not create a roll. We have found from experience that wherever post-production splicing can be avoided it proves to be an advantage both technically and economically. Recently, there was demonstrated a device which allows a video tape machine to be locked to an external synchronizing source or another tape machine. This device allows the picture from two tape machines, or a live and tape machine picture, to be supered, dissolved, or even portions of these pictures to be keyed into one another. In this manner, we now can do a great deal of our post-production editing all electronically. The use of this machine for post-production editing requires a tightening of our over-all quality because our composite master, by necessity, becomes a second generation. With adequate control of grey scale and noise in the video tape machines themselves, it is possible to produce second generation or "dupe" masters which are completely satisfactory. There are improvements even now in design which should make multiple generations indistinguishable one from the other.

The engineer involved in video tape production should be willing to accept a certain amount of responsibility in assuring that the product has proper exhibition. As we know, a video tape recording replayed on a similar machine normally makes an excellent reproduction of the original product. The excellence of exhibition will, of course, always be a matter of degree. It is theoretically impossible to reproduce without degradation the information exactly as presented to our original television camera. At KTTV we have found, for instance, that, in a large production which is in shooting over a period time, it is desirable to assign a video tape recording head assembly and use this head for no other purpose during this period. In this manner, what post-production editing is required will prove to be more easily accomplished. Smal differences in the physical position of control track heads as well as variable distance of penetration tends to create problems if many different heads are used in production. If details of this nature are carefully controlled during production, higher playback quality becomes assured. Even though we provide an excellent master and video tape duplicates or prints, we are finding that throughout the industry exhibition on video tape alone is inadequate.

With proper preparation and processing, exhibition of our electronic production can be made either on video tape or on film. There are still stations which have no tape machines, and a considerable number that have only one tape machine. It is obvious that the station with no tape machine cannot play back a magnetic print, and the stations with one tape machine may find difficulty in scheduling playbacks around their own productions. In addition, handling video tape commercials within a video tape program requires that splices be used to integrate them. Even the stations with multiple video tape machines are finding it uneconomical in some cases to have a $55,000 projector standing by for a long period of time to play back short segments of tape. The solution to these problems is in an adequate system for transferring our video tape to a 16 or 35mm film. Back in 1956, with the advent of the video tape recorder to replace kinescopes, the quality of kinescopes was quite high. Since that time, due to the lack of demand for kinescopes, insufficient improvement has been made along these lines. It should be pointed out that the transfer of video tape to film, should also be considered from an economic standpoint. For instance, in the case of a one-hour program in syndication, we have found that the distribution and exhibition on video tape is less costly than on film transfer. This is due to the ability of a video tape print to be played many times as opposed to film prints which have a maximum life expectancy in distribution of between ten and fifteen plays. We also find it satisfactory to the exhibitors to tie up their machines for longer segments such as a program. The main necessity for film transfers is in the area of short segments such as commercials. Because of the desirability in many instances of handling electronically produced tapes at the exhibition point as film, the availability of a high grade tape to film transfer will remove one of the last production bottlenecks in the use of video tape for production. Several groups are working on the improvement of kinescopes and one of those of interest is a system used in England. In England, there is a fast pull-down camera manufactured by Rank Precision Industries, with electronics by Marconi Wireless Telegraph Company, which, when available in this country, might well provide a major step forward. The British have, in this case, an advantage of a 50-cycle power system which means a 25-cycle frame rate. They merely increase their film transfers from 24 frames to 25, which is a 4% change in speed apparently unnoticeable either in action or sound. In doing this, they then can perform the pull-down during vertical blanking and photograph fully each frame. In our system, having the conversion requirement from 24 frames of the film camera to 30 frames of the television system, requires a spliced frame to appear at regular intervals. This spliced frame creates one of the most critical problems of the film transfers today. The noise level, grey scale and resolution of many of our kinescope systems is excellent. However, the inconsistency of removing the flickering "splice line" is annoying to the point where many agencies reject film transfers solely on this basis. This problem is being attacked from many angles. The fast pull-down camera from England could allow, even with our 30-frame system, an increase of the "dwell time" during which period a more accurate registry of the film itself can be accomplished. At such time as a high quality, "no flicker" transfer is available, the electronic system of video tape production will show a marked rate of increase.

In January of this year, General Electric announced a new system of electronic recording. This system uses a thermoplastic material as its storage medium. The capabilities of thermoplastic in conjunction with this electronic recorder indicate the possibility of a direct permanent transfer of an electronic image to the equivalent of a film optical negative. This would mean that a film print could be made directly from an electronically produced negative. From a theoretical standpoint, thermoplastic recording could create as dramatic a change in our industry in the next few years as magnetic has in the past.

Whatever the medium of making the recordings, it appears that the age of electronic production is here. It is my feeling that the position which the television engineer fills within this industry will be limited only by his own imagination and ability.

A MODERN TV TRANSMITTER PLANT INPUT SYSTEM

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Summary

All the complex products of the television studio plant flow to the viewing audience through the transmitting plant and as the final link in the system it has an extremely heavy responsibility. To meet this responsibility the transmitting plant must have an input and control system that can act like a nerve center; be capable of continuous quality monitoring and instant corrective action. As part of a program of plant modernization and quality improvement a completely new and simple transmitting plant input system was designed. This paper outlines the study of transmitting plant functions and responsibilities that dictated the design, and describes the circuit and operating features of the resultant system.

Introduction

The audio/video product of a modern television plant travels through many complex processing and control points on its path to the viewing audience. The last control point in the system is located at the transmitting plant and this control point is the transmitter plant input system. The design of the input system must take into consideration the tremendous responsibility assigned to it.

As part of a continuing program of modernization and quality improvement, and in the course of designing a new transmitting plant, the CBS Television Network Engineering Department decided to completely review the philosophy of input system design. With consistency, quality and simplicity as the major criteria to be met an analysis was carried out and a general design formulated which attempted to fulfill these criteria. The analysis included (1) the detailed functions to be performed at the transmitting plant, (2) a study of the assignment of signal-quality responsibilities, (3) manpower assignments, (4) equipment evaluations, (5) consideration of maintenance programs, and (6) a careful study of the most common errors made at transmitting plants. The following is a partial review of the analysis and a description of some of the major items of the resultant design.

Analysis

Function and Responsibility

In the present system of television broadcasting the primary function of the transmitting plant is the transmission of information - consistent, reliable and faithful transmission of the TV program information. Any small equipment failure or misalignment at the transmitter plant can negate the efforts of hundreds of technicians working under extremely heavy pressure to provide proper lighting, proper video level, correct hue, signal integration and proper audio level. The entire transmitting plant must operate at peak efficiency and optimum alignment at all times to faithfully transmit the signal product it receives.

To help meet this responsibility the transmitting plant must have an input system that is similar to the human nerve center; it must monitor the transmissions continuously and be capable of taking instant action to correct deficiencies. One set of operating conditions should prevail within the plant for the transmission of all signals. It is not a processing center -- signals should not be modified in any way except to compensate for the plant's own internal characteristics. The plant design should allow sufficient flexibility to meet emergency conditions with no degradation of transmitted signals. The plant should run without the need of continuous adjustment and the operator's job should be that of maintenance; maintenance of the transmissions and maintenance of the equipment.

The art of television broadcasting has developed to the degree of complexity where compensating adjustments and/or signal realignments during programming, by the transmitting plant, are not beneficial and, in fact, constitute a serious hazard. While such an adjustment may be effective at the instant, it is usually detrimental to program quality in the long run. The transmitting plant's responsibility is transmission, not processing.

Constant liaison between master control

and the transmitting plant is imperative. Signal difficulties observed at the transmitting plant should be reported to master control immediately. Only if master control cannot correct the deficiency and requests assistance should any emergency processing be attempted.

The transmitting plant is a collection of complex inanimate objects which require the control of a qualified operator to properly perform its functions. In detail, these functions are:

I. Process Master Control Signals to Feed Transmitter

A. Audio
1. Pre-emphasize.
2. Amplification to modulator input level.

B. Video
1. Pre-distort for FCC required envelope delay characteristics.
2. Pre-distort to correct for transmitter envelope delay characteristics.
3. Pre-distort to correct for transmitter non-linearities.
4. Limit signal bandwidth to meet FCC requirements.
5. Amplification to modulator input level.

II. Transmission of Aural and Visual Signals

III. Monitoring of Signals

A. Audio and Video Amplitude and Quality
1. Signals received from master control.
2. "In" and "out" of each "block" of the input system.

B. Radio Frequency
1. Demodulated aural and visual signals, as transmitted.
2. "In" and "out" of each "block" of RF system.

IV. Status Monitoring

A. Transmitter
1. Power output.
2. Frequency, and modulation percentages.
3. Operating currents and voltages.
4. Temperature.
5. Condition of emergency circuits.

B. Studio-Transmitter-Link
1. Operating constants.
2. Condition of emergency circuits.

C. Audio and Video Amplifiers
1. Operating constants.
2. Condition of emergency circuits.

D. Power Supplies
1. Operating constants.
2. Condition of emergency circuits.

E. Primary Power Supply
1. Operating constants.
2. Condition of emergency circuits.

V. Emergency Action

A. Instantly substitute emergency circuit component or routing for any audio, video or RF "block" exhibiting difficulties.

VI. Maintenance

A. Perform operational maintenance to insure consistent transmission.

B. Perform preventive maintenance to minimize equipment failures.

C. Perform corrective maintenance to repair faulty circuits or equipment.

Manpower

The ideal transmitting plant design is the one which allows the entire plant operation to be performed by one man. Even if two men are to be assigned to the plant the input system design should still allow for full control by one operator. With the increasing hours of on-the-air time the second man can be occupied performing the corrective and preventive maintenance tasks that are required, while the first man performs all of the plant's control and monitoring functions.

The operator is the most essential and critical part of the input and control system in the transmitting plant. A comprehensive design must give him full consideration, analyzing his needs and his relationship to the equipment he operates. Control area lighting should be designed to provide ease of viewing picture monitors and comfortable observation of oscilloscope patterns. In addition, the operator must have a well-illuminated view of all pertinent meters and operational areas, with simple and readily accessible lighting controls.

The acoustics of the control area must be considered as carefully as the acoustics of a studio control room. Since the transmitter operator is the last audio control point, he must be able to distinguish the sound of hum and distortion from the equipment and blower noises in his plant. In addition to allowing the audio signal to be carefully monitored, proper acoustical treatment and speaker placement make a great contribution to the alertness of the operator. A noisy plant area dulls the senses and thus increases reaction time in an emergency. The complete design of the system must also include careful consideration of heating and ventilation. A comfortable environment is conducive to alertness and considered judgments -- both prime requisites for efficient, consistent operation.

Equipment

There are usually two or more commercial designs of equipment available that will perform the required functions and proper equipment selection requires very careful study. Performance, cost, ease of maintenance, and past history are a few of the pros and cons which must be weighed. Additionally, some thought should be given to keeping the number of different equipment types in the entire television plant to a minimum so that tube and spare parts stocks throughout the studio and transmitter plant are kept to a minimum.

The stock designs of the broadcast equipment suppliers are intended to cover the requirements of the average stations. A considerable saving in cost and a considerable improvement in operations may often be effected through the use of custom-built equipment. Such equipment is usually thought to be more expensive than "standard" items but this is not always the case. Quite often the "standard" commercial design will include features that are not required and will thus complicate the operation of the plant and add to the chances of equipment failure. In custom-built equipment the designer can get precisely the mechanical and electrical performance required usually with considerable savings in space and in maintenance. Equipment selection is extremely important for no matter how well designed the system may be it can never perform any better than its weakest element.

Maintenance

The word maintenance means different things to different people but it can be defined very definitely in the case of a TV transmitting plant. Three general classes cover all conditions -- operational maintenance, preventive maintenance and corrective maintenance. These three classes of maintenance are extremely important considerations in the design, installation and operation of a transmitting plant.[1]

A good site, tall tower and high power will provide service to a large viewing audience but this service is of little value unless it is consistent service. The entire transmitting plant design must be laid out with maintenance problems clearly in mind. Care must be taken to include the best available equipment to give the desired coverage and the best available equipment to give consistent transmission; consistent both in time and fidelity. This cannot be achieved by simply providing over-rated component parts with high life guarantees for even a component with a 5,000 hour guarantee can fail in 100 hours. Neither human beings or electronic components are infallible and it is the responsibility of the design engineer to anticipate failures in his system. The system must be designed so that preventive maintenance will minimize these failures and corrective maintenance will allow for rapid replacement or correction of the faulty parts.

While good engineering practice dictates the use of high quality components, even the best of components will not do the job if their full limitations are not taken into consideration. While preventive maintenance will keep the equipment working at top efficiency there must be designed into a plant the corrective maintenance procedures to instantly replace or repair any part which may fail.

The system design should include provision for substitution of equipment or routing to allow routine preventive maintenance to be performed during program hours. This will allow the hours after program time to be utilized for maintenance of the transmitter and equipment which cannot be touched during the active program periods.

Operating Errors

The ultimate system, designed to minimize operating errors, would include a completely duplicate plant for substitution in case of difficulties. This very expensive method of providing a continuity of service is rarely used but a sound economic case can be made for the partial use of duplicate equipment in many areas of the input and control system.

A large number of operating errors occur following emergencies wherein the operator must "jury rig" a substitute for the equipment that has failed. At this critical moment the operator assesses the difficulty and then must find a way to repair the difficulty or by-pass it. His first goal is to stay on-the-air and often the pressure of this "prime commandment" leads him to the quickest but not the best decision. To minimize the chances of error there should be included in the system design a simple method of equipment or routing substitution for the most likely of difficulties. One which the operator can apply as an instant reaction, not requiring the process of assessment and decision; simply a practiced and conditioned response.

The second most common operating error results from misguided attempts to "ride gain" to correct for difficulties in some other portion of the television plant. It is not uncommon to find a transmitting plant operator correcting for a studio control operator's error only to find that his correction has been premature and detrimental a moment later when the studio corrects for its own error. To eliminate this type of error a careful assignment of responsibilities must be set up and, the number of variable adjustments at the control console must be reduced to an absolute minimum.

Design

The system to be outlined below was developed for use at CBS's new KMOX-TV transmitting plant in St. Louis, Missouri. The analysis which outlined this system had been in process for about two years and certain elements of the new system had already been installed in a modernization program at CBS's WBBM-TV transmitter plant in Chicago when plans were started for the construction of the KMOX-TV plant. The resultant system thus had the advantage of a partial field test and is the product of the analysis, this field test, and many many hours of discussions between the Engineering Department and the engineers in charge of these two transmitting plants.

Control Console

The control console is the operating center of the transmitter plant. The console is the action and reaction center tying all components of the transmitting plant together.

Figure 1 is a photograph of the control console installed at the new KMOX-TV transmitting plant. Four standard rack-width housings make up the console: one unit for audio/video control, one unit for transmitter control and two units for video monitoring. The section on the right (Figure 2) contains all of the controls for selection and routing of the audio and video signals feeding the transmitter. The major portion of the panel is taken up by push button controls for the audio and video equipment, laid out in a schematic representation of the actual circuitry of the system. (This installation was designed for use with a regular and auxiliary transmitter but the auxiliary transmitter was not installed initially. Pending the installation of this transmitter its video control section on the panel has been covered by a blank plate.) Illuminated push buttons select the program source and route the signals through either of two program channels to the transmitter. The layout of the audio and video controls are very similar, as are the schematic routings of the audio and video circuits themselves. The details of these circuits will be described below.

The right side of this panel contains controls for the emergency power supply and for the plant's lighting system. The well in the desk section contains momentary push buttons which operate a gold plated stepper relay to select audio monitoring points. This monitor system, as well as the video monitor relay system, is self-homing so that when a button is released, the system homes on the most important monitoring point - the outgoing signal. The well also contains the only knob on the entire console (excluding, of course, the picture monitors and CRO's). This is the monitor speaker volume control.

Located immediately below the audio level and modulation meters are two rows of illuminated readouts. The top row, labeled "Functions," gives visual indication of the condition of the more or less supervisory and routine elements of the plant's operations such as the deicers, fans, tower lights and air temperature. The lower row is a part of the plant alarm system which, along with an alarm bell, signals the operator when visual or aural RF is off, when the air supply fails, warns of fire and also provides an indication of a Conelrad Alert. Provisions are made for silencing the alarm bell and, if the trouble has been cleared, for extinguishing the read-out. The alarm system will be further detailed below.

Lighting controls are momentary lever switches which operate a relay system controlling most of the plant's lighting. In addition to providing individual controls for all lights in the control area and the transmitter area, one of the switches operates all relays to turn on all the lights at once -- for the emergency or panic condition.

The two middle sections of the console (Figure 3) contain identical sets of picture monitors and oscilloscopes. The desk well contains momentary contact push buttons for video monitor selection. The video monitoring system is self-homing and so arranged that the left monitor will home on the incoming line and the right monitor will home on the output of the station's demodulator. The CRO's are mounted at the highest point in the console, contrary to the usual practice, so that the oscilloscope screen is directly in line with the operator's eyes. The 14-inch picture monitor is easily viewed from almost any position but the fine trace on the scope can only be carefully viewed directly, and close up.

The left panel (Figure 4) is the transmitter control panel. It contains aural and visual reflectometers, frequency meters, transmitter control system readouts, level and power controls, and the control switch for a coaxial relay cutback system allowing the use of the 6KW driver or the 25KW transmitter. (This panel was also designed for use with a regular and auxiliary transmitter and the lower quarter of the panel has been left blank pending the installation of the auxiliary unit.)

The console is completely isolated from the active program circuits through the use of amplifiers, relays or transformers. There is no active routing through the console and, if needed, the entire plant can be operated without the console. In an emergency the console can be "patched out" and the plant can still transmit a high quality signal. This type of isolation prevents the console from becoming the "millstone" of the plant and allows it to be maintained quite freely without the fear of jeopardizing the entire plant. Every important control function performed at the console can be performed at some other point in an emergency. A cup of coffee spilled into the console will not put the plant off the air.

Control Room

To provide the transmitter operator with the environment most conducive to high quality operation this transmitter plant was built with a completely separate control room rather than a control area located in the transmitter room. Figure 5 is a view of this control room, looking over the control console into the transmitter room. The control room is isolated from the transmitter room by cinder block walls, a wall of equipment racks, fiberglass insulation and a large double pane picture window. The operator seated at the control console, or standing at the racks, can see the transmitter quite clearly and yet has none of the annoyance of the usual transmitter noises.

The main monitoring speaker is mounted in the suspended acoustical ceiling, directly over the control console. The speaker is in an infinite baffle type of mounting and provides excellent sound to the seated operator while giving fairly good coverage throughout the room. Flush mounted ceiling spots and fluorescent troffers are provided so that the lighting can be adjusted to suit the operator's preference and still keep the console well illuminated without providing any "hot spots" on the picture window or on the monitors.

The room is carefully air conditioned with a number of low velocity anemostats placed to keep direct air flow away from the operator. A separate air conditioning system tempers the air in the transmitter room. This unit does not serve as a comfort air conditioning system as the control room package does but only serves to minimize the differential between the two rooms in very warm weather.

A complete all-call, no-hands intercom system is provided in the plant, controlled from the console. Even though the plant is operated by one man the intercom is provided for maintenance periods or emergencies when more personnel may be involved. Intercom stations are provided in the control room, shop, transmitter room, toilet and kitchen areas. The house speaker system tied to the aural station monitor is also provided at all these points. As a security measure for the one man plant a separate intercom is provided to the outside entrance which, along with electrical latches and a window in a double door entry, allows the operator to interrogate, view and then admit callers.

Video System

Figure 6 is a simplified block diagram of the general video system that evolved from this study. The system shown here is designed to provide video inputs to two transmitters, a regular unit and an auxiliary. The circuits feeding both transmitters are essentially identical with the exception that the inputs to the auxiliary transmitter are derived from isolation amplifiers bridging the incoming line while the main transmitter is fed directly.

Incoming signals are routed through variable video attenuators to provide for amplitude equalization, allowing a unity-level system to be followed throughout the entire plant. The input switcher will feed either of the two incoming lines to either of two channels to the transmitter. The switcher operates at both ends of the corrective amplifier chain; as a two-by-two unit at the input and as a two-by-one unit at the output.

Following the signal through Channel A1 -- the signal is predistorted and amplified by this chain of filters and amplifiers until it meets all the transmitter input and complementary FCC transmission requirements and is then fed to the transmitter modulator input. The emergency channel, A2, shown directly below the corrective amplifier chain is a simple copper connection made within the switcher itself. The input switcher consists of a single chassis and the entire emergency path consists of one and one-half inches of number 16 wire. In emergencies the operator can switch to the emergency channel and then proceed to locate the trouble in the main channel as soon as he has assured himself of the continuity of transmission. No attempt is made to remove portions of the corrective chain, or main channel, for all units in the chain are interrelated as regards overall gain and predistortion. There are no jacks provided between elements of the corrective chain in Channels A1 and B1 and this is done specifically to prevent any emergency patching which would upset the system's operation. The video input switcher is shown in Figures 7a and 7b.

Monitoring is provided by bridging isolation amplifiers and from equipment monitor outputs. Monitor selector relay inputs are connected to the following points: Line 1, Line 2, transmitter 1 input, transmitter 2 input, transmitter 1 modulator output, transmitter 2 modulator output, transmitter 1 corrective chain output, off-the-air receiver, and demodulator system output. The demodulator can be connected to any of four points in the RF system by coaxial relays controlled by the monitor selector push button; providing a demodulated signal from transmitter 1 output, transmitter 2 output, diplexer output or dummy load probe.

The monitoring system is set up to allow the two sets of monitors and CRO's to check the "in" and "out" of each important block of the video system. The system will allow either monitor to look at any signal or both monitors to look at the same signal, with the illuminated push buttons "tallying" the circuit being checked. A side-by-side comparison is available to check for minor differences in signal quality or to check for minor differences in monitor performance. The monitor system is self-homing to preselected points ("Line 1" for the left monitor and "Demod Out" for the right monitor) but a "disable" switch is provided, with a suitable warning "tally," to allow any monitor point to be "held" for special test conditions.

Audio System

Figure 8 is a simplified block diagram of the audio system. The audio system closely follows the layout of the video system, with pads and transformers replacing isolation amplifiers. Once again two program circuits are provided and they are fed through attenuators for level setting. The two transmitters are fed the same signals in the case of the audio system but the signal may travel through a regular or an emergency amplifier path. The regular path uses the main limiting amplifier and a spare limiter is provided in the emergency channel. The input switcher can take inputs from the two program lines, a tone generator or a speech/turntable input unit provided for emergency originations. Monitoring is provided by bridging transformers, and station monitor and receiver feeds.

The four incoming signals available to the input switcher can be monitored at normal transmitter input levels through the use of the "unused" emergency amplifier. The output of the monitor selector feeds the input of the "unused" limiting amplifier and the output of this amplifier feeds the station volume indicator and loudspeaker through the VI monitor selector and the speaker monitor selector. All monitoring is push button controlled utilizing gold plated stepper relays to set up the proper monitor channels. With this arrangement it is possible for the operator to be assured that the signal level of a program source to be used, or of an amplifier to be switched, is proper before the transfer is made. The system is self-homing, under normal operations, to provide a volume level indication of the incoming line and feed the loudspeaker with a signal from the station monitor. A "disable" switch is provided to allow the system to lock on any other preset position for maintenance or trouble-shooting operations. Normally, however, the operator can select his monitoring point and then release the button and find the system "back to normal." He is hard put to forget to monitor the correct point in the system.

Terminal Equipment

Eight equipment racks containing all of the plant's terminal equipment form one wall of the transmitter control room. These racks, shown in Figures 9a and 9b, contain all components of the plant's input system as well as the STL receivers and auxiliary test equipment. All racks are enclosed by both front and rear doors and are cooled by a forced air supply fed through the floor base and exhausted through the rack tops.

Wiring enters all racks from overhead troughs and terminates at audio, video, control and power blocks mounted in the upper portion of the racks. Figure 10 is a photograph of the type of video terminal block that is used[2].

Video Amplifiers

CBS type 3B video distribution amplifiers are used in the video system for both isolation and video distribution.[3] These simple, plug-in, single output amplifiers (Figure 11) provide a high degree of reliability with extremely high quality performance. All of the amplifiers in the system are adjusted for unity gain and can be used interchangeably in any part of the video system. The use of single output amplifiers eliminates the problem of a failure in one amplifier circuit causing an outage in more than one circuit of the system.

The amplifiers mount in compact fan-cooled trays (Figure 12) which accept eight units. In the KMOX-TV installation the eighth position is left vacant and is set up as a test position for alignment work and for level adjustments.

Audio Amplifiers

The audio system uses a total of five amplifiers. Two limiting amplifiers are provided for the program circuits along with one monitoring amplifier, a preamplifier for the speech input unit, and an intercom amplifier. Identical amplifiers are provided for monitoring, preamplification and intercom use to simplify maintenance. In an emergency the intercom amplifier can be used for monitoring or speech input service, or vice versa.

Power Supplies

Unitized, germanium rectifier regulated power supplies are used to provide B-plus voltage for video amplifiers and test equipment. These plug-in units shown in Figure 13 furnish .800 amperes at 280 volts and mount in trays similar to those used for the CBS type 3B video amplifiers. Separate power supplies are provided for the main and emergency channels of the video system and B-plus to the monitoring amplifiers are also split to minimize difficulties in the case of a power supply failure. A spare power supply is provided in the tray for instant plug-in replacement in case of failure.

Since the entire plant is controlled by a system of relays it is imperative that a reliable source of relay voltage be available. Two selenium rectifier 24 volt supplies furnish relay voltage through an automatic power supply switcher shown schematically in Figure 14. This unit samples the voltage furnished by the number 1 supply and transfers to the number 2 unit as soon as the number 1 package fails. The transfer system operates rapidly enough to prevent relays from dropping out but, if they should drop out due to any unusual problem, the "home" position of all relays is the plant's emergency routing, providing for continuity of transmission under the worst of conditions. Figure 15 is a photograph of the 24 volt power supply switcher.

Jackfields

Jacks are supplied only where absolutely necessary for maintenance and for emergencies beyond the capabilities of the built-in by-pass circuits. As shown in Figures 6 and 7, very few jacks are supplied. Generally, individual equipments are not supplied with jacks at their inputs and outputs; this is only done for the complete "blocks" of equipment which make up important sections of the system.

The layout of the video jackfield conforms rather closely to the video flow in the system. No multiples are supplied and all in-circuit jacks are of the self-normalling type designed by the CBS Engineering Department[4]. Figure 16 is a photograph of one of these jacks and Figure 17 shows its electrical circuit.

Audio jacks are also self-normalling and consequently the operating jackfields contain no "hairpins" or patch cords for normal operation[5]. The operator can tell at a glance that all circuits are properly connected if he has a clean jackfield.

Alarm System

A special alarm system has been built into the plant to call the operator's attention to any serious problems that may jeopardize the transmissions. An alarm condition is signaled by a bell and the difficulty is spelled out to the operator on the readout contained on the upper portion of the right console section (Figure 2). Probes in the transmission lines sample the RF energy to operate the alarm if either aural or visual power drop below normal limits. Fire detectors throughout the plant also tie to the alarm system. A vane switch in the air exhaust monitors transmitter cooling and a Conelrad receiver is tied in to indicate "Alert" conditions.

The system is designed to indicate one or all alarm conditions at once. The bell can be silenced from the console leaving the readout indication lighted until the fault or alarm condition has been cleared. The bell will sound again for subsequent alarm conditions. A test switch is provided on the alarm chassis to allow for maintenance checks of each alarm circuit. Readouts are illuminated by two long-life lamps in parallel minimizing the chances of indicator failure.

Immediately above the alarm readouts on the console panel is a row of readouts labelled as "functions." These indicators are not tied into the alarm system but they complement it by spelling out the operating condition of the plant. For example, supply and exhaust fan operating conditions are indicated in the "function" row while the flow of air in the duct system is indicated in the "alarm" row.

Conclusion

The system described above has been in operation at two different installations for a total of two and one-half years. Both transmitting plants have proved consistently reliable, have records of extremely high quality transmission, and a minimum of operating errors. This excellent record has proved the effectiveness of the analysis and the efficiency of the resultant input system design.

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2. H. A. Chinn, R. S. O'Brien, R. B. Monroe, P. E. Fish, "CBS Television City Technical Facilities," Proceedings of the IRE, pps. 1089-1090, July 1954.
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4. C. J. Neenan, "CBS Self-Normalling Video Jack," Journal of the SMPTE, Vol. 68, No. 10, October 1959.
5. H. A. Chinn and R. B. Monroe, "Single Jacks for Broadcast Application," Audio Engineering, Vol. 31, No. 6, July 1947.

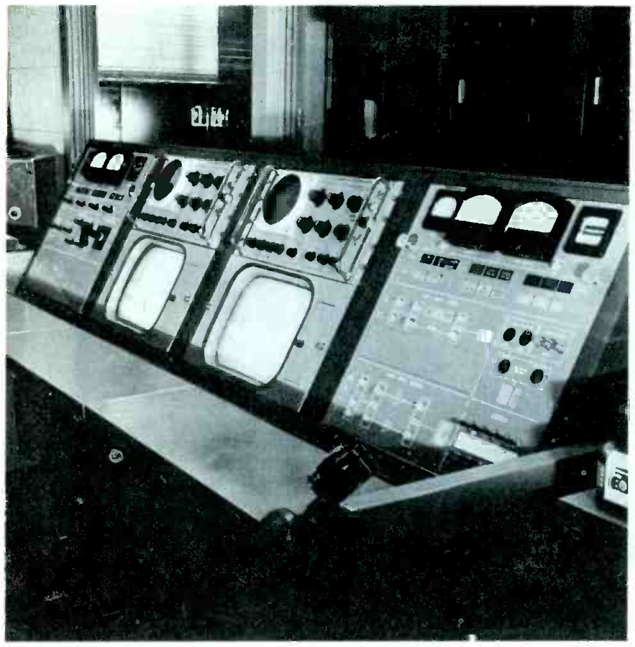

Fig. 1. KMOX-TV control console.

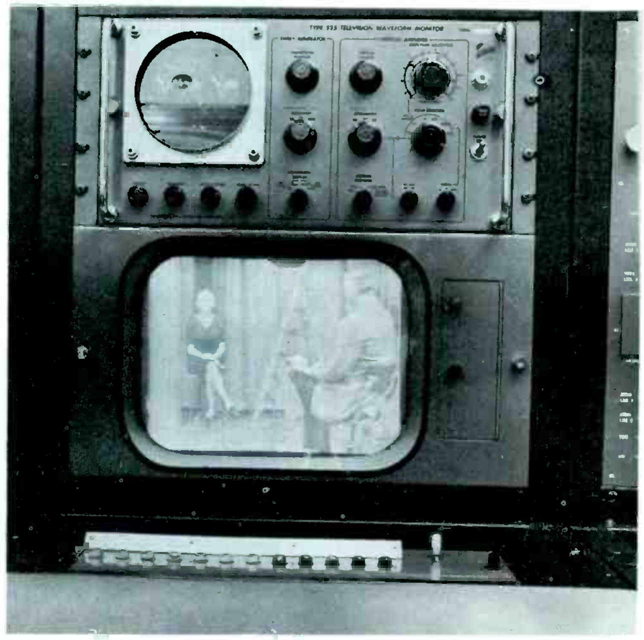

Fig. 3. Control console video monitors.

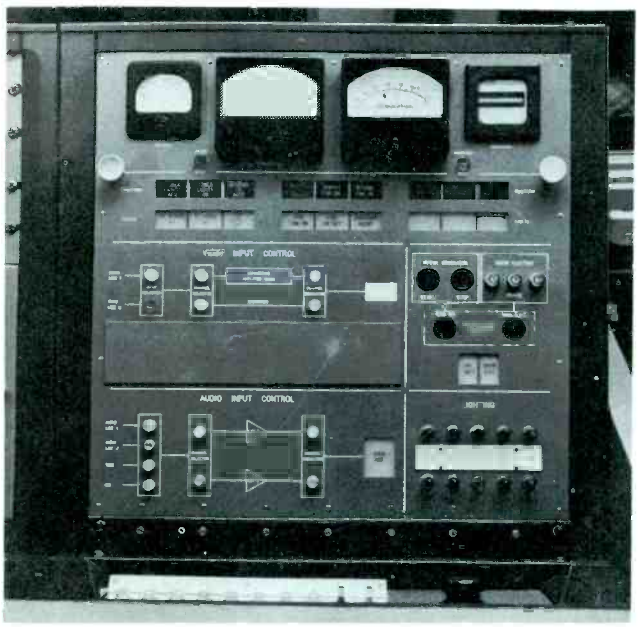

Fig. 2. Control console right section, audio/video control.

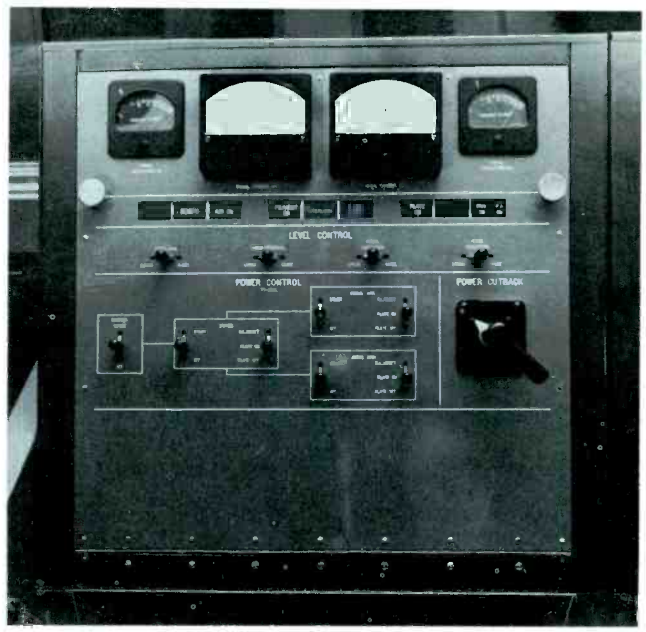

Fig. 4. Control console left section, transmitter control.

Fig. 5. KMOX-TV control room.

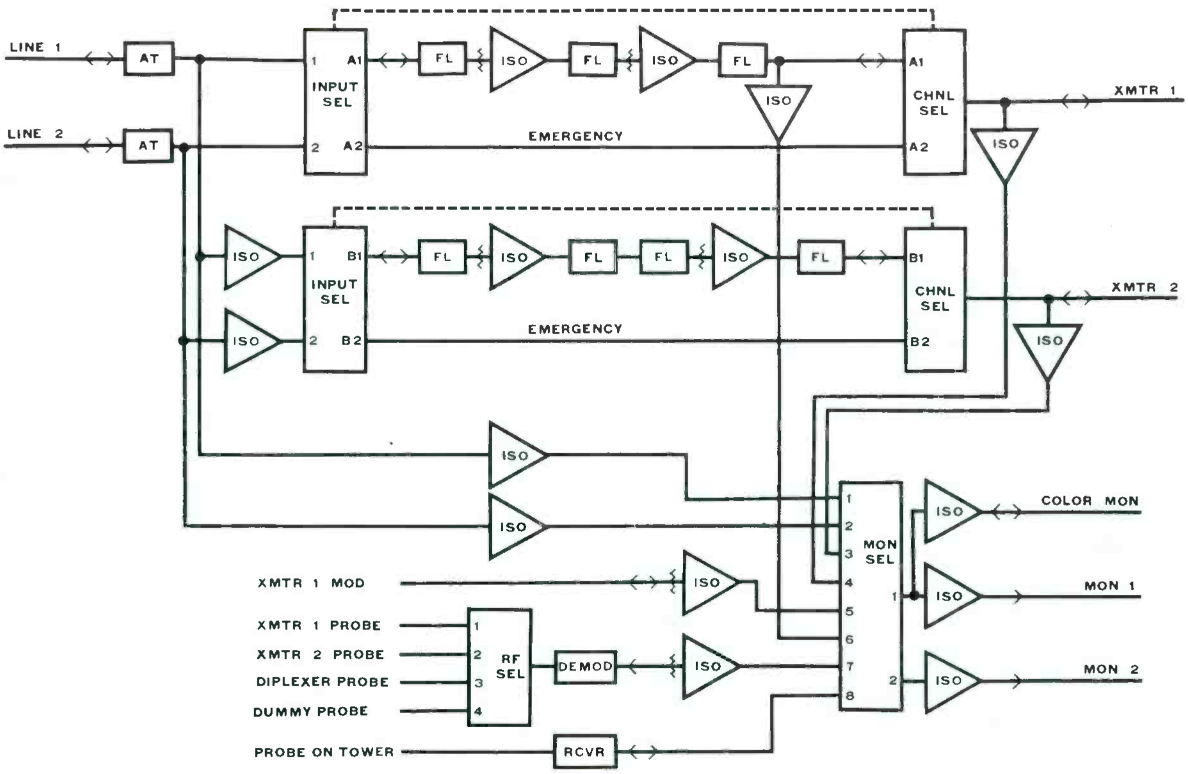

Fig. 6. Block diagram, video imput system.

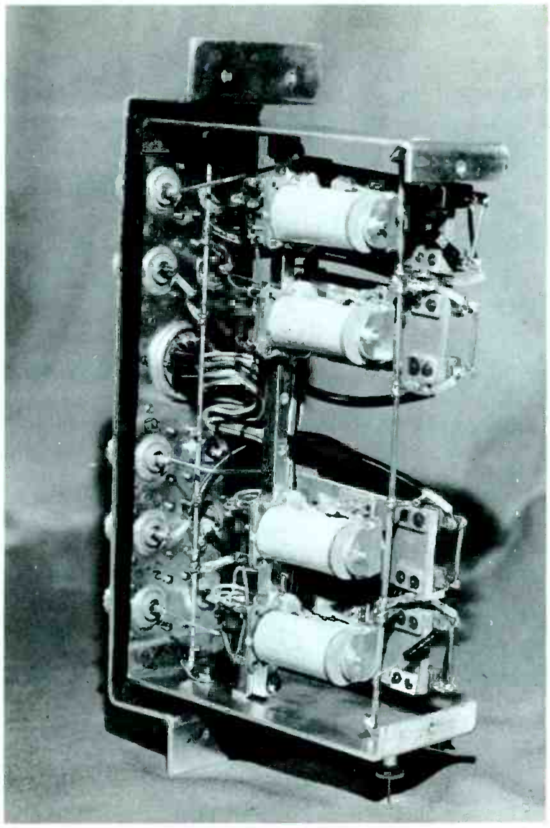

Fig. 7a. Video input switcher, cover removed.

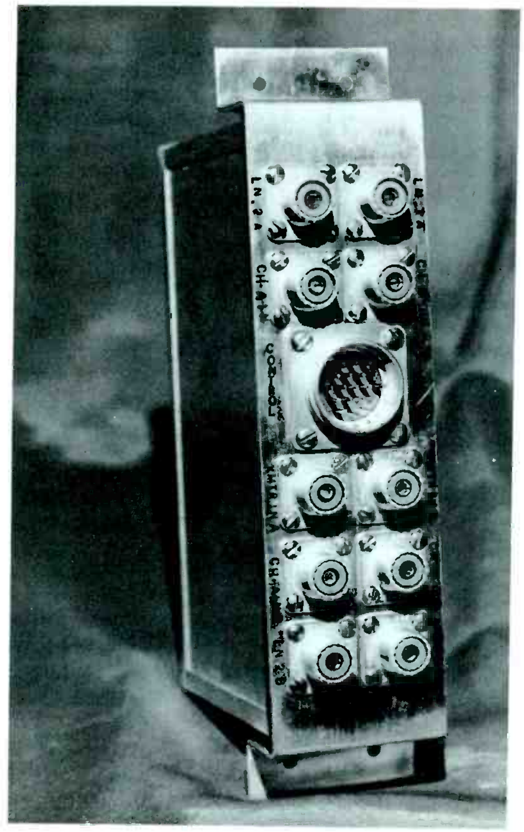

Fig. 7b. Video input switcher, front view.

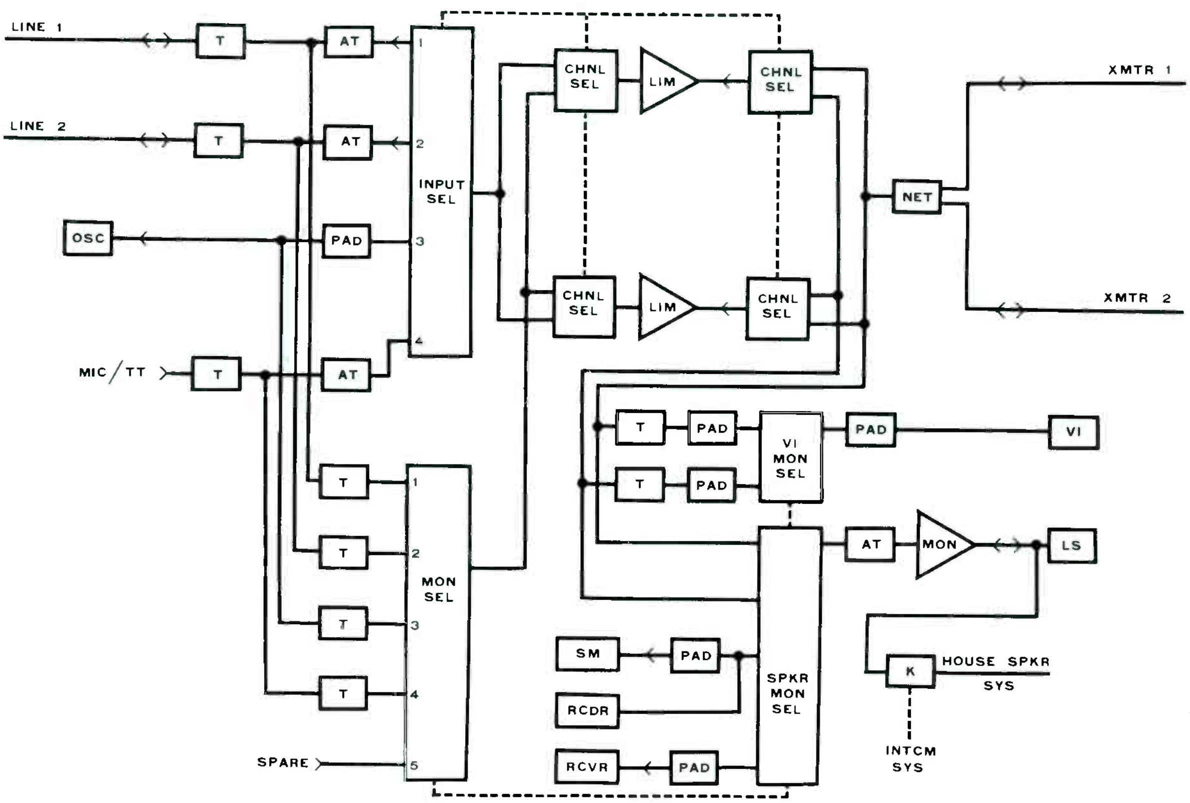

Fig. 8. Block diagram, audio input system.

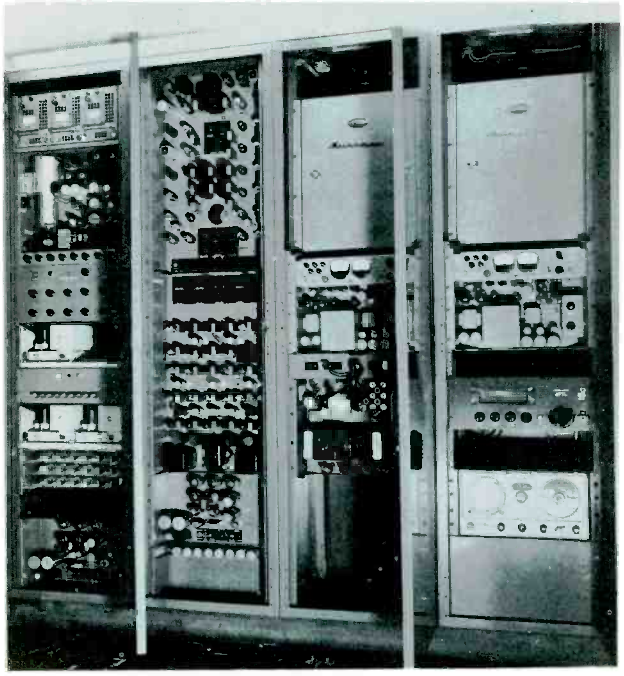

Fig. 9a. Terminal equipment racks, left group.

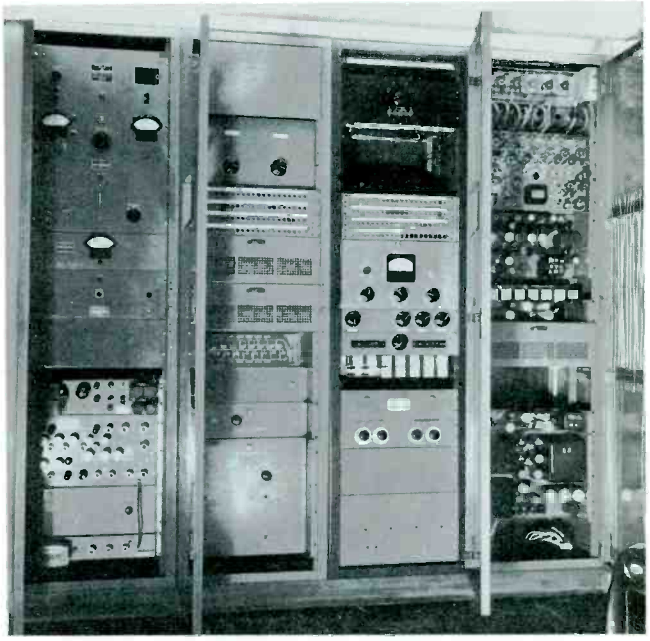

Fig. 9b. Terminal equipment racks, right group.

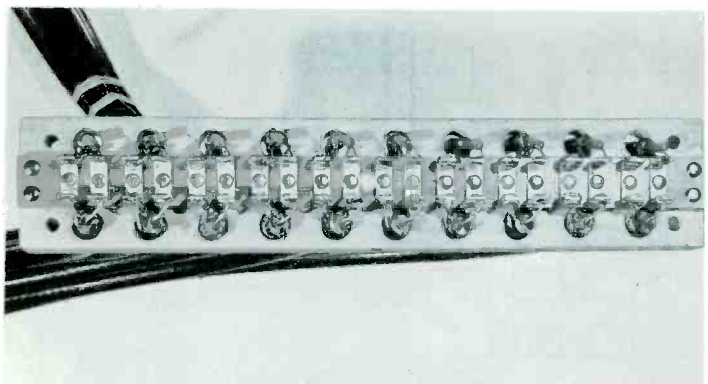

Fig. 10. Video terminal block.

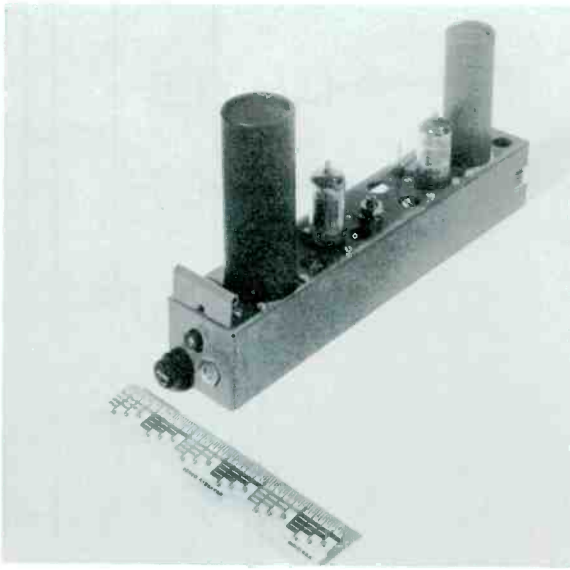

Fig. 11. CBS Type 3-B video distribution amplifier.

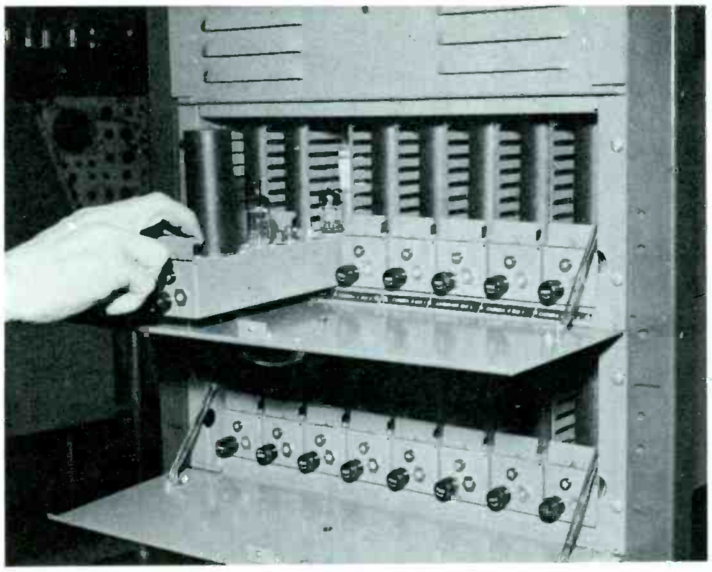

Fig. 12. CBS Type 3-B video distribution amplifiers mounted in tray.

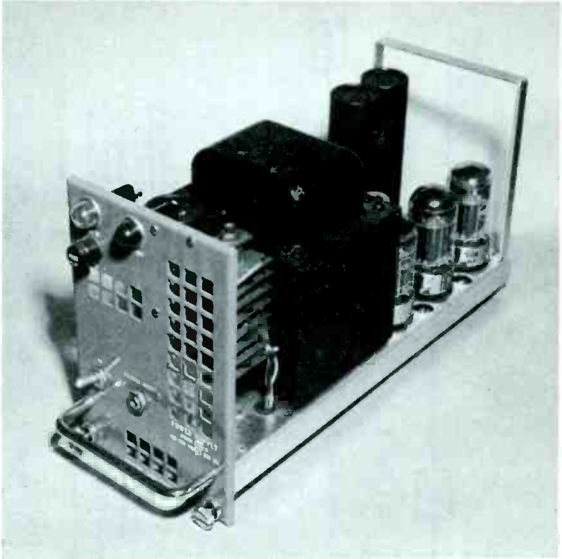

Fig. 13. Plug-in regulated power supply.

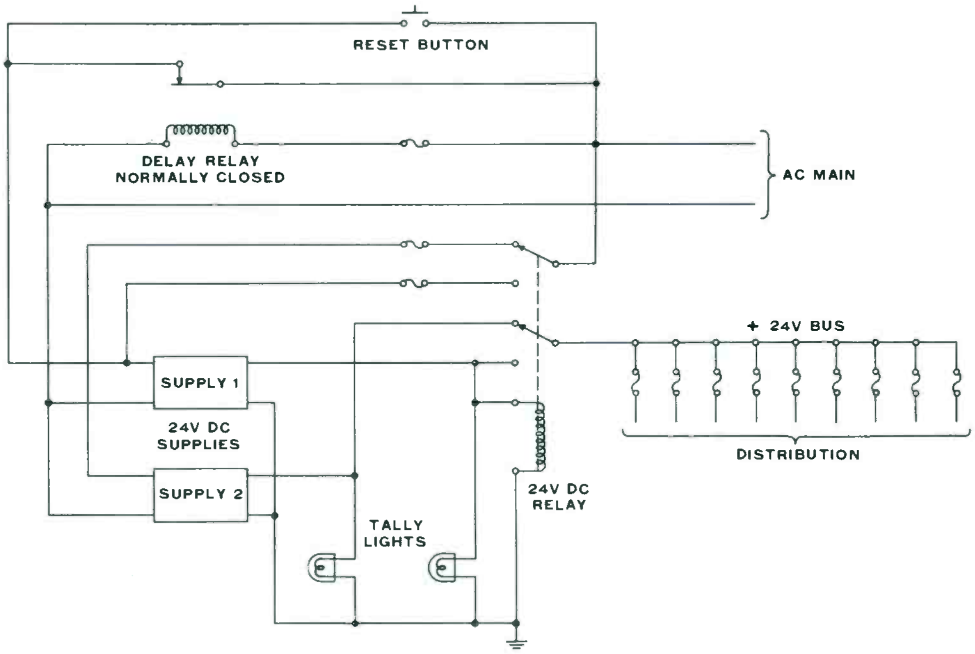

Fig. 14. Schematic of 24-volt power supply switcher.

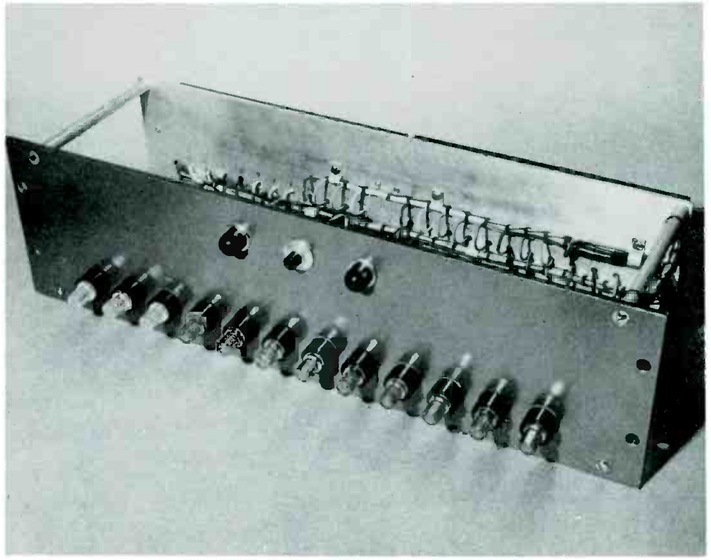

Fig. 15. 24-volt power supply switcher.

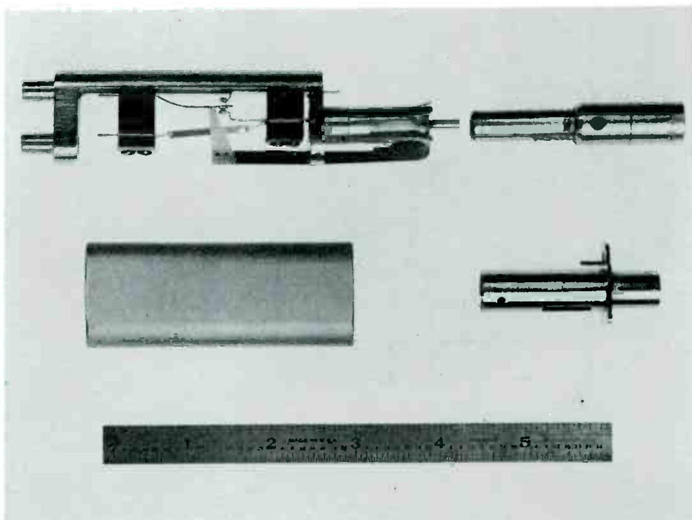

Fig. 16. CBS self-normalling video jack.

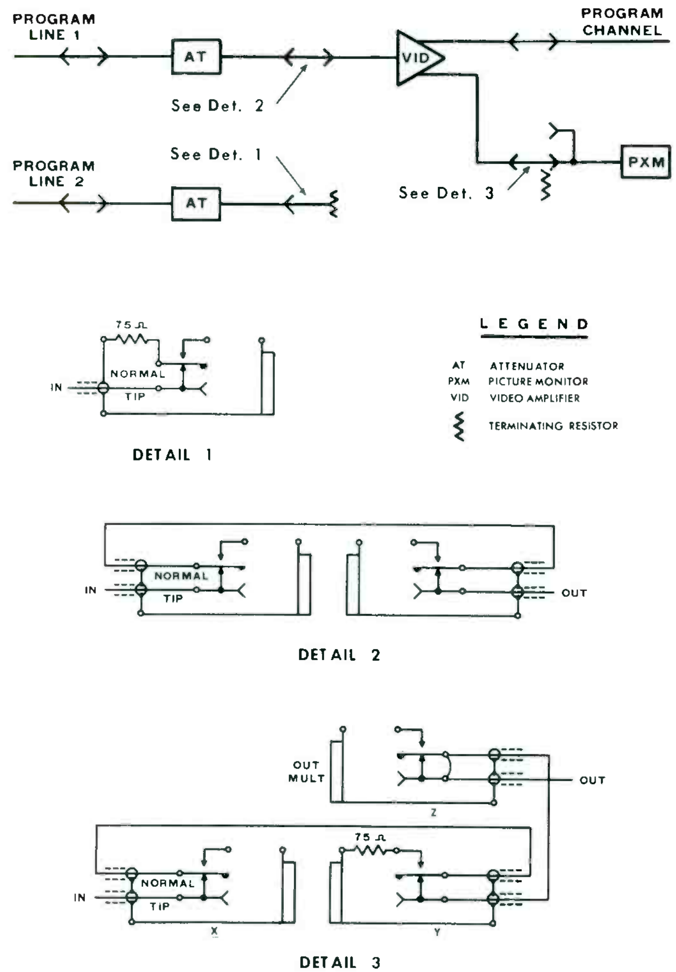

Fig. 17. Schematic of CBS self-normalling video jack.

A SPECIAL EFFECTS AMPLIFIER
FOR NON-COMPOSITE OR COMPOSITE,
MONOCHROME OR COLOR TELEVISION SIGNALS

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Introduction

Upon the introduction of special effects techniques for monochrome television in the late thirties, there evolved two philosophies concerning the proper location in the system at which the synchronizing signals should be combined with the video signals. One thesis has contended that the two signals should be united as soon as possible, preferably in the camera, while a second one has advocated the addition of the synchronizing pulses to the video information after the studio switching operations have been completed. The latter method has been so widely accepted by the networks and local stations that until now it has been almost universal in its adoption.

Color television, due to its compatible nature, has been processed the same as monochrome wherever possible and as a result, the addition of synchronizing pulses has also occurred after camera switching.

When NBC began planning the new studios for Washington, D C, it was decided to build the plant upon the concept of composite signal switching for both monochrome and color signals. There appeared to be many advantages for such operation. Greater flexibility could be realized; studio timing problems were simplified; and less equipment was needed. This added up to reduced space, air conditioning, and power. Naturally all the equipment associated with the creation of special effects had to be capable of handling the higher signal level when synchronizing pulses were present. There were in addition, however, many other problems which had to be solved before composite operation could be as flexible as non-composite. Further, it was immediately recognized that all the new apparatus in order to be universally applicable would have to function properly with both composite and non-composite signals. With the above considerations kept in mind, the several systems components were appraised. From this survey, it became apparent that a new special effects amplifier would have to be designed since the existing equipment did not adequately satisfy the new requirements.

Possible Circuit Improvements

The heart of any special effects amplifier is the fast acting switch. One type of switch[1] had been in use for several years and it was decided to see if any improvements might be made in it. Clamper diodes had been vacuum tubes, so it was decided to try to see if any of the new semi-conductor diodes could be adopted for this purpose. Switching pulses had been shaped previously by regenerative clippers. Investigation showed that there might be other ways that could possibly prove to be superior. This was to be given further study. All of these facets and indeed any others which could effect improvements on previous amplifier designs were to be incorporated in the new unit.

Amplifier Description - Input Stages

The investigation has resulted in the amplifier shown in Figure 1. The two program signals to be switched are fed to two identical feed-back amplifiers V1 and V2. The input goes to the triode half of a 6U8A and the pentode half acts as the output stage. Such an arrangement permits wideband interstage gain due to the reduced Miller capacity of the pentode. These two stages have approximately 15 decibels of feed-back and a gain of 2. The impedance seen looking in at plate 6 of the 6U8A is 100 ohms. High frequency compensation is obtained by proper adjustment of condensers C22 and C23 while the gain is adjustable by means of pententiometers P1 and P2.

Clamper Considerations

The output of V1 and V2 is fed to the halves of 6922-V3 connected as cathode followers. The grids of V3 are clamped so as to establish proper signal references for d-c coupling to the video switch. The clamper diodes are Hughes 1N625 and 1N191 crystals connected in series. The reason for using two diodes may be understood if one considers the requirements for a clamper diode. First, the diode must have quick recovery from the conducting to the non-conducting state. Second, it must have a very high back impedance and very low forward impedance. Third, it must have a very low capacity so as not to cause undue shunting at high frequencies.

Silicon junction diodes, e.g., the 1N625, meet the fast recovery time requirement (400K ohm in 1 usec) as well as having the low forward and high back impedance characteristics. These resistances are about 200 ohms and 20 megohms respectively. However, the capacity of the junction is about 20 uuf which is much too high. On the other hand, the 1N191 is a germanium point contact diode having a capacity of 0.5 uuf, a back resistance of a megohm and a recovery time of 3.5 usec to 400K ohms. By using one of each in series, an entirely satisfactory element for clamping color signals may be obtained.

Composite color signals must be clamped during the burst interval. Since the clamping action results in essentially short circuiting the signal path, there must be a means provided to preserve the burst. This is accomplished by use of antiresonant circuits comprising L1C27 and L2C28. The coils of each are adjusted so that the clamp pulse as viewed at TP-13 has a minimum of burst sine wave on its peak.

As has been pointed out,[2] the optimum time constant for video clampers is 2.5 usec. This is the product of the impedance of the clamper driver plus the clamper diode impedance times the capacity of the clamper condenser. The output impedance of V1 and V2, the clamper drivers, has already been given as 100 ohms. The forward impedance of the 1N625 and 1N191 diodes are about 200 ohms each so that the total resistive component of diodes and driver is about 300 to 400 ohms and the clamper condenser is therefore about 6800 uufs.

Switch Considerations

The desirable features which are found in semiconductors appeared encouraging enough to warrant investigating their use in the switch. The Hughes HD-2109 has proven to be acceptable in all respects. It has the fast recovery time and low forward impedance required. The back impedance is rather low and the capacity is somewhat too high. However, 40 decibels rejection in the off mode is sufficient and the diode meets this requirement satisfactorily.

In order to be able to balance out the switching component, a sample of the switch pulse which appears on the grid of V5 is injected in the same phase on its cathode. By properly adjusting the Black Balance Potentiometer P3, the switching pulse may be degeneratively neutralized so that none remains. Similarly, the capacity C34 may be adjusted for optimum transitional symmetry which approaches the unit doublet impulse very closely. The elapsed time for peak to peak excursion of the doublet impulse response is less than 0.05 usec (see Figure 2) and the amplitude is approximately 3.5% of the signal amplitude.

Output Amplifier

The plate of the 12BY7A-V5 amplifier drives a two stage feedback output amplifier. The 404A-V6 amplifier is d-c coupled to the shunt regulated[3] output tube 6BX7-V7. This stage is non-inverting and as a result, the feedback is to the grid of V6. Without feedback, V7 has a terminated impedance of approximately 30 ohms. With the feedback loop closed, the resulting 18 decibels of feedback lowers the output impedance to approximately 3 or 4 ohms.

Switch Driver

A cathode follower 5687-V8 is used to actuate the switch. This stage has its grids clamped so as to maintain black balance in the switched output signal. Clamper diodes D5 and D6 are Hughes type 1N627. These are biased to +5 volts. With a 20 volt keying or switching pulse at the grids of V8, the switch changes modes between +13V and +29V. With no pulse applied, the voltage on the cathodes of V8 is at +13V and signals from input A2 appear at the amplifier output.

Switch Pulse Processing

The techniques of reshaping pulses are well known in the art and require no elaboration. However, the techniques for shaping the waveform from a television camera is an entirely different matter and requires considerable effort to assure success. First of all, the output signal of the camera has high frequency picture data and noise in it which tends to camouflage the desired pulse. Second, very few camera tubes have flat landing. Instead of having a uniform signal output from beginning to end of each line or from top to bottom of each field when scanning a flatly lighted white area, they tend to have greater output in the middle of the scene than toward the edges thereby producing a waveform somewhat resembling a haystack. To produce a flat top rectangular pulse from such a waveform is indeed very difficult. Admittedly, shading may be introduced in an attempt to correct matters but the degree and form of the shading introduced is dictated by the appearance of the picture rather than by the appearance of the resultant pulse to be used for operating the switch. The usual shaping technique is to amplify the signal greatly, clip out a small segment, and amplify it sufficiently to drive the switch.

The success or failure of such a procedure depends on whether the portions of the line scan which are supposed to be black have smaller noise spikes going toward white than the amplitude of the scan at the end and beginning of blanking. If such be the case, it is obvious that a thin band exists parallel to the direction of scan where no signal data exist. If means are available for clipping off all data above and below this area, a suitable switching pulse may be obtained by sufficient amplification.

If the above condition does not exist, there are two possible situations which may occur. An attempt amy be made to move the clipping level or thin slice up toward white. The spikes rising from the black area toward white will be deleted but the edges adjacent the end and beginning of blanking will become ragged due to the "haystacking" mentioned earlier.

Conversely moving the clipping level down toward black will result in improvement at the edges of the picture but will cause spurious keying or switching to occur in the central positions of a picture.

It is obvious that large amplification of the camera signal is essential followed by suitable clippers which can be adjusted for picture content. The present unit has a high gain feedback amplifier consisting of 6BQ7A-V9 and 6BK7A-V10 each of which is connected as a shunt regulated stage.[3] With 18.6 decibels of negative feedback, the overall gain is approximately 80.

In order to remove burst and chroma components from a color signal, a high Q antiresonant circuit comprising L3 and C42 is connected in the cathode of 6BQ7A-V9. This circuit degeneratively reduces the overall gain of the amplifier at subcarrier frequency by approximately 27 decibels resulting in a luminance signal which is substantially free of chroma components.

This signal is applied to both halves of 12AT7-V12 whose grids are clamped by 6AL5-V11. The bias on the grids of cathode follower V12 is controlled by means of the "Clip Level" potentiometer P5. The output of V12 is coupled through diode D7 whose anode is referenced to a potential of +27 volts by means of the zener diode D8. Thus when P5 is at ground potential, the cathode of V12 is at approximately +12 volts. All the sync, black and gray portions of the signal are clipped off in the grid of V12. Only the white portions of the signal appear at the cathode of V12. Diode D7 conducts and the same signal appears at the input to 6BK7-B V13. The magnitude of the signal, however, is not large enough to trigger V13 and no output pulse is produced to drive V8.

Increasing the potentiometer P5 increases the signal at the input to V13. When this level is sufficient to cause V13 to operate a keying pulse appears at the input of V8 which operates the switch.

When the input to V12 is sufficient to raise its cathode potential above that established by D8, D7 becomes back biased and acts as a clipper for any further signal level increase. Thus V12 acts as a negative clipper while D7 is a positive clipper. The two produce the thin "slice" referred to above.

In order to more clearly explain the operation of the circuit refer to Figures 3 through 9.

Figure 3 shows a ten step test signal with blanking and sync, modulated with subcarrier, and having a peak to peak amplitude of one volt. This waveform is introduced at J5 and appears at the input to V9.

The same signal after amplification to a peak to peak value of approximately 80 volts in V9 and V10 is shown in Figure 4 as it appears at the input to V12. Note the absence of subcarrier due to the rejection caused by L3 and C42.

Figure 5 shows the waveform appearing at the input to V13 with the "Clip Level" potentiometer P5 at ground. Notice that only the white or top step of the test signal appears. The signal amplitude, 3V peak to peak, is too small to unbias the regenerative clipper V13 and no output appears at the input to V8.

Increasing the clipping level at P5 to approximately 17 volts produces the waveform shown in Figure 6 whose peak to peak amplitude is 17 volts. This is sufficient to operate V13 and the pulse shown in Figure 7 appears at the input of V8. This keying pulse having an amplitude of 23 volts peak to peak is sufficient to operate the switch.

Increasing P5 to 30 volts results in the waveform shown in Figure 8 at the input to V13 while the corresponding keying pulse is shown in Figure 9. The peak to peak amplitudes are the same respectively as in Figures 6 and 7. It is apparent from Figures 7 and 9 that the "slice" referred to earlier may be selected from any portion of the signal between black and white levels. Figure 7 is set at white while Figure 9 is the seventh step above black or in the gray region.

Nonlinear Amplification of Camera Signal

Inspection of Figures 6 and 8 reveals that the amplification of the camera signal by V9 and V10 is substantially linear due to the negative feedback used. To improve what might be termed the "switching resolution", it is necessary to reduce the thickness of the "slice" producing the switching pulse. Manifestly, reducing the slice to DE/DI where E is signal voltage for brightness it might not result in a perfect picture at the output but, with such a pulse, if the switching was not perfect, it would definitely be due to the signal from the camera and not due to the processing in the effects amplifier.

To provide additional gain for the whole signal requires considerable design effort. Further, 80 volts to drive the regenerative clipper is far more than is necessary and such high energy, steep wavefronts contain high frequency components which may contaminate the video signals being switched.

The alternative approach has been to introduce non-linear amplification so that only the brightness region of interest is subjected to full amplification. Figure 10 is a circuit diagram of the nonlinear amplifier. This circuit is introduced ahead of the input to V9. The signal is amplified in half of a 6BQ7A from 1V peak to peak to 2.6V. This is fed to the clamped grid of a 404A. The cathode resistor of the 404A is 2700 ohms providing high degeneration and resulting in a signal of 2.6V at the input to 6BQ7A-V9.

The second half of the 6BQ7A is connected as a cathode follower with the cathode resistor of 3900 ohms bypassed with 100 uf condenser and connected by means of two 1N100 diodes to the 404A cathode. The voltage on the grid of the follower and hence that at its cathode is adjusted by a potentiometer.

The amplified signal appearing at the 404A grid is inverted and appears with sync or blanking up and white down. If the follower grid is at ground potential small plate current flows and the follower's cathode potential is below that of the cathode of the 404A, the diodes are thus cut off and the 404A has low gain.

In the voltage on the cathode of the follower is increased by increasing its grid voltage to where the crystals just begin to conduct for the most negative excursions (white) of the signal appearing at the 404A cathode, the 100 uf bypass condenser now shunts the 404A cathode resistor and the gain of the 404A increases several times. Actually gain increases of 8 db may be easily attained. Obviously, this increased gain may be applied to any brightness level of the signal by proper adjustment of the follower grid voltage. Figure 11 shows the effect of such nonlinear amplification in the white region when applied to the signal in Figure 6.

The improvement realized by such a circuit may be appreciated from the fact that the required change in the "Clip Level" potentiometer is of the order of five to six volts in moving the clipping level between two adjacent steps when linear amplification is used. On the other hand, the same change in clipping level when nonlinear amplification is used requires two to three volts. Based on such data, it is possible to say that at least a 6 decibels improvement is possible or that the thickness of the slice has been reduced by a factor of 2.

The situation may be further appraised in the following manner. The input step signal having a value of one volt peak to peak contains 0.7 volt of video. Each step represents a 10% or 0.07 volt change of brightness. With linear amplification, the clip level must be changed approximately 6 volts for a change of one step. Therefore, the ratio of brightness change to clip level is 0.0117 volts to one or 1.67% per volt. With nonlinear amplification, the corresponding values are about half.

Camera Control Tallys

The unit is remotely controlled by means of a cable connecting to J15. The tallys are operated by relays #1 and #2 which are actuated by 6BQ7A V14 and V15. This circuitry follows conventional practice and it is felt that no further explanation is required.

Clamp Pulse Generator

Horizontal drive introduced at J9 is amplified and shaped by half of 6BQ7A-V16. The clamp pulse which is developed from the front edge of horizontal drive, may have its delay varied by means of C58. The output of V16 is amplified in 6BQ7A-V17. The plate of the first half consists of a ringing circuit L4 and C59 damped by diode D13. The leading edge of the pulse is negative on the plate which back biases D13 and permits a pulse to appear at the output of V17. The next half cycle which is positive on the plate forward biases D13 causing it to conduct and thus damps out that pulse. The positive pulse at the input to 5687-V18 likewise rings the transformer T1 in a similar fashion, the diodes D14 and D15 damping all succeeding pulses after the first negative excursion.

Pulses of various amplitudes are obtained by the resistive divider R118 through R122

Voltage Regulator

Several circuits require very well regulated voltage sources. The video clamp pulse generator and the switch circuit require very stable potentials to assure maintenance of black balance in the switched video output. Regulated +285V power is fed to the unit and additional regulation is provided by 12AX7-V20, 6BX7-V19, and OB2-V22. The circuit uses V20 as a high gain amplifier. The stage is so connected that variations in the +285V source appear on one grid while load variations appear on the other grid. The resultant of the two effects are amplified and d-c coupled to the grids of V19 which acts as the "D" tube. A negative reference potential is required (in this case minus 105V) and is supplied from the circuit using D16 and OB2-V21.

Conclusions

Several of these units have been built, installed, and are in operation in various studios. They have been found to operate very satisfactorily in either monochrome or color installations and plants using both composite and non-composite video switching.

The major portion of the project was completed by Mr John Schroeder who has since left NBC. Acknowledgement must be made for encouragement and suggestions made by Mr A L Hammerschmidt, NBC Vice-President of Engineering and Facilities Administration and Mr George M Nixon, Director of the NBC Engineering Development Group during the course of the investigation.

References

1 - A.M. Spooner & T. Worswick, "Special Effects for Television Studio Productions". Proc. IEE, Vol 100, Pt 1, pp 288-299, April 1953.

2 - S. Doba, Jr and J.W. Rieke, "Clampers in Video Transmission", Trans AIEE, Vol 69, Pt 1, pp 477-487, 1950.

3 - V.J. Cooper, "Shunt Regulated Amplifiers", Wireless Engineer, May 1951, pp 132-145.

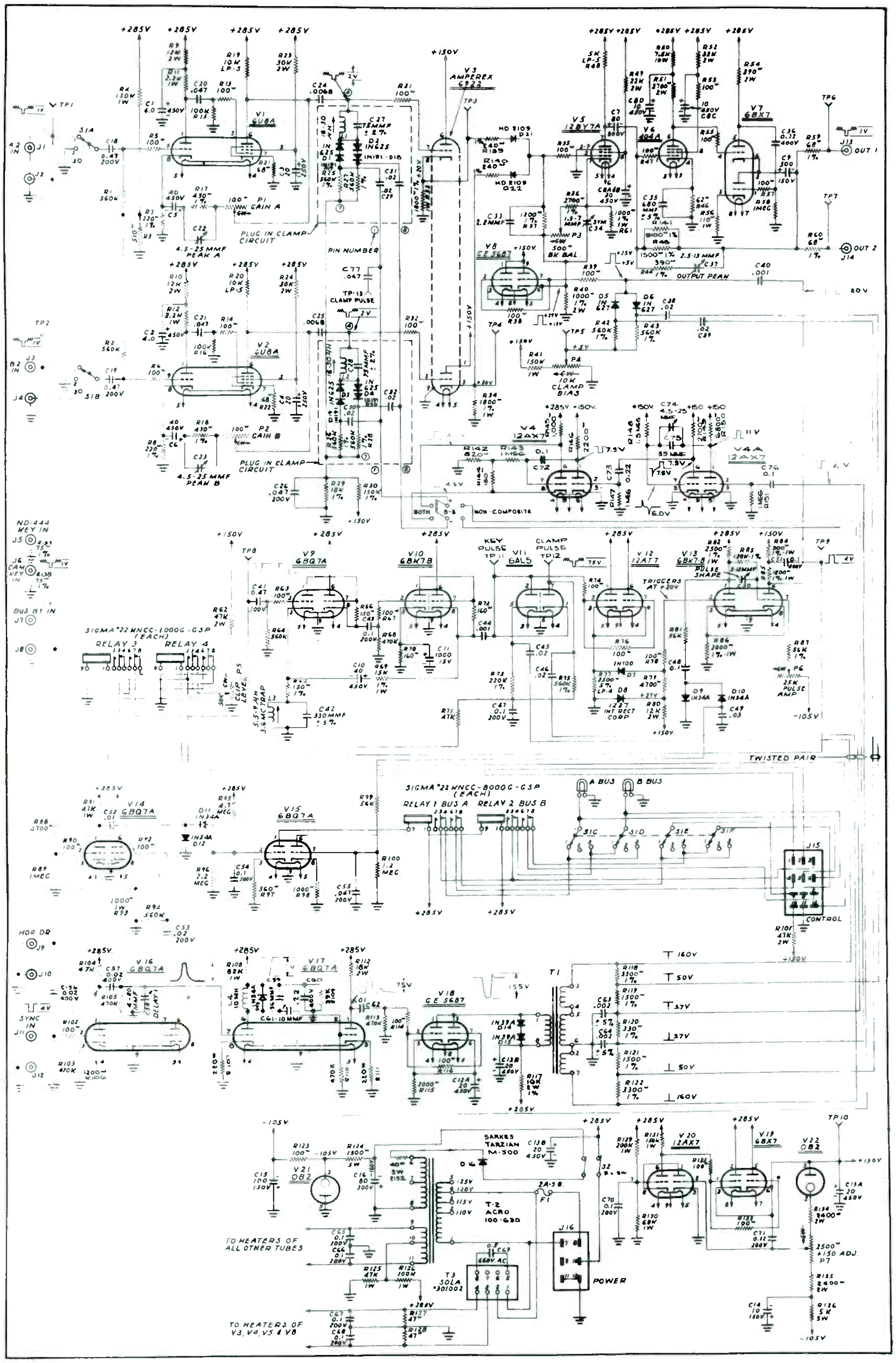
PLUG IN CLAMP CIRCUIT
PIN NUMBER
OUTPUT PEAK
TWISTED PAIR
A BUS
B BUS
CONTROL
POWER
TO HEATERS OF ALL OTHER TUBES
TO HEATERS OF V3, V4, V5 & V8

Fig. 1.

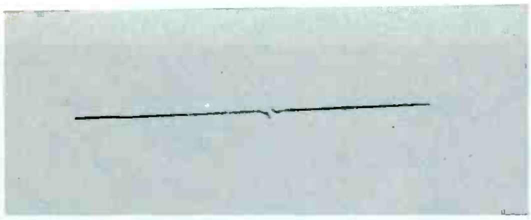

Fig. 2. Doublet impulse switching transient at output of amplifier.

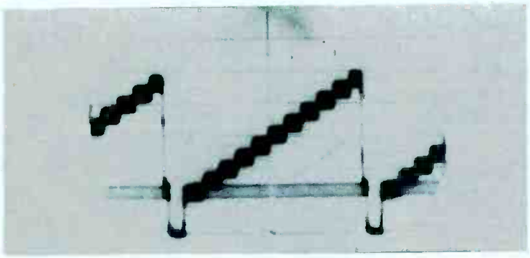

Fig. 3. Input signal at J5, 1 volt P-P.

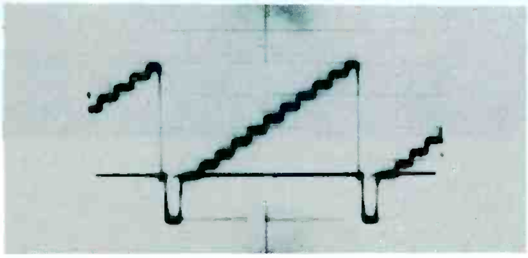

Fig. 4. Input to V12, 80 volts P-P.

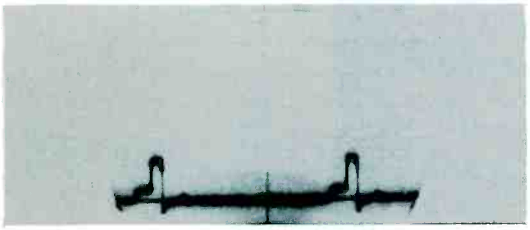

Fig. 5. Input to V13, 3 volts P-P, clip level at ground.

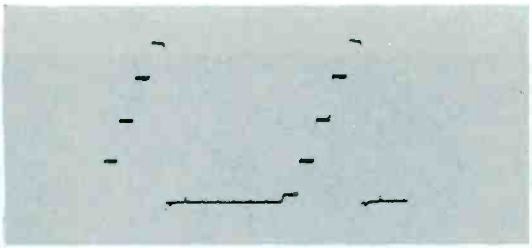

Fig. 6. Input to V13, 17 volts P-P, clip level at 17 volts.

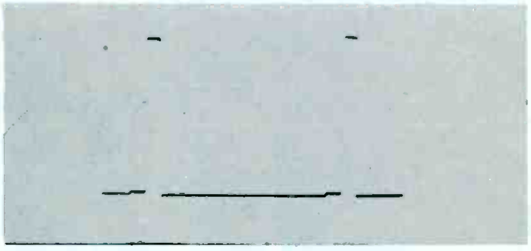

Fig. 7. Switching pulse at input to V8, 23 volts P-P.

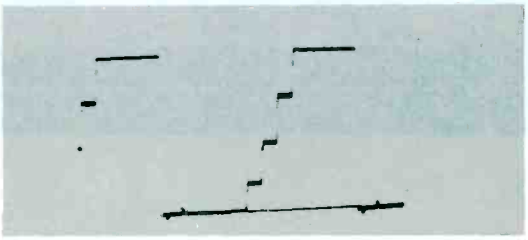

Fig. 8. Keying at seventh step above blanking, clip level at 30 volts.

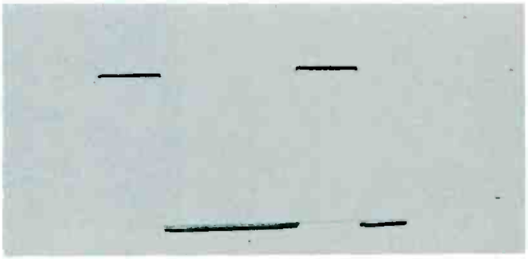

Fig. 9. Keying on seventh step, input to V8.

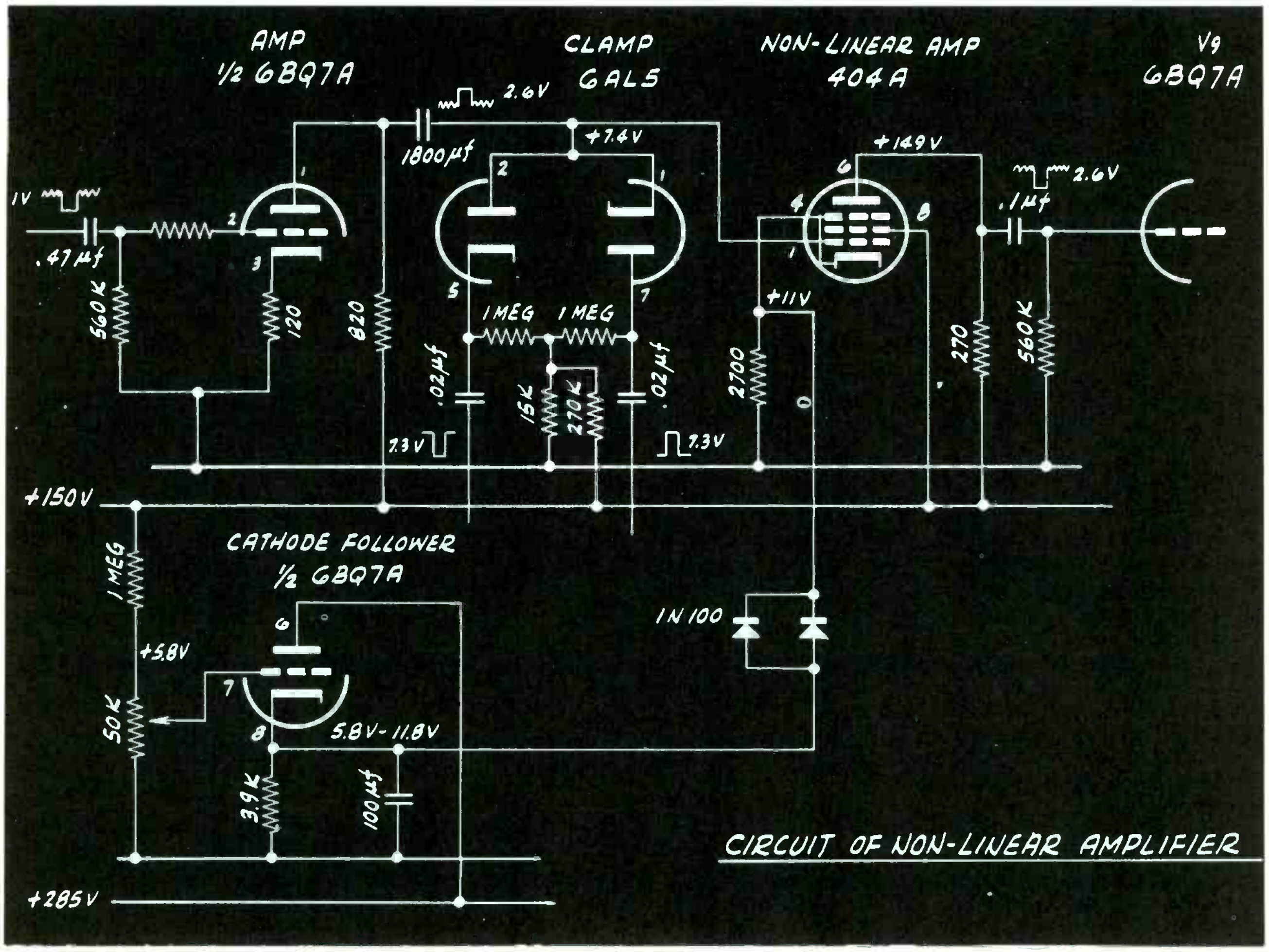

Fig. 10.

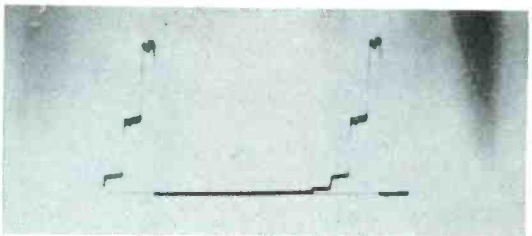

Fig. 11. Nonlinear amplification of signal of Fig. 5.

REMOTE CONTROL OF TV MICROWAVE EQUIPMENT

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Summary. Recent actions by the FCC have made it possible for privately owned and operated microwave links to be constructed by television stations. The need for remote control of the systems has brought about the development of some novel techniques for input switching, system reversal, and the transmission of control information. Hardware designed for these functions will be described.

The utility of a microwave relay system can often be greatly increased by the addition of such features as remote switching of system input, remote actuation of transmitter shutdown, fault location and reporting. If the system is one way, the addition of remotely controllable reversing can add an entirely new dimension to its use.

The incorporation of these features into an equipment intended primarily for relaying TV signals poses certain unique problems. Such a system is generally one way and has no microwave standby. Its entire base (video) band is occupied by the TV signal except for a limited space above the TV spectrum. Here one or more subcarriers may be added without degrading the TV signal, and these provide the only potential control channel(s) without adding parallel wire lines or radio equipment.

The RCA TVM-1A microwave relay equipment operates in the 5925-7425 mc band. The transmitter utilizes a directly frequency-modulated klystron with one watt of r-f power output. The receiver is a superheterodyne, employing a klystron local oscillator, crystal mixer and an i-f centered at 130 mc with a nominal bandwidth of 25 mc. A repeater in a multi-hop system simply consists of a receiver and transmitter back to back. TV sound is included in the transmission by a subcarrier at 6.8 mc, well above the video spectrum to avoid introduction of delay distortion by the combining filters. The equipment may be mounted in portable carrying cases or in standard 19 inch racks. Accessory units which make possible the remote control functions to be described are designed for integration in the rack mounted system only, inasmuch as such facilities are not usually needed in portable systems.

This paper will describe the methods worked out at RCA to provide simple and economical solutions to remote control, fault location and switching operations in the TVM-1A microwave relay equipment.

System Shutdown

The basic multi-hop TV relay system is a one-way system, and has no parallel telephone line or radio link. It must be shut down when not in use as required by FCC regulations. This is accomplished in the TVM-1 equipment by the simple expedient of monitoring each receiver's agc voltage in a multi-hop system. When the first transmitter of a system is shut down, the following receiver agc voltage drops to a very small value and this actuates a trigger circuit which in turn shuts off radiation from the following transmitter. An entire multi-hop system can thus be shut down by an operator, by the agc of the TV receiver from which it gets its video, by the agc of a broadcast radio receiver, or by remote means to be described later in this paper. If one of the agc schemes is used, then the system shutdown is, of course, tied to the "sign off" of the television or broadcast station being monitored.

An auxiliary unit of the TVM-1 equipment actuates this shutdown function. It is the afc/radiation switch. A secondary function of this unit is to disable the afc of the microwave receiver to which it is attached in order to prevent the local oscillator from being taken off frequency by the open loop output of the afc amplifier; hence, the name afc/radiation switch.

A delay of about 10 seconds is provided in the shutdown to prevent short fades from causing system shutdown. Complete system shutdown is, therefore, delayed by the sum of the amounts of delay at each repeater station.

Remote Selection of Video Input

Figure 1 indicates a remote selection scheme which has been installed at WLEX and at WMTW. In both of these cases an external telephone line has been provided, and it also carries fault alarm tones and voice communications.

In Figure 1 the video and audio signals to be selected are fed to the remote audio/video selector. This unit is simply a solenoid-operated step switch, which moves in sequence from video #1 to video #2 to test signal and back to video #1. This sequence can be wired to repeat in any desired order, there being 12 positions total. Generally, one position with no modulation, followed by a transmitter shutdown position is provided so that system shutdown can be initiated.

The remote audio/video selector is operated by a tone receiver which responds to a frequency shift tone. This unit also contains a carrier detector which disables the switching circuit when tone is not present. This removes any requirement for having tone present at all times, though there is an added protection afforded against erroneous switching, such as that caused by crosstalk tones or prolonged high level noise bursts if the tone is left on.

The sequence of operation is the following. If tone is left on at all times it is "space" tone. Whenever the tone is shifted to "mark" frequency, the selector advances one step. The shifting to "mark" frequency is actuated by a pushbutton, and the tone reverts to "space" when the button is released. If tone is removed, the carrier contact in the receiver opens and the system is rendered inoperative until tone has been re-applied for a few seconds. This momentary delay affords protection against the switching circuitry being restored to active status by noise or short transients.

Reversible System

Reversing of a microwave system can be done on a wire line or radio link, or on the microwave system itself. The former is diagrammed in Figure 2 and the latter in Figure 3. The system of Figure 2 is now in service between WBTV and WBTW, and another is currently under construction between Rio de Janiero and Belo Horizonte in Brazil.

The wire line system of Figure 2 operates in the following manner. Tone receivers are provided at each station to be switched, except at the attended terminal where actuation can be direct. If the tone generator at the terminal puts "space" tone out on the line the system is oriented in the A direction. If the generator is switched to "mark" tone, the receivers respond by switching the system to the B direction. The tone is left on the line in each case to provide increased protection against accidental switching by noise bursts or interfering tones. In the event of failure of the tone, however, a carrier detector in each tone receiver operates to prevent further switching.

System shutdown is achieved by simply orienting the system away from the attended terminal and turning off radiation of the first transmitter.

The units marked "antenna reversing control" serve as junction points between the tone receivers and the waveguide switches, and they display the "answer-back" information which indicates the direction of orientation of the waveguide switches. This information can be relayed back to the attended terminal by the fault reporting system if one is provided. The report is turned off after a 5 minute delay by a relay in the antenna reversing control unit.

The system of Figure 3 shows how the reversing can be accomplished on the microwave system itself without the need for an external telephone line. A subcarrier at 6.2 mc is used, on which the switching tone is frequency modulated. The tone is allowed to stay on at all times as an added safeguard against accidental switching due to noise or spurious tones. The use of the 6.2 mc subcarrier does not preclude the simultaneous use of the normal sound subcarrier at 6.8 mc.

In this system switching must always be actuated from both ends of the system. In the event that one end must remain unattended, then a single telephone line or radio link to that terminal (rather than one going to every repeater) can be provided. Both ends must be actuated because, while the tone sent from the then-transmitting end of the system actually initiates switching, the system will not remain switched unless the new transmitting end acts to hold it so. The switching method is the same as for Figure 2 in that "space" tone in the tone receivers at each station causes the waveguide switches to orient in the "A" direction while switching to "mark" moves them to the opposite or B direction. Failure of the tone, again, operates a disabling relay via the carrier detector and thus prevents further switching.

Failure of the subcarrier is also interpreted by the carrier detector as failure of the switching tone. However, failure of a microwave transmitter causes a large noise output from the following microwave receiver and this noise signal ultimately holds the carrier detector closed as would carrier. The system may then become randomly oriented. To allow for recovery from such a situation, the system shutdown is arranged so that upon shutdown it always orients itself to be transmitting away from the major terminal.

System shutdown in Figure 3 is effected by orienting the system away from the attended terminal and then turning off radiation from the first transmitter. The succeeding transmitters then have their radiation turned off in sequence by the afc/radiation switch units as each succeeding receiver agc voltage goes to zero. In this system an added delay (1 minute is suggested) must be inserted in the transmitter shutdown because of the fact that during the reversing operation a receiver might lose agc due to a sluggish waveguide switch and this, if shutdown were not positively delayed, would interrupt the switching tone and result in an outage. System shutdown, therefore, takes a bit longer in this type of system, but there is no delay in turning radiation on. The delay is provided by the contact repeater unit.

Fault Location Reporting

Fault reporting is divided into two basic groupings in the TVM-1 system. The first is called fault location reporting, and is shown in two forms by Figures 4 and 5. The plan of Figure 4 is presently in service in several field installations.

In Figure 4, video is sensed at each unattended station by the video presence detector unit, and agc is sensed at each unattended receiver. The failure of either immediately substitutes a single frequency identifying tone for the video at the transmitter input at that location. This identifies the link which is in trouble to the tone receiver at the final terminal. As the diagram indicates, a monitor may be used as the "tone receiver".

No attempt is made in this system to detect transmitter troubles. Such detection is futile since the transmitter is called on to forward the fault information. Also, it must be noted that if modulation is removed from the first transmitter, all the links immediately report trouble. However, when modulation is restored the reports all cease immediately. This is a reporting system of the least possible complexity, merely intended to locate the link which is in trouble.

In this system the afc/radiation switch is used to detect loss of r-f signal (agc failure). This same unit also functions to provide system shutdown so increased delay must be inserted in the shutdown contact to allow time for the fault report. This added delay is provided by the contact repeater unit, and is normally set at five minutes.

A more sophisticated fault location reporting scheme is outlined in Figure 5. In this plan a single identifying tone is also provided at each station, and it is actuated by failure of video or loss of r-f signal. However, in this case the tone is fed to an f-m subcarrier channel at 6.2 mc and sent along with the video. Thus the video detector can be set to alarm on low level rather than failure, and the low-signal alarm can do likewise. Thus trouble on a link can be anticipated. Another advantage of this "simultaneous" reporting is that alarms such as tower light failure, illegal entry, etc., can be sent without disrupting transmission of the program. Separate tones can, of course, be used for each fault. Transmitter failures cannot be reported, but reduced power from the transmitter can be. Thus while the scheme can only report the link which has failed, it can report the unit which is failing.

Transmitter shutdown is accomplished as in Figure 4, but here, also, it must be delayed to allow time for a report in the event of r-f failure, and the delay is afforded by the contact repeater.

Alarms are identified at the final terminal by a CRO or by tone receivers. The latter are recommended in this case since the increased capacity of the reporting system increases the probability of multiple reporting.

Fault Reporting

Fault reporting, as distinct from "fault location reporting" just described attempts to convey information on the location and the identity of the trouble to the attended terminal. Such a system is diagrammed on Figure 6, and is in service in whole or in part at WBTV, WLEX, WMTW, and other stations.

In this system, such faults as low transmitter power, low received signal level, low video level in and out of a transmitter, tower light failure, and about any other item a user may desire to sense up to a capacity of 10 faults from any one station may be fed to the reporting system. The feed to the reporting system is through the delay timer, which also serves as a junction panel or fault collection point, and then to the Indicon coder. The coder in turn keys a tone generator and fault information is forwarded by wire line or radio link to a tone receiver at the attended terminal. The receiver's output is decoded by the Indicon decoder and displayed in lights on that unit.

The Indicon units are a long established product of RCA's Communications Products line and are well suited for use with the TVM system. As many as 10 closures may be fed to the coder at a station, each representing a fault. When a closure occurs, the coder starts a cycle and sends first a series of five pulses which are either long (360 ms) or short (90 ms). By their arrangement the station is identified, and up to 31 combinations can be achieved. These five pulses are then followed by 10 more, which also are either long or short, and if long, indicate a particular closure (fault) at that station. The length and spacing of these pulses are such that one can listen to the coded tone with headphones or a loudspeaker and readily decipher the report. The long-short arrangements of the five station identifying tones allow identification of as many as 31 stations, a number which is far in excess of the number envisioned for private TV relays in the near future.

The delay timer (it is called a junction panel at the unattended terminal) shown in Figure 6 is for the purpose of preventing simultaneous fault transmissions. It does this by delaying the Indicon coder operation at each station until the preceding stations have had time to report. The coder requires 20 seconds to send its report, so the timers are generally set to allow succeeding stations to report in 30 second intervals. Thus, for example, a modulation failure at transmitter #1 would result in reports of no receiver video and no transmitter monitor video from stations all along the line, each reporting in 30 seconds after its predecessor. After 10 minutes, if the fault still exists, each station will report in again. This time no delay is required since the 10 minute interval at each station is reckoned from the start of its previous transmission.

The timer does not protect against coincidental faults which might cause simultaneous transmission from two stations, but where the number of stations is low, the probability of coincidental faults is not great. If there are 10 or more hops in a system, then a more elaborate "lock-out" feature of the Indicons may be used to prevent simultaneous reporting in lieu of the delay timer method.

Automatic Standby

Automatic switchover to standby can be incorporated into any TVM-1 system. In the transmitter, the switcher unit senses the video output of each transmitter "off-air" monitor unit. This output will fail with either r-f or modulation failure, and the switcher then operates to place the non-failed transmitter on the air. Switching is actually initiated when a 6 db differential in levels is reached.

The receiver standby switcher operates similarly. It senses receiver video output and receiver agc voltage, and the failure (6 db differential in video or drop below desirable signal-to-noise ratio as indicated by agc) of either acts to select the output of the non-failed receiver for program use. The sensing of agc makes possible the use of the switcher for operating the two receivers in space or frequency diversity.

Combined Systems

The systems for achieving shutdown, selection of input, reversing, and fault reporting can be combined in nearly any manner desired, and standby can, of course, be added to any. Just a few comments will be made here on some of the features of combined systems.

Combining remote control functions and fault reporting is easiest in those cases where wire lines are used. It simply requires the combining of Figures 1, 2, and 6, in whole or in part, and the use of differing audio tones, with filters, for the various functions. Voice communication is also easily added by confining the tones to frequencies above 2 kc. The reversing with fault location is in operation at WBTV, and the input selection with fault reporting exists at WLEX and WMTW. Standby with fault location is in single hop use at numerous stations, the reporting channel sometimes being a wire line, sometimes a subcarrier.

The plan of Figure 5, which shows only fault location reporting via subcarrier without standby, is expandable to full fault reporting using the Indicon system when automatic transmitter standby is provided. This is true because with standby, a transmitter failure no longer interrupts the reporting medium. Addition of receiver standby then provides for reporting in the event of failures at more than one station in a multi-hop system.

If the plans of Figure 3 and Figure 5, reversing and fault location reporting via subcarrier, are combined, fault report receiving equipment must be installed at both ends of the system because faults will be reported to whichever end of the system is in the receiving condition. Separate frequency tones are, of course, used for switching and reporting. A switch answer-back can be sent from each antenna reversing control to the receiving terminal via the fault reporting system as in wire line reversing system. The object of such a report in this case is to identify the most remote station which has obeyed a switch command in the event of a switching failure. The antenna reversing control turns off this report after a nominal five-minute interval, thus clearing the fault channel.

The control functions described in this paper cover rather completely the applications which have thus far become apparent as useful adjuncts to the TVM-1A microwave relay system. The methods and equipment have been made as straightforward and reliable as possible, and they are flexible enough to permit integration into a system in whole or in part without undue increase in cost.

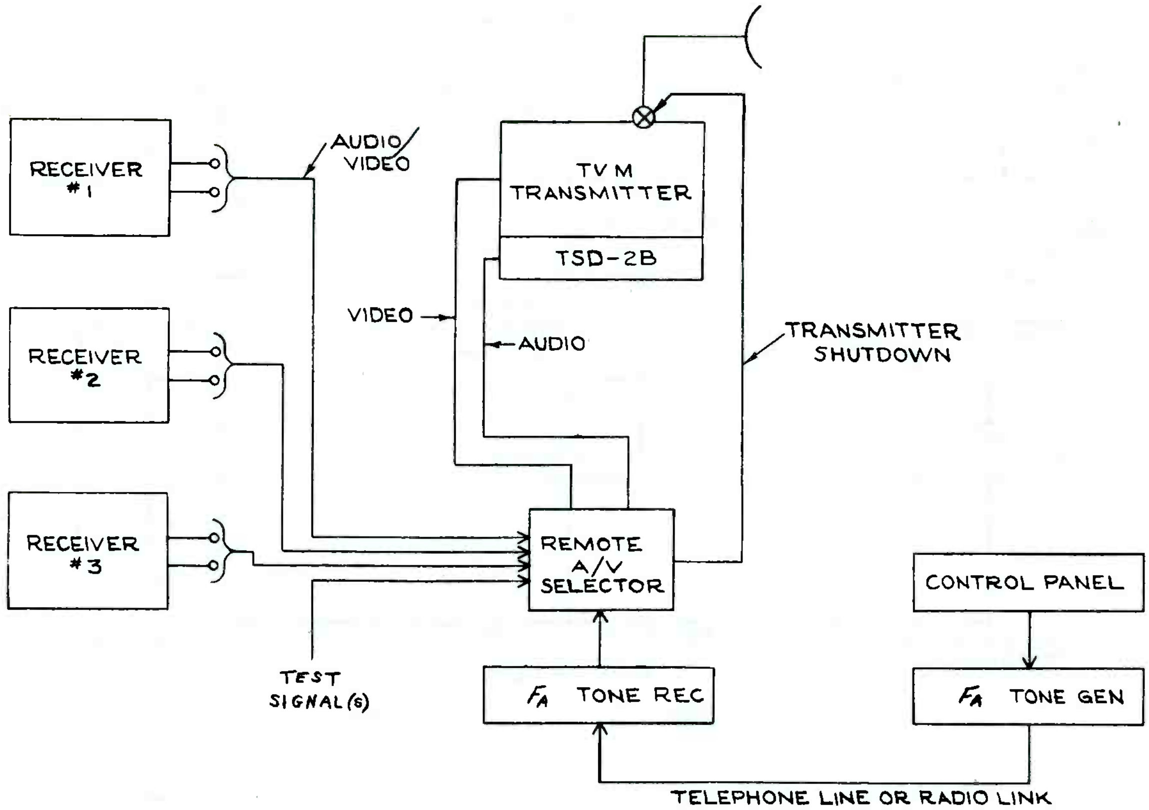

Fig. 1. Use of remote audio video selector.

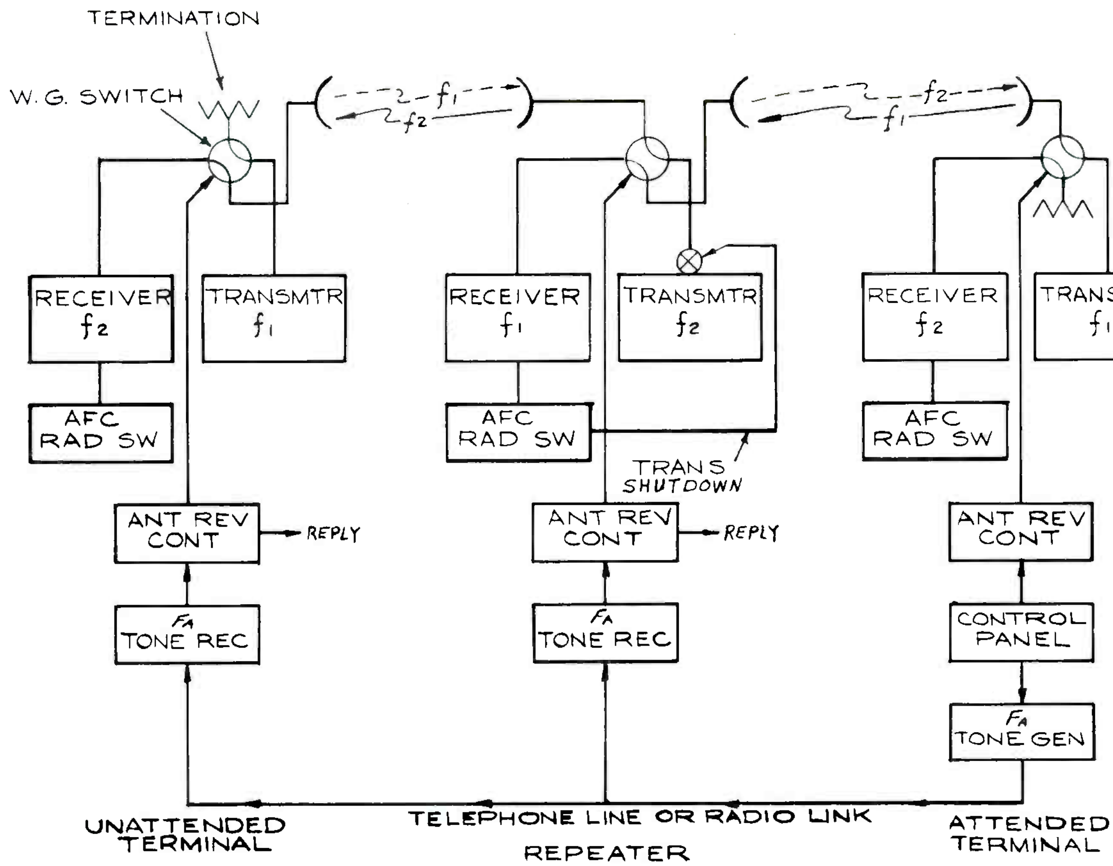

Fig. 2. Reversible system via wire line or radio link.

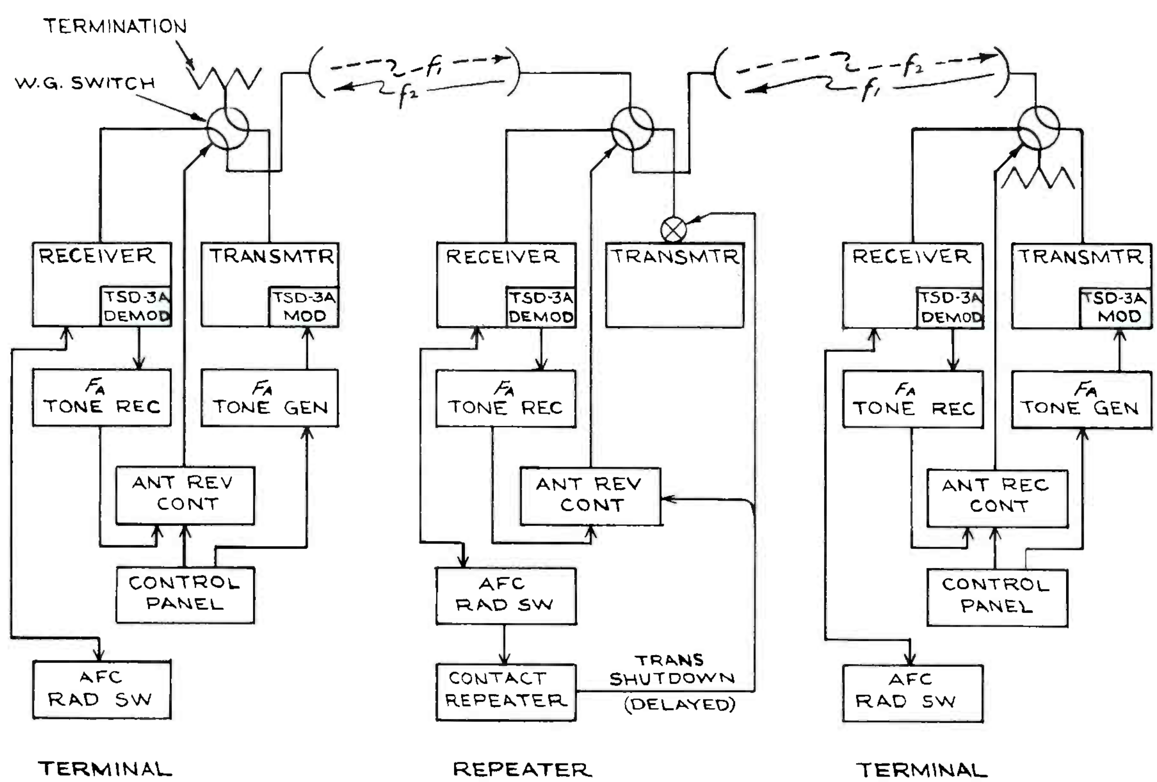

Fig. 3. Reversible system via subcarrier microwave.

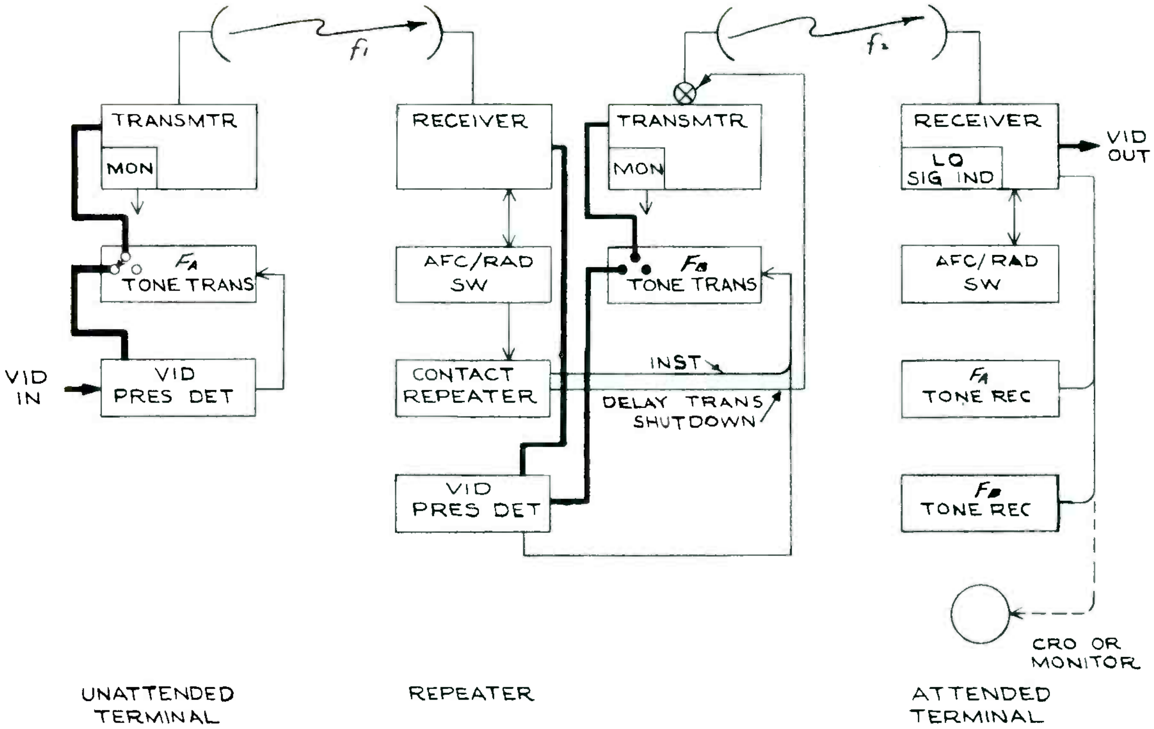

Fig. 4. Simplified fault location reporting via microwave video.

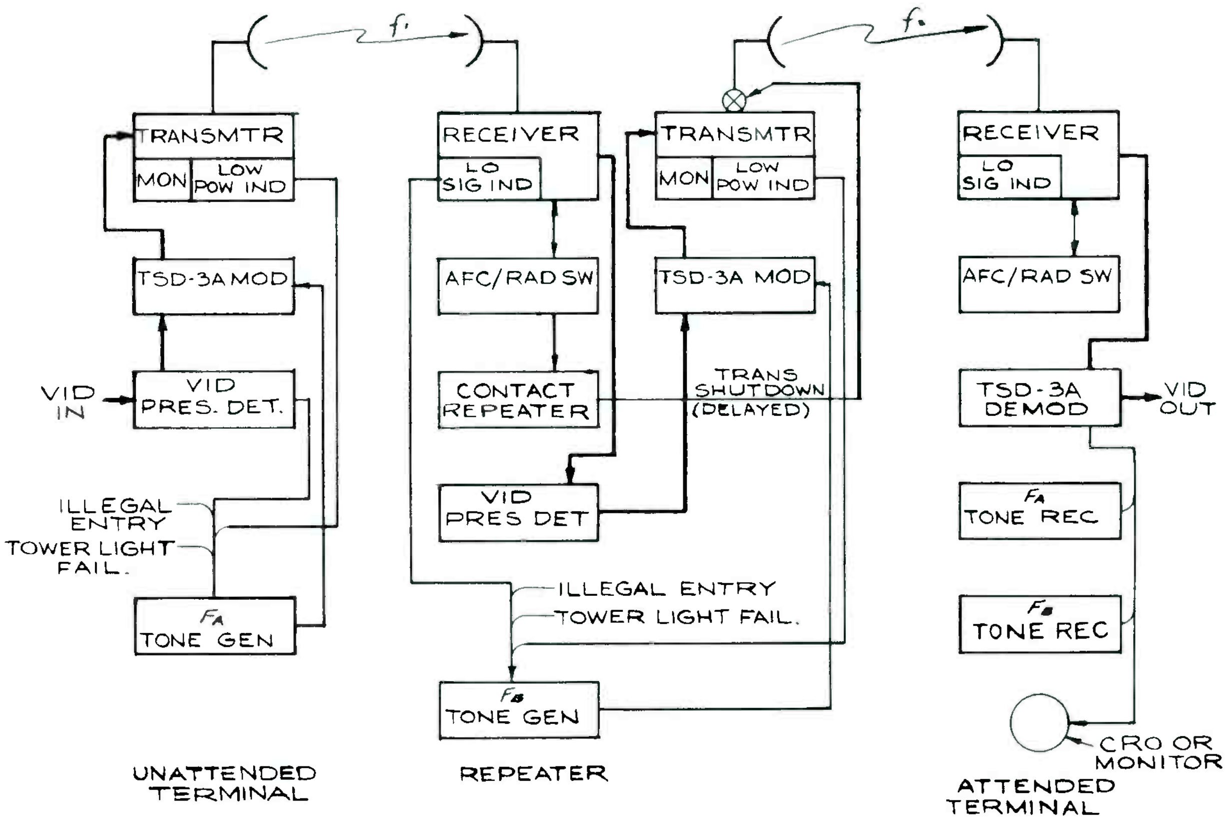

Fig. 5. Fault location reporting via subcarrier on microwave video.

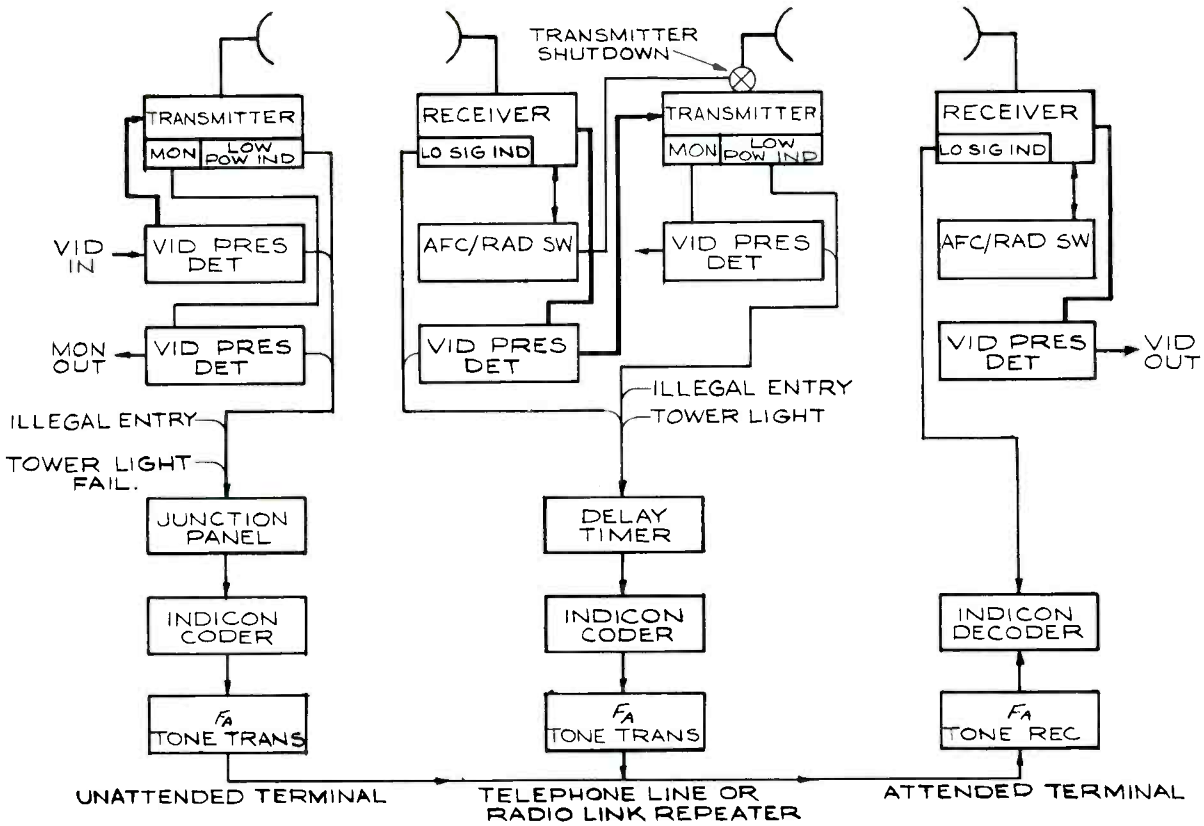

Fig. 6. Fault reporting system via wire line or radio link.