# *Section* 4

## PROGRAM-TRANSMISSION FACILITIES

# *Part* 1

# NETWORK FACILITIES FOR RADIO AND TELEVISION TRANSMISSION*

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## GENERAL CONSIDERATIONS

### Network Requirements

#### *Multiple-channel Requirements*

Whenever it is desired to broadcast the same program material, either audio or video, simultaneously from two or more broadcasting stations, or when it is desired to record a program at a point remote from its origin for retransmission at a later time, it is necessary to provide a transmission channel of suitable grade from the point of origin to the remote point or points. The combinations of transmission facilities which make up such channels are known as networks. They are further distinguished as radio or television networks, the latter consisting of a "package" which includes video channels and associated TV-audio channels.

If such channels were required only to connect a few fixed points to a single program source, the operation would be relatively simple. In the United States, however, there are several principals who operate networks to provide program material to associated stations. Programs on each of these networks may be originating at different poiuts, and at various times the points of origin on each network may change. In addition, in many population centers, there are several broadcastiug stations, each associated with a different network and operating competitively for the available audience. Thus, while the networks are independent of one another, they largely serve the same geographical locations and duplicate facilities are required on essentially the same routes.

* The material in this section has largely been abstracted from technical papers and operating information published by the American Telephone and Telegraph Company. The contributions of the anonymous authors of this material are hereby acknowledged.

### *Reliability and Protection*

Reliability of service and satisfactory transmission are essential requirements. Any transmission channel, however, is subject to complete interruption by the failure, in service, of any one of the thousands of individual components of which it is composed. Since there is no known way of completely avoiding such failures, the reasonable approach is to provide similar facilities which can be rapidly interchanged for the defective parts with a minimum of lost service time. This adds a further requirement for duplicating facilities.

### *Flexibility*

The variation in time across the United States is another factor which enters into network operations. A program which originates in the East at a time when the greatest audience attention would be expected would not, if broadcast simultaneously in the West, encounter the same favorable time period. Regional shifts to daylight saving time further complicate the time factor. It has, therefore, become standard practice to record a program at some strategic point from a regional network on which it is being carried "live" and then to retransmit it later on another regional or subnetwork. At any given time, therefore, a station associated with a network may be:

1. Broadcasting a local program
2. Broadcasting a network program simultaneously with all other stations on the network
3. Broadcasting and recording one program from a network while retransmitting to another network a program previously recorded
4. Broadcasting and feeding to the entire network a local program of national interest
5. Other possible combinations of these conditions

From the foregoing, it is fairly obvious that if each network principal were to establish his own network facilities with the requisite distribution, reliability, and flexibility, the economic burden would be considerable. If, however, the channels could be provided on a cooperative basis, avoiding duplicate construction and maintenance costs, and if backup facilities and equipment could be provided for groups of channels rather than for each individual channel, a considerable saving could be effected. If these costs could be further shared through the combination of network facilities with other communication channels which also serve the same geographical areas, further economy is apparent.

### *Common-carrier Operation*

It is primarily for these economic reasons that the provision and maintenance of audio and video network facilities, for the most part, have become the responsibility of communications common carriers. It is the function of such carriers to provide channels for the transmission of electrical communications of every type between any points where it is economically justified to provide them.

## The Bell Telephone System

### *Functions of Major Corporate Units*

The Bell System includes the American Telephone and Telegraph Company, the parent organization; the Bell Telephone Laboratories, the research and development organization; the Western Electric Company, the manufacturing and supply organization; and 21 associated operating companies, such as the Northwestern Bell Telephone Company, the New York Telephone Company, the Bell Telephone Company of Pennsylvania and the others, and the Long Lines Department of the American Company. The areas served by the associated companies are shown in Fig. 1-1.

The American Telephone and Telegraph Company, with headquarters in New York, as the parent company, coordinates the various Bell Companies into a system having a common policy. With respect to network service particularly, this includes basic research and development work, planning and coordination of manufacturing and construction activities, assistance in financial matters, and expert assistance in all phases of operation and maintenance.

The development and research function is carried on by the Bell Telephone Laboratories, which is owned jointly by the American Company and the Western Electric Company. For the American Company, the Laboratories carries out the necessary fundamental research in all branches of communication; for the Western Electric

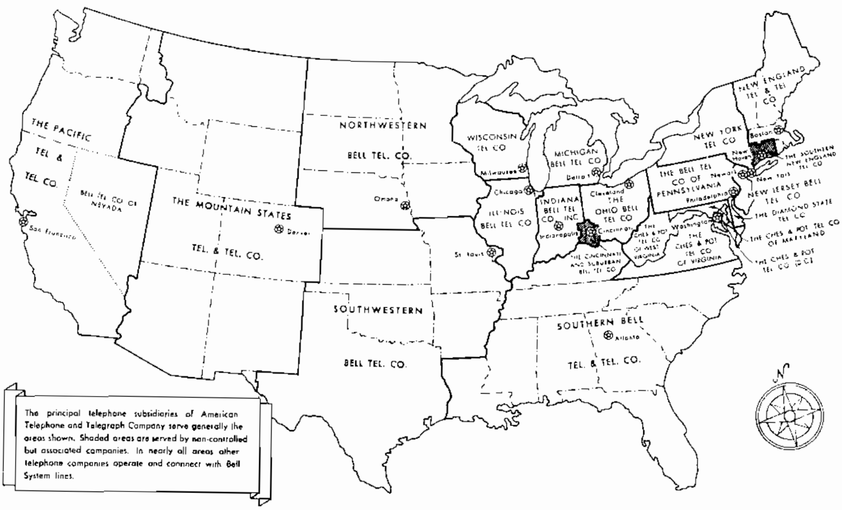



FIG. 1-1. Map of the areas served by Bell System operating companies.

Company it prepares manufacturing designs and specifications based on these researches. In the field of broadcasting, both the American Company and the Laboratories maintain active contacts with broadcasting principals and the engineering societies to keep abreast of progress and requirements in the art.

The Western Electric Company, which is owned almost wholly by the American Company, manufactures most of the equipment, cable, and wiring used in the construction of communications facilities; arranges for the acquisition of the remaining supplies; and installs all central office equipment. It also maintains stockpiles of material at strategic points for use in emergencies. Through this source, a supply of standard, uniformly high-quality equipment is available at reasonable cost to all the associated companies. This standardization also makes possible emergency assignments of maintenance personnel in any area, since the equipment and arrangements are uniform and standard regardless of location.

The associated companies engineer, install, maintain, and operate all the local communications facilities in their respective territories and also the short-haul (primarily intrastate) intercity services. In carrying out this function they have arrangements with the independent companies in their areas for extending services and providing intercommunications. In certain cases they may offer engineering assistance or other similar services.

### *The Long Lines Department*

The Long Lines Department is the operating department of the American Company. Broadly, its function is to provide, maintain, and operate the long-haul facilities which interconnect the facilities of the associated companies.

Within the Long Lines Department, the Commercial Department is responsible for conducting the business relations of the Company with the network principals, for establishing the regulations and rates under which service is furnished, and for filing this material with the proper governmental regulatory bodies. In the conduct of the business relations one of the functions of the Long Lines Commercial Department is to be continually aware of new customer requirements in both the immediate and more distant future. If the new requirements are for plant expansion of facilities similar to those already in use, routine channels are followed to provide them when required. If advances in the art are in prospect which require capabilities beyond those of existing facilities, the full cooperation and facilities of the Bell Laboratories, the American Company, and the Long Lines Engineering Department are enlisted. The Laboratories normally would provide the design of the new systems to meet the requirements, the American Company would coordinate the activities of all companies, the Long Lines engineer would plan and coordinate the installation and construction of the interexchange facilities, and the associated companies would do likewise for local connecting facilities. Using information provided by all the engineering and manufacturing groups, the Commercial Department would handle all matters pertaining to a coutract for a new type of service.

The Long Lines Engineering Department is, in general, responsible for the planning and construction of the over-all network facilities, basing layouts on standard components developed by the Bell Laboratories. It is responsible for determining the most propitious time for introducing new types of equipment or systems into the plant. The new facilities need not be for the purpose of handling a new service. It is a natural outcome of Bell Laboratories continuing fundamental research to develop systems and equipment which will perform the same functions as existing equipment more reliably, more efficiently, and more economically. These new systems are introduced into the plant under existing rate structures at the time and in the location decided by the engineer after consideration of all related factors.

### *Network Operation*

Operation of network facilities is the function of the Plant Departments of the associated companies and the Long Lines Department in their respective areas. Maintenance personnel carefully check all components of every system and test and line up over-all channels before they are put into service. Subsequently, they perform regularly scheduled routine tests on components and systems, set up and execute network changes, and handle reports of trouble. Reported troubles are verified, network reroutes are established, the source of trouble determined, and men dispatched to clear the trouble.

In connection with the development and maintenance of network services, mention of two special committees is of interest, the Video Transmission Engineering Advisory Committee (VITEAC) and the Network Transmission Committee (NTC). The VITEAC is composed of the engineering and operating heads of the major networks and the American Telephone and Telegraph Company, both Headquarters and Loug Lines Department, and the New York Telephone Company. It is the function of this committee to promote the common understanding of the various factors of an engineering and policy nature related to network service. Special emphasis is placed on avoiding consideration of day-to-day operating conditions.

The Network Transmission Committee is the working subcommittee of the VITEAC. This group is composed of broadcasting and telephone engineering personnel who are normally concerned with network operation. It is the function of this group to collect data for the VITEAC, to check the over-all performance of the networks by periodic surveys, to investigate those network operating difficulties which require engineering attention, and to devise standard testing procedures and transmission objectives.

## Routes of the Bell System

### *Message Service Routes*

It is the function of the Bell System and the independent telephone companies to provide channels for the transmission of electrical communications among any points in the United States and, by interconnection with the facilities of other agencies, from points in the United States to points anywhere in the world. Within this country, as pointed out previously, local communication channels are provided by associated companies and independent companies in their areas and long-haul interconnecting channels are provided by the Long Lines Department of the American Telephone and Telegraph Company. Since the major requirement for long-haul channels exists among major population centers or cities, it is natural that a series of "routes" has been developed, linking groups of these cities in tandem. The wire or radio facilities on these routes are equipped at all intermediate points with through or terminal types of equipment to provide groups of channels between any two cities on the route and, from them, to any connecting channels in their areas. At the terminals of the routes, interconnecting facilities are provided between routes to extend connections to any part of the country. Through the normal growth of the system, new routes have been developed and added, so it is now possible to interconnect many points by any of several routes. This provides protection against a major failure on any route.

It is fortunate that the broadcasting stations which desire network service also are close to or in the cities through which the major long-distance routes extend, although some television stations are notable exceptions. This makes it possible to provide for network-transmission channels along with channels for other communication services and thereby to derive the economies previously pointed out.

### *Network Facilities*

Since the inception of network service it has therefore been Bell System policy to include in all new construction facilities which are suitable for various grades of network transmission. The number and types of such facilities provided in any section are determined by long-range forecasts, based on the best available customer and company estimates, to be adequate for a considerable time. It, therefore, is possible that wire facilities would be constructed in advance of actual requirements to secure the construction economy but that central office equipment would not be added nntil some later time when service was actually ordered.

In the development of network service over the years, it has frequently been necessary to make temporary modifications of existing communications channels in order to adapt them to meet an early service date for network service. These short-term arrangements have then been superseded as soon as possible by standard arrangements developed and installed particularly to meet specified service requirements. This article will not refer to any of the temporary arrangements but will discuss only the standard facilities now provided for network service.

Figure 1-2 shows the major routes along which facilities have been provided for full-time television network service. Radio-network facilities are available on these routes and to many other points not included on the map. The facilities provide for all present full-time radio- and television-network requirements, iucluding adequate facilities for protection and for occasional services.

Facilities are also available for occasional and recurring services on short notice, and facilities can be provided, as for remote pickups, to points not on existing routes by special inquiry. In most cases these pickups require special temporary construction.

Channels are also available for audio-program service from all the principal cities in the world. Normally these are not considered as part of a network. Rather they are provided for short periods in the form of "mike leads" as for news commentators. The mike lead may be fed live to a network, or a recording may be made for later broadcast. Most of the overseas channels are derived from radio message circuits suitable for voice transmission only. The undersea cables to London and Hawaii recently added to Long Lines plant, however, are equipped to provide wideband (schedule A or B) audio-program channels. Arrangements for these channels are handled through normal Commercial Department contacts.

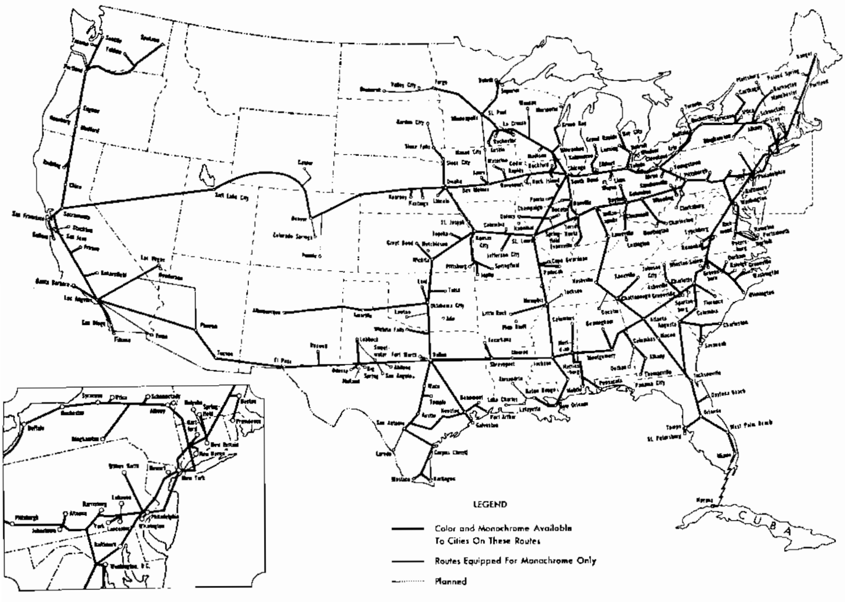



FIG. 1-2. Routes of the Bell System television network as of July, 1958.

## Network-facility Arrangements

### *Network Sections*

The facilities which are provided for network services are normally established in sections. For audio networks they are designated as PGCU's, or program circuit units, and for video networks they are designated as VUR's or VUC's, or video units, radio or cable. The various units are further identified by number and letter codes which indicate the type of facility, the direction of transmission, the terminal cities, aud, in some cases, additional information.

The units are combined to form network sections. Audio network sections which are operated as units by the broadcasters are designated by letter codes assigned mutually by the broadcaster and the telephone company. Combinations of units, which are not specifically assigned to a network, are designated SPC's, or special program circuits. Television units are combined to form TVS's, or television sections, which are identified by number and letter codes. Combinations of TVS's are used to provide complete networks which are designated by the same procedure as the audio networks.

Units and sections of the same type are identical with one another at their terminals and in their component parts so that such sections are interchangeable in whole or in any part. Units and sections on different types of facilities are identical with respect to levels and equalization at their terminals, through the use of appropriate terminating arrangements, so that different types of facilities can be either interconnected or substituted at these terminals. This provides a layout which is completely flexible in relatively large units. These units may be permanently connected into a fixed network, or switching arrangements may be included to permit rapid switching to convert the over-all network into several regional networks. Some combinations of facilities have remained in relatively fixed arrangement with respect to routing and connections for long periods and thereby have tended to become identified with a particular network principal. Despite such identification, networks are provided, not as physical entities, but as transmission or channel services at charges based on distance and period of use.

Since network facilities are provided in sections along major communications routes, the most economical method of reaching all points which desire network service is to establish a channel by the interconnection of sections which pass successively through each service point. This leads to some long and circuitous routings for some service points, but with the present transmission performance of network facilities, the transmission penalty is small in comparison with the operating economies derived.

### *Reversible Operation*

It has been pointed out that programs may be originated at different points on any network or that it may be desired to operate several regional networks over the same facilities that normally comprise a larger network. Two features are available which facilitate network operations in these situations, namely, reversible channels and round robins. Reversible operation is limited to audio channels, but round-robin operation is applicable to both audio and video channels.

Program channels assigned to cable or open-wire program units are normally reversed by the operation of remotely controlled relays which reverse the input and output connections of the amplifiers at each repeater point through suitable associated equipment. Program units assigned to carrier systems on cable or radio are not susceptible to this type of reversing. However, since carrier channels are normally assigned in pairs for opposite directions of transmission, as required for telephone service, switching is normally accomplished at the ends of a channel where remotely controlled switches are operated to select the desired direction of transmission. Reversible operation is normally furnished on a nominal 15-sec basis in order to allow time for the sequential operation of all the circuit features. The remote-control features may be operated by the telephone company on orders from the broadcasters which will specify either a time cue or an audible cue, or the control may be extended to a studio location on the network. Reversible channels normally will result in shorter mileages between pickup points and service points than will be obtained by round-robin operation. This results in an automatic improvement in those transmission parameters which are directly related to length.

### *Round-robin Operation*

Round-robin operation consists of connecting facilities in tandem through the points desiring service in a manner to form a closed loop back to the originating point. Transmission over such a network is always in the same direction, either clockwise or counterclockwise as required by the broadcaster. Stations may be bridged onto the main line by local channels, or the network may be routed "in and out" of the local studio. With the latter arrangement programs or inserts can be originated and fed to all stations on the round robin. It is important that the previous originating studio close through the in-and-out connections for continuity, but the closing must be delayed sufficiently after the cue to permit opening the loop at the succeeding originating studio. This will avoid setting up a closed loop which, in the case of audio networks, would produce an audible oscillation and, in the case of video networks, would produce bright flashes on video monitors or receiving sets. At any point on the round robin, side legs of varying lengths can be connected which, for audio, are usually reversible.

While round-robin operation has many operating advantages, it does result in long, circuitous routings for many points. An audio round robin, for example, might start at New York, go to Boston and then back via Albany to Buffalo, Cleveland, Chicago, St. Louis, Pittsburgh, Washington, and other intervening points to New York, for a total distance of about 3,000 miles. Thus, Philadelphia, about 90 airline miles from New York, is fed at the end of the 3,000-mile channel.

### *Network Layouts*

The basic, or backbone, layout of a particular network as regards routing and stations connected is normally a relatively long-term condition which is provided in accordance with orders for service by the network principal. Thus, as previously mentioned, some combinations of facilities have come to be identified as permanent networks. The regional shifts to and from daylight saving time are the principal factors which influence recurring major revisions. These layouts are established by the Plant Departments involved on the basis of permanent circuit orders which are prepared by the Engineering Departments. The broadcaster knows that this basic layout, equipped with the necessary switching equipment, is at his disposal during all service periods contracted for.

### *Operation Orders*

Directions and cues for the daily switching and temporary rearrangements of the network are transmitted to the Plant Department either in service orders or operation orders. These orders are received at the plant general control office two days in advance and are transmitted to every point on the network where a change is to be made one day in advance of the requirement. At all such points, on all networks, program and television operating centers (TOC) have been established. In some cities, as for example, New York, where large local networks are also maintained, the associated company provides locations where testing and facility rearrangements are concentrated. At all these locations specially trained personnel execute network operations, conduct and direct routine local and over-all channel tests, and take action to sectionalize and clear any troubles noted or reported.

### *Separation of Audio and Video Networks*

In the discussions thus far reference is made to network service in general and three classes of networks have been mentioned, audio, TV-audio, and video, indicating that the audio and video portions of television programs are carried on separate networks. In this country this is usually so.

As far as technical considerations are concerned, the two networks could be derived from the same basic facilities and travel together throughout. Since sound broadcasting preceded television by many years, however, substantial quantities of audio facilities had been built up about the country and could be added to in kind, readily, when the television sound requirements began to materialize. As a result, video and associated sound networks are completely independent, often not even traveling over the same route among the cities in which they serve broadcasting stations. This has no important disadvantage, since the sound channels used are from pools of such channels existing on all routes to the extent required to care for established needs for all types of broadcasting. On the contrary, this independence usually has the advantage of making the sound channels largely immune to failures affecting video channels.

The method of charging for broadcasting channels is based, in general, on airline distance between service points, so charges are not affected by the fact that the video and accompanying sound channels may travel different routes between television service points unless intermediate service points are provided for the broadcaster on the sound channel.

Although video and associated audio networks thus remain independent in operation, a "package" audio-video service was made available in 1954 at some saving in cost, based on a limited service period per day.

### *Differential Audio Delay*

Although the television sound and picture channels are physically independent, they function essentially as though they were derived from the same basic facility. The only special consideration involved is that the picture and sound signals travel nearly enough at the same speed so that sounds heard will appear to be properly in step with the action on the screen from which they seem to emanate. This does not require absolute synchronism. Human perception normally experiences considerable delay in sound accompanying action seen. For example, a sound coming from action observed only about 100 ft away will arrive at the ears of an observer nearly $\frac{1}{10}$ sec delayed without his being conscious of anything unusual. This is contributed to somewhat by the fact that the exact instant that the sound is produced is not so readily discerned at even a 100-ft distance as at a shorter distance, a conclusion supported by the fact that a comparable delay from action observed as a close-up on a television screen a few feet away will be less tolerable. The nature of the action plays an important part in this.

A sharply defined impulse type of sound where the action is such that the eye can easily detect the exact instant the sound is produced, such as that of a hammer striking a nail, is most susceptible to differential delay effects. Lip sounds coming from a clearly enunciating speaker observed in a close-up also are particularly revealing of differential delay, if present. In both of these instances observation is aided by unconscious ability of average human perception to recognize rhythm or rate of development of a motion and to anticipate the exact instant of its completion whether it actually occurs or not.

A series of tests conducted by the Long Lines Department with different types of program material and different amounts of sound delay over loops of regular network facilities showed that a differential delay of the sound up to about 0.06 sec (60 msec) was not detectable on any of a number of representative commercial programs observed by a group of average observers under conditions comparable to those in the average home. The tests also showed that in much of the action a differential delay of 100 msec or more would pass unnoticed. Beyond about 100 msec the effect became observable more frequently when looked for specifically.

Tests have also been made with "leading" sound (in advance of visible action), which showed considerably less tolerance for this condition. This is consistent with the fact that it is a condition not encountered in nature. It is also a condition not encountered in the networks with current routing practices, since most long sound channels include some relatively slow-speed program-loaded cable circuits and usually have a number of sets of carrier terminal equipment in tandem, all of which introduce more delay than encountered in the video channels. A typical transcontinental audio channel of this type about 3,500 miles long (New York to Los Angeles) before television affected the situation might have had about 150-msec total delay. A video channel on microwave over the same distance, on the other hand, would probably have only about 20-msec delay. The differential of 130 msec would be considerably more than desirable. Special measures are applied in the circuit layout engineering of channels to be used for television sound to minimize the transmission time of the sound. In particular, loaded cable is avoided on "backbone" routes over which service reaches large areas. Also, carrier program channels are so arranged or routed that they will make the longest practicable jumps between terminals where the carrier channels have to be brought down to voice frequency. By such measures differential delay on transcontinental hauls can be kept within acceptable limits.

While it would be possible technically to delay the video signal by the use of delay networks to accomplish the same purpose, it has not been necessary to attack the problem in this way.

### *Grades of Service—Audio*

Facilities for both program and TV-audio network services are offered in a number of grades and for different time intervals, including the following high-quality services:

Table 1-1. Grades of Audio Services

| *Designation* | *Approximate frequency range, cps* | *Notes* |
|---|---|---|
| Schedule AAA | 50–15,000 | Full time 8-hr day |
| Schedule AA | 50– 8,000 | Full time 8-hr day |
| Schedule A | 100– 5,000 | Full time 8-hr day |
| Schedule B | 100– 5,000 | Part time by hour or fraction |

NOTE: As of July 1, 1958, there were roughly 183,700 miles of Schedule A service in operation about the United States under Long Lines contract alone, not counting a substantial mileage under associated company contract. Of those 183,700 miles, about 82,000 miles were used for TV-audio.

In addition to the high-grade channel services listed, several lower grade services, Schedules C, D, and E are also available. Aside from bandwidth, there is an important difference between the lower and the higher grade channels. The high-quality channels are amplitude- and delay-equalized to provide satisfactory transmission over the longest distances between originating and delivery points that should be encountered normally within the continental limits of the United States, and with something to spare. The lower quality services, on the other hand, make use of channels designed and constructed primarily for telephone purposes, which are equipped with telephone-type repeaters (amplifiers), repeating coils (transformers) and other equipment. Some modifications in the adjustment of this equipment are made to secure small increases in effective bandwidth or improvement in signal-to-noise conditions. These changes are possible because the channel need transmit in one direction only, thereby eliminating balance requirements involved in normal two-way telephone service. While the improvements thus obtained are beneficial for program-transmission purposes, transmission impairments accumulate to objectionable magnitudes for program purposes at relatively short distances with the lower grade circuits. The controlling factor in this is usually delay distortion which increases with distances and with bandwidth. Delay distortion is much more objectionable in broadcast reception than in speech over a regular telephone instrument. For these reasons the Telephone Company usually places some limitation on the distance over which the lower quality services should be used, particularly where transmission of music is a requirement. Despite these limitations, however, there is an extensive demand for the lower quality services, particularly for baseball and similar sports reporting, because of the saving in cost afforded.

### *Service Preferences*

At the present time the preponderance of full-time sound network service is of the 5,000-cps type. The nearest approach to this is a 3,500-cps medium-quality service of which about 30,000 miles were in use in 1958. The 5,000-cps service appears to represent a balance point between cost and quality, including consideration of such things as limitations in response of the average radio receiver, indifference of a large segment of the listening public to wider band quality, and the fact that a 100- to 5,000-cycle band can provide pleasing results. The weighting of these various factors is, of course, established by the broadcasters who pay for the service.

The same preference for 5,000-cps audio service appears to be extending to television, as will be noted from Table 1-1. The possibility exists that the picture will tend to divert critical attention from the sound quality. Relative cost to the broadcaster can be expected to be the controlling consideration.

### *Grades of Service—Video*

For video-network service two grades of facilities are offered, one suitable for the transmission of monochrome signals and one suitable for the transmission of color signals. These services are available on a time and distance basis.

As is the case with audio facilities, the higher grade facility for color transmission requires closer attention to the control of frequency response and differential phase and gain in the region of the color carrier, which necessitates the provision of additional equipment and greater maintenance effort.

### *Special Services*

Special services, as for example, 15-kc audio service or 8- or 10-Mc video service can also be provided. The demand for such services at this time is not sufficient to justify the maintenance of permanent facilities of these grades. They are provided therefore only on special inquiry and with a time interval to permit engineering and, when necessary, special construction and installation or modification of central office equipment at the points involved.

Service of standard quality to points not located on existing routes normally is also provided only on special inquiry as previously mentioned.

## VIDEO-NETWORK FACILITIES

## Local Channels—The A2 System

### *General*

Local video serviee is that service which includes such channels as remote studio to master control, studio to transmitter and master control to and from the telephone company intercity network connecting office. This service normally does not involve a multiplicity of channels between any two points and the distances are usually quite short. For these reasons carrier-type facilities are not economically justified and, while some channels are established on single-channel radio links, the majority of them are established on wire facilities which transmit the video base band. The channels are usually required in urban areas in which other communications services are provided in exchange-type cables. The usual wire facilities in these cables, however, have very high losses at the higher video frequencies, and are unsatisfactory for a number of other reasons. Because of these factors the Bell Telephone Laboratories designed a wire facility particularly for short-haul video service and developed a complete transmission system based on the use of this cable. This system is known as the A2 System. A newer version of the basic A2 System designated the A2A System is also in use for local video service.

An over-all system includes, in addition to the wire facilities, transmitting and receiving terminals with associated amplifiers and equalizers and intermediate amplifiers and equalizers as required by the length of the channel. All of these units are provided in equipment blocks which may be combined as required to meet the over-all requirement. The maximum length channel in current use is about 13 miles long and the median length is about 1.5 miles.

### *Video-cable Facilities*

Three types of video cable pairs are now in use in the plant. These are illustrated in Fig. 1-3.

The 16 PSV-S pairs are polyethylene-string-insulated 16-gauge wires covered with two copper wrappings, spirally wound in opposite directions.

The 16 PSV-L pairs are similar to the 16 PSV-S pairs except that the inner copper tape is applied longitudinally instead of spirally. This construction results in improved crosstalk performance and a small reduction in attenuation.

The 16 PEV-L pairs are also 16 gauge but the conductors are individually insulated with expanded (foamed) polyethylene and the fillers are the same material. Longitudinal and spiral copper tapes are applied as for 16 PSV-L. This construction results in a cable whose impedance can be held to closer tolerances and one with reduced internal echoes due to manufacturing irregularities.

A number of video pairs may be enclosed in a sheath to provide a cable exclusively for video service or a number of these pairs may be enclosed in the same sheath with the paper-insulated pairs used for local service. Both arrangeemnts are in use and, by virtue of the inclusion of video pairs in many exchange area cables in the larger metropolitan areas, where the need is anticipated, a local network of channels is readily made available by adding the necessary amplifier equipment.

Because of the effective shielding in this type of video cable, there is no limitation on the direction of transmission or the number of pairs which may be operated in a single sheath, either with respect to interchannel interference or interference to or from the paper-insulated pairs in the cable. Freedom from such interference is important since impulse noise from relay contacts, switch-hook operation and other sources is high in local cables.

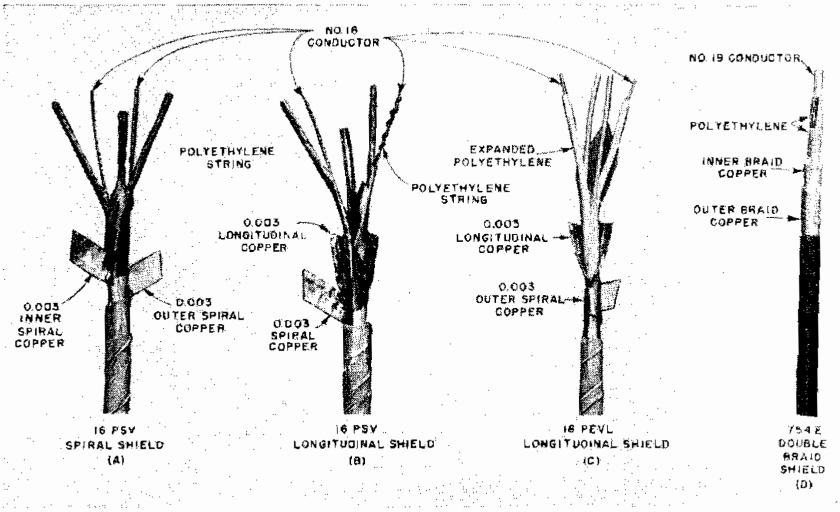



Fig. 1-3. Video-cable pairs and balanced office cable.

The transmission loss of the heavy-gauge copper pairs is not excessive at high video frequencies so that reasonable repeater spacings may be achieved. Normal repeater spacing may be as much as 3.5 miles but, with the use of network amplifiers, this may be extended to 4.5 miles. The actual transmission losses of video cable pairs are given in Table 1-2.

Variations in attenuation due to temperature changes in 16-gauge video cable are about $\frac{1}{10}$ of 1 per cent per degree Fahrenheit, expressed in decibels. For all practical purposes it may be assumed that this change is a change of slope equal to one-tenth of 1 per cent per degree Fahrenheit of the normal 4.5-Mc loss of the cable at 75°. Thus the primary effect of seasonal temperature variations is to change the effective length of the cable. This may be compensated by a change in the variable equalizers that are provided.

The characteristic impedance ($Z_0$) of 16 PSV and 16 PEV cable is almost a pure resistance of 124 ohms at the higher video frequencies. Below about 500 kc the resistance component increases to a value of about 1,000 ohms at 60 cycles and the reactive component, which is essentially zero at the higher frequencies, increases to about the same value as the resistance at 60 cycles. The characteristic impedance approaches infinity as the frequency approaches zero. Certain of the characteristics of 16 PSV and 16 PEV pairs are given in Table 1-2.

In the design of equipment components which are associated with the video cable plant in the A2A system, particular attention was paid to matching the characteristic impedance in the range below 500 kc. This results in a smooth over-all frequency-response characteristic and decreases the need for field-designed supplementary mop-up equalization for systems of nominal length.

### *Inside Cabling*

Several types of balanced and unbalanced office cable also have been designed for video circuits. The conductors are insulated with a solid polyethylene dielectric and shielded with a double copper braid. The outer covering can withstand pulling into cable ducts so that it may also be used in outside plant but here its use is limited

**Table 1-2. Attenuation of Video Line Facilities**

| Type | Shielding | Loss per 1,000 ft, db at 75°F | | Loss per mile, db at 75°F | |
|---|---|---|---|---|---|
| | | 0 * | 4.5 Mc | 0 * | 4.5 Mc |
| Shielded video pairs: | | | | | |
| 16 PSV-S | Spiral inner tape | 0 | 3.65 | 0 | 19.3 |
| 16 PSV-L | Longitudinal inner tape | 0 | 3.52 | 0 | 18.6 |
| 16 PEV-L | Longitudinal inner tape, expanded polyethylene | 0 | 3.52 | 0 | 18.6 |
| Office cabling: | | | | | |
| Paired: | | at 70°F | | | |
| 720 | Single braid | 0 | 10.0 | | |
| 754A | Single braid | 0 | 5.3 | | |
| 754B | Single braid | 0 | 5.3 | | |
| 754D | Double braid | 0 | 5.2 | | |
| 754E | Double braid | 0 | 5.2 | | |
| KT51 | Double braid | 0 | 6.6 | | |
| KT52 | Double braid | 0 | 5.3 | | |
| Coaxial: | | | | | |
| KS-8086 | Double braid | 0 | 11.0 | | |
| 724 | Double braid | 0 | 5.2 | | |

* It can be assumed that for the lengths of cable employed in A2A repeater sections the loss at essentially zero frequency is 0 db.

to temporary service, as for pickups or for emergencies. The transmission characteristics of these cables, also given in Table 1-2, are sufficiently similar to video cable pairs that the same equalizers may be used in conjunction with them.

### *Cable Terminations*

Interconnection between inside and outside wire facilities is made through special cable terminals which most frequently are located in the video equipment bays and are spliced directly to the lead-sheathed PSV or PEV facilities. If the video facilities which enter a building are in a completely video cable, the cable is extended directly to the terminals. If the video facilities are included in an exchange cable with paper pairs, they are separated at the building entrance and extended to the terminals in a separate lead-sheathed video cable. This avoids any exposnre to low-frequency noise or impulse noise due to relays, pulse circuits, or switch-hook operation which might occur if the cables were routed through the office distributing frames.

### *A2A Equalizaztion System*

The basic equalization plan provides a highly flexible video-transmission system through the use of blocks of equalization which can be combined in the number and type required to equalize a given repeater section. Amplifier units are then provided

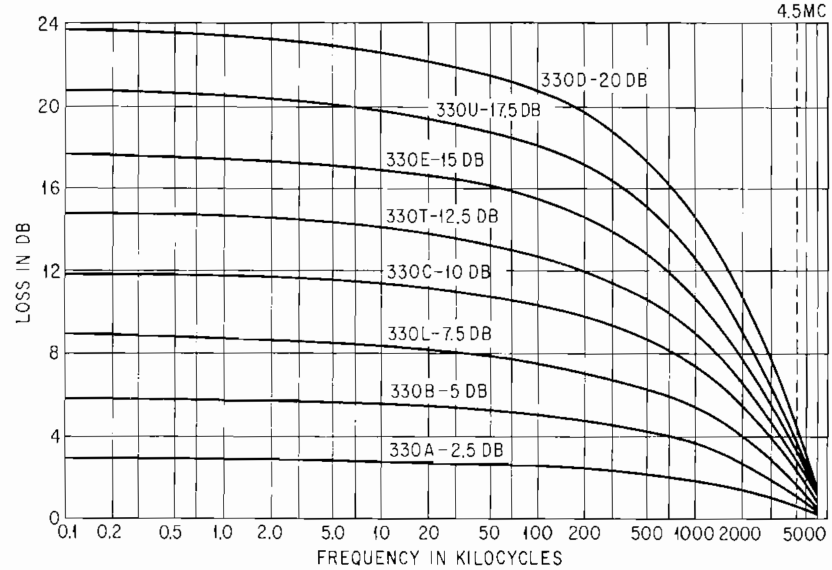



FIG. 1-4. Characteristics of 330 type fixed equalizers.

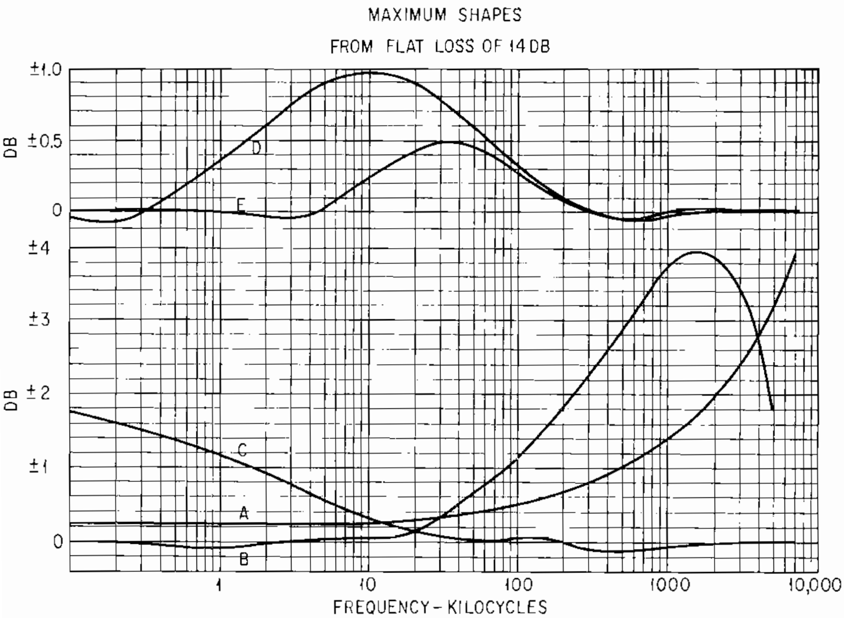



FIG. 1-5. Characteristics of 331 type variable equalizers.

to supply the necessary gain. The fixed equalizer units which are used in the A2A system, whose characteristics are shown in Fig. 1-4, provide for equalization in 2.5-db steps at 4.5 Mc so that at any repeater point the equalization will not necessarily be flat. In general, the transmitting point will be preequalized, and at the receiving terminal the equalization will be adjusted by fixed equalizers to within ±1.25 db.

Each block of the attenuation equalizers also provides the amount of phase equalization required for the length of cable involved. Therefore, as the channel is being attenuation-equalized, phase equalization is automatically provided.

In the A2A system the fixed equalizers are supplemented at the receiving terminals by three variable equalizers, each of which in turn consists of several independently controlled shapes. The characteristics of these equalizers are shown in Figs. 1-5 to 1-7. It is the function of these equalizers to provide the fine adjustments necessary

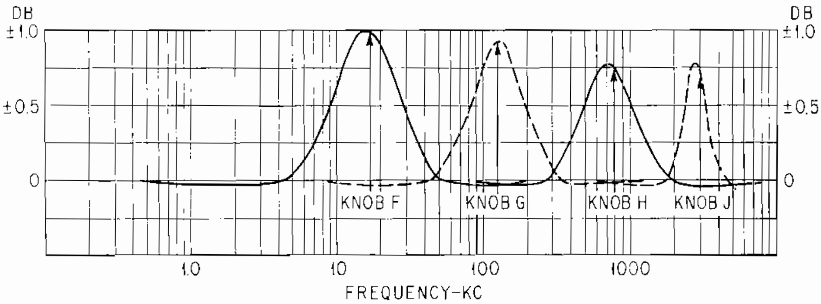



Fig. 1-6. Characteristics of 330M type variable equalizer.

to compensate for response variations which result from such factors as manufacturing variations in the cable, differences in characteristics between PEV and PSV cable, interaction effects due to impedance mismatch at cable terminations, and seasonal variations due to temperature changes.

Except in the case of very long channels, the provision of these adjustable equalizers largely eliminates the necessity for constructing mop-up equalizers in the field. They also simplify the adjustment of equalization which is necessary to compensate for the seasonal variation of the video cable characteristic.

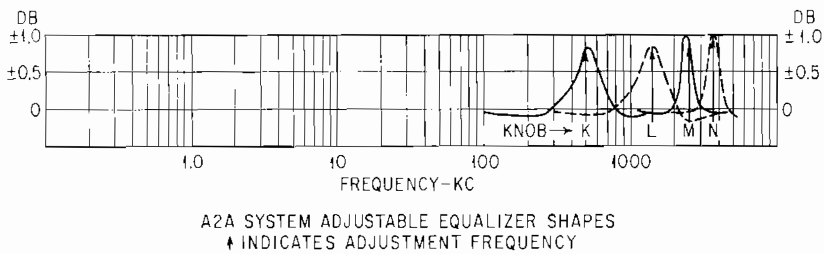



Fig. 1-7. Characteristics of 330S type variable equalizer.

## *A2A Amplifiers*

Four basic types of amplifiers are provided for the A2A system. These are combined with the fixed equalizers in the arrangement that is required to provide the necessary gain in the channel. A further extension of the equalization range of a repeater point is provided by network input and network output amplifiers.

The output amplifier, used at transmitting terminals and at repeaters, is a two-stage balanced amplifier whose gain characteristic is flat over the frequency band extending from a few cycles to 4.5 Mc/sec. The input may be either 75 ohms unbalanced or 150 ohms balanced. The balanced 150-ohm input may be considered as 75 ohms to ground on either side and is provided so that the same unbalanced equalizer that is used in other parts of the system can be used. The output contains a ($Z_0$ – 124-ohm) network to match the output of the amplifier to 16-gauge video cable at low frequencies. An inductor is connected to provide a high impedance to interfering longitudinal voltages encountered on the cable pair. The amplifier is operated at a nominal gain of 11 db, which can be adjusted by means of the gain control which is provided.

The input amplifier is used at repeater points and receiving terminals. It contains a $Z_0$ network in shunt with its input to provide the termination for the 16-gauge cable pairs. It is a two-stage balanced amplifier which is flat to 4.5 Mc. The output is 75 ohms, and it is normally connected to the fixed cable equalizers through jacks and plugs. Suppression of longitudinal noise is accomplished in an electron-tube circuit which acts as a high resistance to longitudinal voltages. The amplifier is operated at a nominal gain of 10 db and has a manual gain control.

The intermediate amplifier is used at repeater points or at receiving terminals to provide amplification among blocks of equalizers where the gain of the input and output amplifiers is inadequate. It is a balanced three-stage amplifier with 75-ohm input and output impedances that match the equalizers to which it is directly connected through jacks and plugs. The nominal gain of the amplifier is 24 db, and a small range of manual gain control is provided.

Network input and network output amplifiers are provided when very long repeater sections are encountered. They are two-stage balanced amplifiers whose input and output impedances are designed to match the video cable pairs. They are further equipped with an input and output high-frequency voltage step-up network and an equalizing network. The step-up network results in about 15-db extra gain at high video frequencies with respect to the low frequencies, and the equalizer adjusts this to have an inverse cable characteristic. The additional available high-frequency gain thus supplements the equalization provided by the fixed equalizers.

The receiving terminal amplifier (RTA) provides the final block of gain in the system at the receiving terminal. The input is 75 ohms unbalanced, and the output is either 75 ohms, with a nominal flat gain of 20 db, or 124 ohms balanced with a nominal gain of 23 db. A 7-db switchable attenuator and a continuously variable gain-control potentiometer permit gain adjustment over a range of 10 db. This range permits precise gain adjustment of the over-all facility.

### *A2A Clamper*

The purpose of the clamper used at the receiving terminal is to attenuate low-frequency distortion and interference, that is, to reduce the low-frequency components which have been added or reduced in transmission. It is bridged on to the circuit at a point where the level ranges from $-26$ to $-14$ dbv at an impedance of 37.5 ohms. It operates by sampling the black-negative crests of the synchronizing pulses and detecting the envelope of the pulses to determine the low-frequency distortion. The detected envelope is amplified and returned to the line in phase opposition to the original signal, thereby reducing the signal distortion.

### *A2A Power Supply*

The A2A power supply consists of two units: a regulator and alarm unit and a metallic rectifier. The regulator unit provides 115-volt regulated alternating current to the filament transformer primaries, which are located in the amplifier panels, and to the metallic rectifier, which can supply a load of 610 ma at 200 volts. One regulator supplies four filament supply panels and two rectifiers and provides connections to an alarm circuit to signal power failures. One pair of units will handle a single channel with the largest amplifier load or more than one smaller channel terminal.

### *Typical A2A System Design*

The general design objectives in laying out an A2A system are as follows:

1. Transmitting terminal equipment is required to provide a proper impedance match to the video cable pair. Normally an active terminal with an output amplifier is provided, but a passive terminal can be used.
2. The signal should be preequalized the maximum amount that will result in a correct level at the input amplifier at the first repeater in order to obtain the best signal-to-noise performance.
3. The number of repeaters should be kept to a minimum for best differential gain and phase performance. Network amplifiers can be used, but if their use does not reduce the number of repeaters required, they should be avoided.
4. The receiving terminal should be made as small as possible.
5. Repeater locations should be in telephone company premises.
6. The low-frequency output level of any output amplifier should not exceed −10 dbv. This will keep the high-frequency, preequalized signals within the output power limit of the amplifiers.
7. The minimum high-frequency input level at any repeater with a nonnetwork input amplifier should be above −57.5 dbv, based on satisfactory random-noise magnitudes in the system.

Based on these general considerations, a typical circuit, as shown in Figs. 1-8 and 1-9, would be designed as follows:

It is required to provide a circuit between two points over a cable route consisting of 25,555 ft of 16 PEV-L cable. The 4.5-Mc over-all loss of this cable is 90 db.

The use of network amplifiers at both terminals will not eliminate the need for an intermediate repeater, so a repeater will be used. It is found that a repeater can be located in an office located 75 db from the transmitting terminal.

The length of this first section determines the transmitting-terminal and, to a large extent, the repeated design. For a section of this length, the preferred arrangement is to provide a network output amplifier at the transmitting terminal and a nonnetwork input amplifier at the repeater.

The network output amplifier provides 31.5 dbv of equalization. With a low-frequency level of −10 dbv at the output of the amplifier, the 4.5-Mc output level is then +21.5 dbv. The input level at the repeater input amplifier is then +21.5 − 75 = −53.5 dbv as shown in Fig. 1-8.

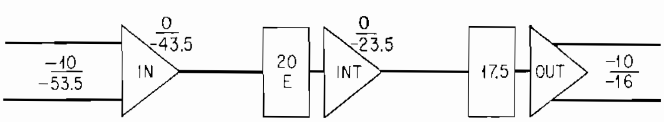



FIG. 1-8. Typical A2A intermediate repeater.

The length of the second repeater section is 15 db. For a section of this length the preferred arrangement is to provide nonnetwork amplifiers at both terminals of the section. This establishes the 4.5-Mc maximum level at the output of the intermediate repeater at +5 dbv and determines the equalization required at the repeater. This is, of course, the sum of the slope at the input of the repeater and the slope at the output, or 53.5 + 5 = 58.5 db.

Referring to the chart of equalizer losses, it is found that the combination of two 330D (20 db) and one 330U (17.5 db) come within 1 db of the requirement. Two intermediate amplifiers would provide the necessary gain.

Looking ahead to the receiving terminal, however, it is found that this repeater arrangement would result in an unsatisfactory condition at the terminal. A more satisfactory design results if one of the 330D equalizers is assigned to the receiving terminal to provide additional range for compensating seasonal variations. When this is done, the 4.5-Mc output at the repeater output amplifier is not at its maximum, but this is satisfactory because the input level at the receiving terminal remains well above the minimum. The intermediate repeater thus contains an input amplifier, one 330D equalizer, an intermediate amplifier, one 330U equalizer, and an output amplifier.

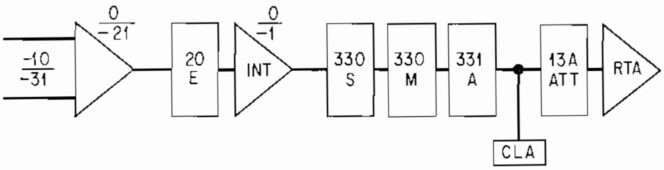



FIG. 1-9. Typical A2A receiving terminal.

The receiving terminal, as shown in Fig. 1-9, will therefore consist of an input amplifier, one 330D equalizer, an intermediate amplifier, the three variable equalizers, a receiving-terminal amplifier, a variable attenuator, and a clamper.

## *A2A Terminating Conditions*

The transmitting-terminal input and the receiving-terminal output can both be arranged for either 75- or 124-ohm impedances. A terminal in a telephone company office is usually 124 ohms balanced. Connections to broadcaster's equipment are normally 75 ohms unbalanced. For either condition the A2A system is designed and aligned to receive a 1-volt peak-to-peak flat signal and to deliver a 1-volt flat, clamped signal.

In the design and alignment of the A2A system, equalization is provided and adjusted to compensate for all cabling to the actual point of interconnection with adjacent facilities. It frequently happens that the last (or first) A2A amplifier is some distance removed from the jack where the interconnection is actually made. The inside cable for this run is equalized within the A2A system. It is important that this cable length, at either terminal, be kept as short as practicable because a long run of unbalanced cable might be subject to excessive noise interference.

## *A2A Transmission Objectives*

The A2A system has been designed to transmit either monochrome or NTSC color video signals without noticeable picture impairment. The transmission objectives are such that several channels can be included in an intercity network channel and provide transmission to meet present standards.

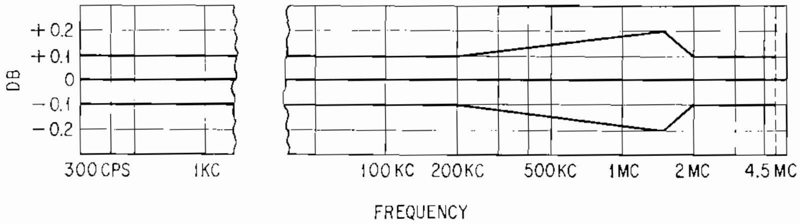



FIG. 1-10. Typical frequency-response objective, A2A system.

A typical frequency-response objective for an over-all A2A system is shown in Fig. 1-10. The region below 200 kc is maintained to very close limits in order to avoid smearing and streaking. The region above 2 Mc is maintained to the same close limits to avoid impairment of color information in that region.

The differential gain objective in a properly adjusted A2A system is ±0.4 db, and the maximum differential phase less than ±0.5°.

The low-frequency noise components, consisting principally of 60 cycles and harmonics, on an rms basis, should be at least 60 db below the peak-to-peak signal voltages.

Low-frequency longitudinal noise voltages encountered on the cable pair will be suppressed at least 60 db by features included in the system.

Impulse noise should be at least 17 db below the peak-to-peak signal voltage.

Random weighted noise on an rms basis should be at least 65 db below the peak-to-peak signal level.

## Intercity Facilities—The TD-2 System

### *General*

The transmission of video program material requires a channel capable of transmitting a frequency band extending from a few cycles to 4.5 Mc. In their search for facilities capable of such wideband transmission, the Bell Telephone Laboratories early recognized the attractiveness of the wide-frequency spectrum in the SHF radio range. Work in this field resulted in the development of an intercity radio relay system which was first placed in service between New York and Boston in 1947. Experience with this system and further development work led to the TD-2 radio relay system which was first placed in service between New York and Chicago in 1950. This system now provides a network of channels which virtually covers the United States. Some 80 per cent of the video network channel miles in service are derived from the TD-2 system.

The TD-2 system operates in the frequency range of 3,700 to 4,200 Mc, which is one of the bands allocated by the Federal Communications Commission for common-carrier use. The over-all band is divided into 12 channels each 20 Mc wide with a guard band 20 Mc wide between adjacent channels. The center frequencies of each channel are therefore separated from each other by 40 Mc. To provide for two-way service, six of the channels are arranged to transmit in one direction and six in the opposite direction. As shown in the diagram in Fig. 1-11, adjacent frequencies,

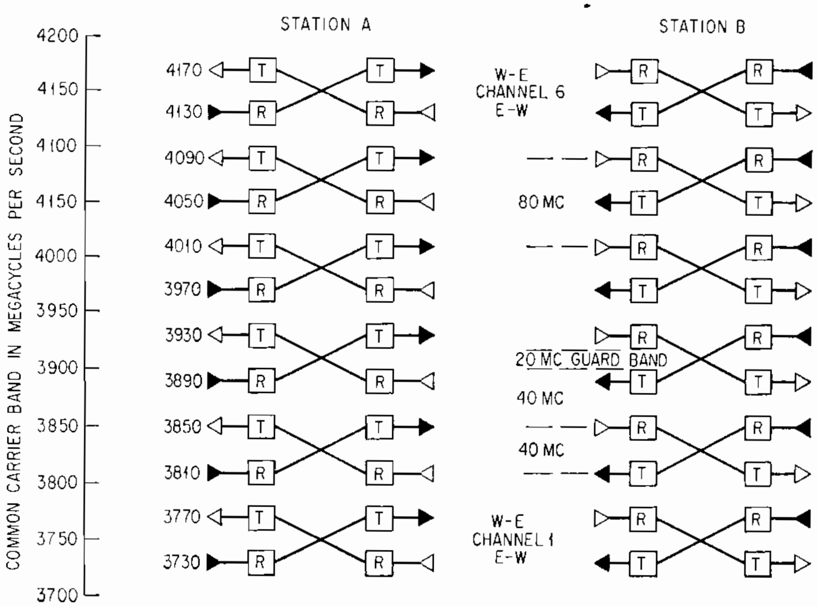



Fig. 1-11. TD-2 frequency-assignment plan.

40 Mc apart, are assigned to the two directions of a given channel. At each repeater point the received signal is shifted 40 Mc toward its oppositely directed mate before it is transmitted to the next repeater point. This is done to reduce interference between transmitters and receivers at the same repeater point and to help overcome overreach at adjacent stations.

Each channel on the TD-2 system is capable of transmitting either a video signal or, by the application of carrier techniques, 600 one-way telephone messages. Most of the routes now in existence, as is common with other telephone plants, are used jointly for video network service and telephone-message service.

### *FM Transmitter*

The major components of the TD-2 system are:

1. Terminal transmitting and receiving equipment
2. Intermediate repeaters
3. Bridging arrangements
4. Protection

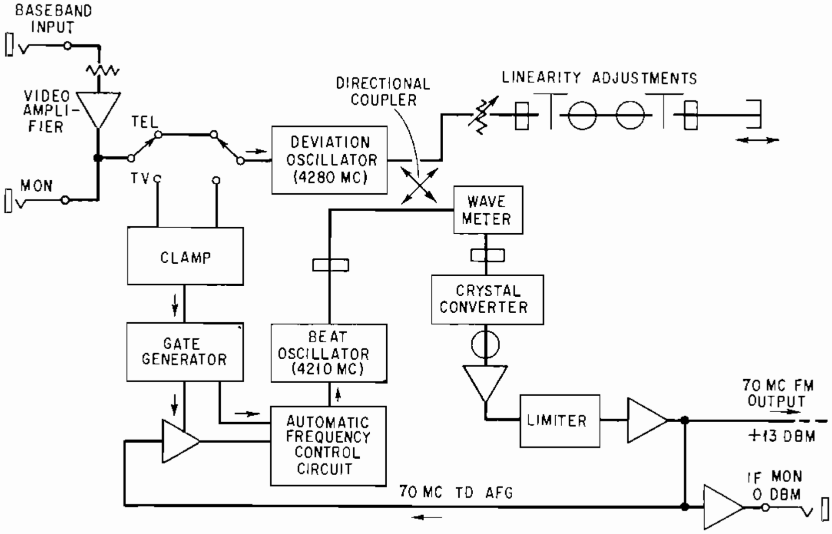



FIG. 1-12. Block schematic of FM transmitter.

Modulation in the TD-2 system is accomplished in two steps, the first of which occurs in the FM transmitter.

The FM transmitter, shown in block schematic form in Fig. 1-12, consists of five major units: a video input amplifier, an FM generator, a control panel, an automatic-frequency-control panel, an automatic-frequency-control unit, and a limiter amplifier. The input video amplifier accepts the input signal from the balanced 124-ohm or unbalanced 75-ohm line at 0.2 volt peak to peak. The input signal is preemphasized by a network which rolls off the low-frequency signal components by 13 db with respect to the components above 2 Mc. Gain adjustment is provided by an attenuator at the amplifier input.

The output of the video amplifier is applied to the repeller of a 4,280-Mc reflex klystron deviation oscillator in the FM generator unit. The signal applied to the repeller is about 10 volts peak to peak, and it causes the oscillator to change frequency in accordance with its magnitude. This type of reflex oscillator has the characteristic of shifting its frequency in a fairly linear manner over ±5 Mc with negligible variation in output power as the voltage applied to the repeller is varied. The maximum swing used in the operation of the TD-2 system is ±4 Mc.

A second reflex klystron is used as the beating oscillator at a nominal frequency of 4,210 Mc. The output of this beating oscillator is combined with that of the deviation oscillator in the directional coupler to produce a frequency-modulated signal with a 70-Mc rest frequency. Automatic frequency control is provided by circuitry which feeds back a rectified voltage to the repeller of the beating oscillator so that the "at-rest" output frequency is maintained at 70 Mc. The AFC circuit therefore acts to correct for drifts of both oscillators.

The limiter amplifier amplifies the FM signal and, through its limiting action, operates to remove any AM introduced in the signal.

### *FM Receiver*

The FM receiver accepts the IF-modulated signal from the TD-2 receiver with a center frequency of 70 Mc and a power level of +3 dbm. The major components are the limiter detector, the video amplifier, and the meter and control panel. Figure 1-13 shows the FM receiver in block schematic form.

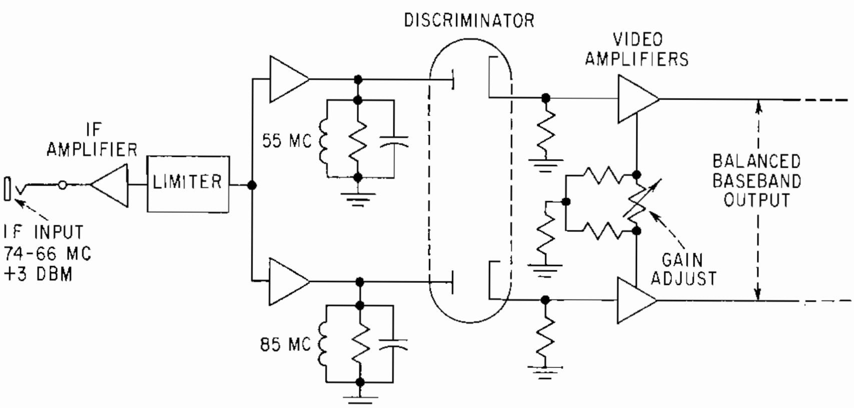



Fig. 1-13. Block schematic of FM receiver.

The first two stages of the limiter detector comprise an IF amplifier from which the signal passes to two limiting stages. Limiting is accomplished by silicon varistors, the bias on which is adjusted to secure proper limiting. The output of the limiter stage is impressed simultaneously on the grids of two independent amplifier stages. Each stage has a tuned antiresonant network in its plate circuit, one tuned to about 55 Mc and the other to about 85 Mc. Consequently, the transmission characteristic through these tubes in the vicinity of 70 Mc will vary with frequency. The slopes of these characteristics are equal but opposite in sign. If the input signal is frequency modulated, the frequency deviations on the input will appear as amplitude deviations on the output of these tubes. These deviations are then applied to two diodes from which, in turn, the video signal is derived.

The video amplifier next receives the signal and amplifies it to +6 dbv for transmission to a 124-ohm output. A restorer network, complementary to the preemphasis network at the transmitter, restores the signal to a flat characteristic. The necessary gain and clamping are provided by an amplifier and clamper in the connecting circuit to the TOC.

### *Antennas*

In the 3,700- to 4,200-Mc range in which the TD-2 system is operated, line-of-sight transmission is required between adjacent stations. This means that repeaters are required periodically on a long route, the locations being governed by such factors as terrain, interference from or with other microwave systems, obstructions, and, of course, the transmission loss of the path. The distances between repeaters on the TD-2 systems vary considerably, but 30 miles is a nominal figure. At main route repeater stations a receiving and transmitting antenna are required for each direction of transmission. Light routes are sometimes built utilizing a single antenna for both transmitting and receiving. These antennas are mounted on buildings or on steel towers at the required heights. Two types of antennas are in use in the TD-2 systems, the delay-lens type and the horn-reflector type.

The delay-lens antenna connects to the waveguide at one end and flares to an opening 10 ft square in a length of 10 ft. The delay lens is constructed across the opening. It consists of a large nnmber of horizontal aluminum strips sealed into blocks of solidified polystyrene foam. The active part of the lens structure is thickest in the middle and becomes thinner toward the outer edges. The effect of the metal strips is to slow down the waves, and since the lens is thickest in the middle, tbe waves are slowed down more in that position, with the result that all parts of the wave emerge at the same time. This forms a flat wavefront which travels as a beam along the axis of the antenna and is very accurately directed to the receiving antenna at the next repeater point.

The horn-reflector antenna opens from a circular waveguide into a vertical metal horn of square cross section. After passing this area, the wave is directed horizontally by a reflector which is an integral part of the antenna structure and whose snrface is a portion of a paraboloid. The over-all structure is about 20 ft high and 10 ft wide at the top. In the TD-2 range it provides the same mid-band gain of 39.5 db as the delay-lens-type antenna, but since it has no freqnency-sensitive elements, it will be applicable in the higher microwave region where new systems will be operated.

### *Repeaters*

At a receiver, the incoming microwave signal from the adjacent station may contain any combination of one to six channel signals. This complex signal is received by the antenna and carried by waveguide to the transmitter-receiver bay. Located in the waveguide at the top of each frame is a receiving-channel-separation filter shown schematically in Fig. 1-14.

The channel-separation filter combines a hybrid junction and a band-reflection filter in such a manner that at each bay the proper channel frequency is dropped, for amplification through that bay, while the remaining frequencies are passed through the waveguide to other dropping filters and amplifier bays.

From the channel-separation filter the signal is passed to the receiver converter, where it is modnlated with a freqnency generated locally by a microwave generator (main stations) or a microwave generator plus a 40-Mc shifter (auxiliary stations). The 70-Mc IF output is then fed to the IF preamplifier and the IF main amplifier, where the major signal amplification occurs. The IF main amplifier includes an automatic-gain-control circuit which is capable of compensating about 30 db of fading.

Phase equalization is accomplished by the use of combinations of fixed units inserted in the IF circuit. Automatic protection switching, remotely controlled program switching, and bridging and patching arrangements, are all provided at the output of the IF main amplifier. At a terminal the IF signal wonld next be applied to the FM receiver, and at a repeater it is applied to the transmitter equipment.

In the transmitter, the 70-Mc IF signal is introdnced by means of coaxial cable to the transmitter modulator. In the modulator, the signal is combined with the local beating frequency to produce a signal of the frequency to be transmitted. After passing through a waveguide filter, the signal is applied to a three-stage microwave transmitter amplifier where it is brought to the desired transmitting level.

The transmitter amplifier consists of three 416B triodes mounted in cavity assemblies. The interstage tuners, input tuner, and output resonant filter are all mounted, with the triode cavities, in one rigid waveguide type of assembly which is bolted into the waveguide.

The amplified signal passes through the channel-combining filter where it is combined with a maximum of five other channels and carried by means of waveguide to the transmitting antenna. A directional coupler is introduced in the waveguide system to provide a means of power measurement and to energize alarms in the event of output failure.

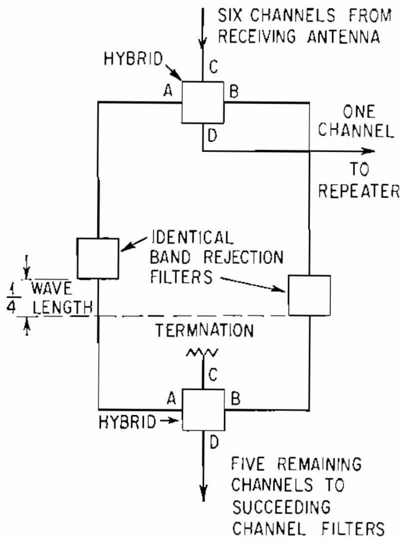



Fig. 1-14. TD-2 channel-separation filter.

### *Bridging Arrangements*

The TD-2 system was designed as a backbone facility with 4,000-mile transmission capability. Video network service, however, requires network interconnections at all points where broadcast stations are located, and these may occur at less than 100-mile intervals. There are also numerous station locations which are not directly on a TD-2 main route, and these must be fed from branches or side legs. In order to maintain the integrity of the main backbone facility and still provide the maintenance and program-switching flexibility required for network operations, an extensive IF switching system has been developed and installed. It was pointed out previously that at each repeater station and terminal office, the microwave frequencies are converted to the 70-Mc IF. It is in this portion of the system that bridging is accomplished rather than at video frequencies, where additional stages of modulation would be encountered.

Where the broadcast station is at or near a city on the main line of a TD-2 route, normal procedure is to provide an IF bridging amplifier on each video channel on the route. The IF bridging amplifier provides two outputs from a single input. One output is for the through channel which passes only through passive elements of the amplifier. The input of a unity-gain amplifier is bridged across this circuit which provides compensation for the shunting effect of the bridging capacitance, and the second path is taken from the output of this amplifier. Each channel obtained by bridging is connected to a receiving FM terminal where the video base band is derived. The base-band channels are then routed by office cable to the TOC, where switching operations are performed.

Broadcast stations not located on the main route may be served by TD-2 side legs. The number of channels on a side leg and the amount of flexibility built into the switching arrangements vary greatly from point to point depending upon the service requirements. In general, however, a bridging amplifier is placed in each channel to which access is required. The branches may then be passed through other bridging amplifiers and a series of remotely controlled IF switches. These are coaxial-type switches specifically designed for the IF switching application. The control point for these switches is at a nearby TOC where the proper combinations of switches can be operated to connect the desired channel to the desired leg.

Access to a channel at any point for transmitting to the network, either on a temporary basis, as for a remote pickup, or on a recurring basis, is obtained in the same general manner except that an FM transmitting terminal is provided.

### *Automatic Protection*

Radio systems are subject to two types of interruption, equipment failure and radio fades. Eqnipment failures can be minimized by the use of conservatively designed systems composed of high-grade components and by continuous out-of-service routine maintenance. Radio fades are due to atmospheric and reflection conditions which affect microwave transmission. The repeaters in the TD-2 system are provided with automatic gain control, which can compensate for about 30 db of fading. During certain periods of the year and particularly in certain sections, deeper fades occur. These are usually of short duration, but they occur frequently enough to prove troublesome on long systems. Manual patching is not effective, not only because of the short fade duration, but because most of these fades are selective, passing through the TD-2 band and affecting different channels successively. To provide protection against these failures an automatic protection switching system has been devised.

A full TD-2 system provides six channels in each direction of transmission. To provide the automatic-protection feature, one channel in each direction, normally Channel 1, is not used for service but is designated the protection channel. An overall system is further divided into switching sections. The number of repeater sections included in a switching section varies widely, being dependent upon the system layout as well as on a statistical analysis of the probabilities of failures. In each switching section the equipment arrangements are identical.

The circuits of the system can be divided into three main categories:

1. Switching circuits
2. Evaluating circuits
3. Control circuits

The purpose of the switching circuitry is to transfer the signal from an impaired regular channel to the protection channel. IF switches are employed both at the transmitting and at the receiving end of each switching section. These are the same type of switches (223 type) that are used for program switching.

The evaluating circuits determine when and where a transfer is to be made and when the transfer back to normal should be made. The evaluating function is located at the receiving end of each section and is performed by the iuitiator.

The control circuits are the connecting links between the evaluating and switching circuits. They accept information from the evaluating circuits and cause the switching circuits to operate. The control circuits are preferably operated over carrier telephone facilities not routed over the TD-2 system to be protected as shown in Fig. 1-15.

The initiator associated with each channel, including the protection channel, is continuously monitoring the incoming frequency-modulated carrier and the channel noise. The protection channel normally carries an 8.5-Mc protection pilot when it is idle. The initiator will respond to a loss of carrier or an increase of noise, either condition signifying a trouble condition. When this occurs on any channel, the initiator associated with that cbannel sends a signal to the receiving switching-control circuit. This circuit enables the receiving IF switch but does not operate it. It also sends a discrete identification tone to the switching-control circuit of the transmitting terminal. This circuit then bridges the protection channel across the impaired channel. The signal then is being transmitted over both the regular and the protection channels.

If the signal arrives at the protection initiator in satisfactory condition, the initiator completes the IF switch and the feed is established from the protection channel. If transmission on the protection channel is impaired, or if the signal fed to the protection channel is impaired because of a failure in a preceding switching section, the protection initiator will not operate the switch. This eusures that a switch will take place only in a failed section.

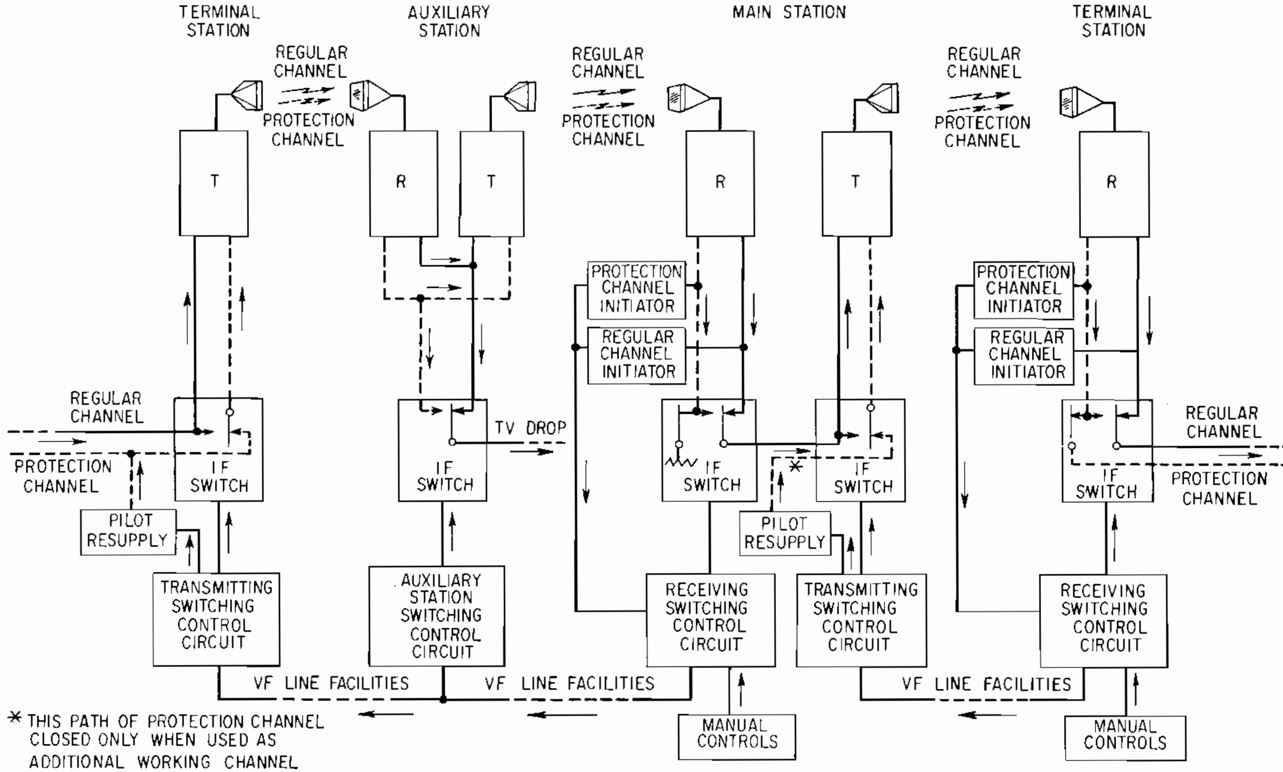



FIG. 1-15. Automatic protection switching for TD-2 systems.

When transmission on the impaired channel has returned or been returned to normal, the initiator so signals the control circuit and the switches are restored.

When transmission is impaired on two or more channels at the same time in the same section, the initiators for each channel will cause the receiving control circuit to apply tone toward the transmit end for each channel. No action will be taken at the transmit end at this time, as the transmitting control circuit is designed to ignore the request for a switch when more than one channel-identification tone is received. At the receive end, however, the control channel locks out all but the lowest numbered channel calling for a switch. When the lockout is completed, the tone of the lowest numbered channel only will be received and the transmitting control circuit will then operate the IF switch for that channel. If, owing to a trouble condition, the switch of the lowest numbered channel cannot be completed within 50 msec, that channel will be locked out for 10 sec and the control circuit will attempt to complete a switch for the next lowest number channel. When a switch is completed, all other channels will be locked out until the protection channel is available again, but if a switch cannot be completed for any channel, the receiving switching-control circuit will try again in 10 sec, starting with the lowest numbered channel.

In order to provide for switching at those stations intermediate in a switching section from which side legs are fed, auxiliary switching circuits are installed. These switches are enabled by a transmitting control circuit but are not actually operated until the IF switch in the backhone receive switching circuit operates. The side-leg feed is then switched to protection channel at the same instant that the backbone route switch is completed.

## Intercity Facilities—Coaxial-cable Carrier Systems

### *General*

In accordance with its basic policy of developing more efficient transmission systems for long-haul message service, the Bell Telephone Laboratories has made extensive progress over the years in developing carrier systems for use over intercity cable facilities. Concurrent with this development, new line structures were investigated which would be capable of handling wider frequency bands with lower transmission losses. One of the structures, the coaxial cable, was ultimately developed as a basic cable carrier facility.

A complete transmission system to operate over the coaxial cable was developed and was designated the L-1 coaxial-cable carrier system. This system operates at line frequencies extending from 64 to 3,096 kc and, by means of terminal chanueling equipment, provides 600 two-way message channels on a pair of oppositely directed coaxials. While the transmission losses at the relatively high frequencies used are considerably less than those of long-haul cable pairs, they are still appreciable and require the use of repeaters (amplifiers) at 5- to 8-mile intervals depending on the structure of the coaxial cable used. The cable routes were laid out so that existing telephone repeater stations could be used for some carrier repeater points, and additional small buildings were erected to house the intermediate repeaters on an unattended basis. The repeater amplifiers provide gaiu and, through the use of networks controlled by pilot frequencies transmitted over the line, automatic regulation of levels and equalization. Additional dynamic equalizers and, also, manually operated equalizers are provided at the section terminals.

The L-1 system was already in use on several major routes in the eastern and north-central portions of the country when the first video network requirements began to materialize in 1945. The system, which was designed primarily for telephone-message use, can be equipped to provide a useful video bandwidth of about 2.7 Mc. It was found by subjective tests that, in spite of the limited bandwidth, very acceptable pictures could be transmitted over the L-1 system. Accordingly, special video terminals and equalization were provided by means of which the entire available bandwidth could be used for a single video channel.

The inherent limitations apparent in the use of the L-1 system for television and the continuing need to keep pace with advances in the art led to additional developmental work which resulted, in about 1953, in the introduction of a new system known as the L-3 coaxial-cable carrier system. This new system, which can be substituted for the L-1 system where this seems desirable, provides a high-quality television channel. Present plans contemplate that the small amount of L-1 in service in the television network at this time will eventually be superseded either by conversion to the L-3 system or by TD-2 radio relay systems which will serve the same points though not necessarily by the same routes.

### *The L-3 Coaxial-cable Carrier System*

A primary consideration in the design of the L-3 system was that it be applicable to the coaxial-cable plant already in existence. Two basic coaxial structures are in use, and the L-3 system can be applied to either. The one most generally used consists of a thin-walled metallic tube of 0.375 in. inside diameter with an internal solid copper wire of about 10 AWG supported coaxially and insulated from the outer tube by polyethylene discs placed at 1-in. intervals. The other is similar except that the outer tube has a diameter of 0.27 in. and the inner wire is about 13 AWG. The coaxials are placed in lead-sheathed cables in the number required on a particular route. As many as eight coaxials have been placed in one cable. In addition, paper-insulated pairs are normally included in the same sheath to provide alarm and control facilities for the system and also to provide additional wire facilities independent of the coaxials.

The L-3 system uses line frequencies up to 8.5 Mc. At this frequency the loss of 0.375-in. coaxial cable is approximately 12 db/mile, and repeaters are required at 4-mile intervals. This necessitates the construction of additional buildings along the L-1 routes which are to be converted. Small variations in repeater section lengths are compensated for in the amplifiers, but very short sections are corrected by the use of cable building-out networks.

The term repeater connotes the combination, in one station, not only of the amplifiers but also the regulating and equalizing networks, power-supply arrangements, and other devices required at the station. The repeater which occurs most frequently is designated an auxiliary repeater. At an auxiliary repeater station no power is generated. The power required for the operation of the repeater is supplied over the coaxial-cable system.

When the layout of a section is such that equalization must be provided at some intermediate point but no line-switching or power-feed functions are required at that particular station, the repeater is designated an equalizing auxiliary repeater.

A main repeater is one from which power is transmitted over the coaxial cable in both directions. A main repeater may be equivalent to an equalizing auxiliary repeater with respect to equalization, or it may be a switching main repeater, in which case additional equalization is provided.

The manner in which the various functions are allocated and the method of gain control are discussed under Equalization Plan and Power Supply.

The 8.5-Mc band of the L-3 system provides, on a pair of oppositely directed coaxials, 1,860 message circuits or a combination of 660 message circuits plus two one-way video channels each with a bandwidth slightly in excess of 4 Mc.

The over-all design objective is to provide high-quality transmission over a channel 4,000 miles or more in length. For video transmission, this involves maintaining in-band transmission flat within $\pm .25$ db and extending the equalization beyond the cutoff sufficiently to ensure that delay differences do not exceed 0.1 $\mu$sec. For network-service requirements, it is also necessary to meet these requirements at intermediate dropping points, which occur at an average interval of 125 miles.

Service protection is provided by means of a spare high-frequency line and by the use of interchangeable components. The transfer to the spare high-frequency line is accomplished automatically at switching terminals, which are located at intervals along the system. A further requirement, then, is that any automatic transfer to the standby channel or any replacement of components shall not result in any noticeable change in over-all transmission.

In a 4,000-mile system the difference in total loss between the extremities of the band is about 40,000 db, which represents amplitude distortion that must be equalized. In a system which contains some 1,200 line and office amplifiers, a systematic change of each amplifier characteristic of only 0.05 db can result in an over-all change of 60 db. In a week, the normal aging of some 7,000 tubes in the circuit can be expected to produce a 6-db change over all, despite negative feedback in the amplifiers. Changes in repeater temperature can produce an 8-db gain change in a week, and cable-temperature changes can result in a 100-db gain change per week over all. These in-band changes of the attenuation characteristic are also accompanied by changes outside the band which result in changes of the in-band delay characteristic. These are the major sources of deviation from the desired transmission characteristic which must be corrected by equalization.

### *Equalization Plan*

Equalization is defined as the process by means of which the loss-frequency and the delay-frequency characteristics of a system are corrected to be within over-all objectives. Regulation refers to that portion of equalization which, by automatic means, corrects for relatively rapid changes in transmission.

From the preceding section, it may be observed that the deviations from the desired flat characteristic can be assigned to one of three categories: (1) fixed deviations, (2) slowly varying deviations, and (3) rapidly varying deviations. The distinction between slowly and rapidly varying deviations relates to the frequency of adjustment necessary to maintain the system within tolerances.

In the design of the L-3 system, each cause of transmission deviation was investigated and evaluated with respect to amount and shape. Certain of these deviations would naturally result from differences in the performance of equipment units, particularly amplifiers, manufactured at different times and from components which differ in themselves. To evaluate the probable deviations, a group of amplifiers was manufactured to extremely close tolerances under laboratory control procedures. These, then, formed the basis of a standard from which performance objectives for all amplifiers were projected.

### *Quality Control*

It is characteristic of equipment manufactured under the usual quality-control methods to have systematic deviations; that is, all units, since they are derived from components which meet certain standard tolerances, will tend to deviate from the design standard. The tolerances are therefore specified so that an accumulation of systematic deviations in an over-all system will never become objectionable. To meet such an objective for the L-3 system, however, would require that all amplifiers, for example, would have to meet a manufacturing tolerance of better than $\pm 0.001$ db, which is a practical impossibility. To meet the over-all objectives, therefore, a completely new quality-control system was developed.

The extent to which over-all system objectives can be attained is largely dependent upon the performance of the amplifiers in the system, and their performance, in turn, is dependent upon the component elements of which they are made as well as upon assembly techniques. The basic concept of the L-3 quality-control system is that, rather than having all amplifiers meet specified tolerances, all amplifiers will have characteristics which follow a normal statistical distribution, within a close average, about the design objective. To meet the over-all amplifier objective, the method is extended to include all those components which were determined, by study, to be particularly sensitive with respect to their effect on the over-all amplifier characteristics. In addition to this control over the components, extremely close control is exercised over their placement in the final assembly, to the position and routing of wiring, and similar considerations. To assure complete uniformity among amplifiers, supporting structures of cold-casting resin are used into which the components are molded and thus held rigidly in place. Further to ensure uniformity, no gain control or other adjustments, other than those which are a function of the regulating network, are provided in any amplifiers. The amplifiers are, however, designed for plug-in operation so that they can be replaced as units in the field and maintained at a central test center.

With the over-all system thus standardized with respect to the amount and shape of transmission variations expected from various sources, it is possible to develop the over-all equalization plan. The equalization system includes three major types of equalizers that correspond to the rates of variation previously mentioned. These are (1) fixed, (2) manual, and (3) automatic.

## *Fixed Equalization*

The line amplifiers may be considered as the first unit of fixed equalization, each amplifier being designed to match closely the loss of a 4-mile cable section under reference conditions. Next are the artificial cable networks which are used to build out short cable sections to 4.0 ± 0.2 miles and the basic amplifier equalizer which adjusts for the difference between the coaxial-cable types. The final step of fixed equalization is the so-called design-deviation equalizer which is associated with all A equalizers, as described under Equalizer Assignment. The function of this equalizer is, first, to correct for the design error of the average repeater and, second, to recenter the manual (cosine) equalizers in their adjustment ranges.

## *Manual Equalization*

A new system of manual equalizers has been developed for the L-3 system and, along with them, a new line-up procedure which gives a positive indication of the best adjustment. The new equalizers, known as cosine equalizers, are based on the principle that any continuous function can be matched over a 180° interval by a Fourier series of cosine shapes. When this principle is applied to the L-3 system, the 0 to 8.5-Mc range is taken as 180° with allowances for out-of-band equalization to preserve the delay characteristics. As illustrated in Fig. 1-16, successive sections of the equalizer are harmonically related to the fundamental which encompasses the 8.5-Mc frequency range. The degree to which any transmission characteristic can be matched is, of course, dependent upon the number of harmonic terms which are provided. In the L-3 system two combinations of terms are provided for the basic equalization pattern and a third combination provides the additional attenuation equalization required for television service.

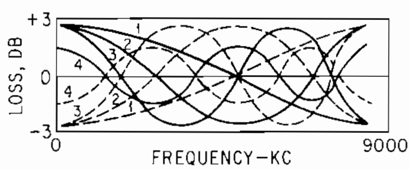



FIG. 1-16. Characteristics of four terms of the cosine equalizer.

## *Dynamic Equalizers*

Automatically controlled equalizers are located periodically in L-3 sections to compensate for those variations which occur too rapidly to permit manual line-up and adjustment in the usual maintenance intervals. To provide the information required by the dynamic equalizers to perform their functions, six pilot frequencies are transmitted over the system. Each pilot controls an individual regulator which, in turn, controls a network with a specific transmission characteristic.

The earliest L-3 systems were installed with only three pilot frequencies and three active networks to control the major, or first-order, variations. Studies were made on these systems, and data were obtained to supplement the calculated design data on the required range and shapes of the three additional networks. The complete pilot systems, which were scheduled to start going into service late in 1958, are based on the principle of providing certain separate noninteracting networks to equalize independently the telephone and the TV line-frequency ranges and certain other networks which will be effective over the entire line-frequency range. The pilot frequencies and the networks they control are as follows:

1. 308 kc. This pilot controls a low-frequency (0 to 4-Mc) shape network active in the telephone band.

2. 556 kc. This pilot controls a second low-frequency (0 to 3-Mc) shape network which operates in conjunction with the first network to provide the necessary composite corrective shape.

3. 2,064 kc. This pilot controls the network which equalizes the coarse deviations in gain due to the changes in transconductance of tubes which result from aging. The network is effective over the entire line-frequency range.

4. 3,096 kc. This pilot controls a network which is effective over the entire line-frequency range and which has a shape similar to that in the feedback circuit in the line amplifier.

5. 7,266 kc. This pilot controls a regulator by means of which the gains of the line amplifiers are varied to hold the pilot at a fixed level. The function of the regulating network is to compensate for deviations due to changes in cable temperature; therefore it has a square root of frequency characteristic which extends over the entire line-frequency range. Dynamic regulation is not required at every auxiliary repeater. At intervening auxiliary repeaters, thermometer regulators are used. At these points a temperature-sensing element is buried with the cable near the repeater building and connected to a thermistor regulator. This regulator, in turn, varies the gain of the amplifier as the temperature changes.

6. 8,320 kc. This pilot controls a network which has a high end whip characteristic. Its function is to provide the correction in the television frequency range which is not provided by the other networks which operate in the same range.

### *The Computer*

Each of the regulating networks provided in the L-3 system acts over a wide frequency range, and the effects of some overlap the effects of others. The range of equalization is also extended beyond the freqnency range actually used in order to maintain the in-band delay-frequency characteristic. In order to allocate properly the amount of correction provided by each equalizer, a multiterminal voltage-dividing network is used. The computer consists of a network of resistances into which voltages representing equivalent pilot levels are fed. The resultant voltages are so distributed at the output of the computer network that, if one pilot changes, all regulating networks correct, but in such proportion and polarity as to produce a gain change only at the pilot frequency which requires correction. Thus, the use of the computer in the regulator circuit prevents interaction between broad equalization shapes.

### *Equalizer Assignment*

Repeaters for the L-3 system are spaced at 4-mile intervals, so that the first step of fixed equalization is located every 4 miles in that the over-all gain characteristic of each repeater is designed to complement the loss characteristic of the preceding cable section.

The design-deviation equalizer, provided in two sizes, one to compensate for sections containing up to 19 amplifiers and the second for sections containing up to 28 amplifiers, is another unit of fixed eqnalization. This unit is one of the components of an A equalizer, described later. If a section contains less than 10 sections, no deviation equalizer is required.

The spacing of the dynamic equalizers is largely dependent upon the lengths of sections between switching terminals or service points. A service point, that is, an office where message circuits or the TV channel are dropped, is naturally a switching point. However, if the service points are widely separated, an intermediate switching point can be assigned. Furthermore, if a switching section is more than 125 miles long, dynamic equalizers are required at some intermediate repeater which then becomes an equalizing auxiliary or an equalizing main repeater, depending upon whether or not it is a power-supply point.

The dynamic equalizers are designated A1, A2, B1, and B2. The A1 equalizer consists of the dynamic equalizer controlled by the 3,096-kc pilot, a manually adjusted flat pad, and four terms of the manually adjusted cosine equalizer. The A2 equalizer consists of the dynamic equalizer controlled by the 2,064-kc pilot, the design-deviation equalizer, and five additional cosine terms. The B1 equalizer consists of cosine terms 11 to 14 and the dynamic regulator controlled by the 556-kc pilot. The B2 equalizer consists of the dynamic regulators controlled by the 308- and 8,320-kc pilots and three manually adjustable "bump" equalizers.

At an equalizing auxiliary or main repeater the A1 and A2 equalizers are assigned, acting through the computer with the line amplifier regulator under the control of the 7,266-kc pilot.

At a switching main or terminal repeater the B1 and B2 equalizers are assigned in addition to the A1 and A2 equalizers, again in conjunction with the line amplifier regulator. At switching points, therefore, all five dynamic equalizers with 14 cosine terms are available for line-up. After the cosine equalizers are adjusted, small residual deviations usually remain at the pilot freqnencies. This results in the introduction of additional deviations determined by the magnitude of the residue at the pilot frequencies and by the shapes of the dynamic equalizers. Three additional bump equalizers are provided at 308, 3,096, and 8,320 kc which are manually adjusted to remove any residue.

When a line carries TV service, an additional mop-up equalizer is provided at about 400-mile intervals or at TV service points. This equalizer provides 23 additional gain terms and 15 terms of cosine delay equalization, all effective only within the television band.

At each equalizing point the major blocks of equalization are followed by flat-gain amplifiers which compensate for the flat loss of the equalizers. The over-all equalization plan, then, is on a block-of-equalization, block-of-gain basis. A typical equalizing auxiliary repeater is shown in Fig. 1-17, which shows how the dynamic equalizing networks are associated with flat-gain amplifiers.

### *Power Supply*

Reference has previously been made to auxiliary and main repeaters. This distinction relates primarily to the power-supply arrangements, a main repeater location being the power source for a group of auxiliary repeaters in the adjacent line section or sections.

At a main repeater station power is supplied by a motor-alternator set which produces 60-cycle power at 230 volts. The a-c motor of this set is driven from a commercial source. On the same shaft as the a-c motor and alternator is a d-c motor which is connected to the central-office batteries. If the commercial a-c power fails, drive for the alternator is immediately transferred to the d-c motor. In addition, a standby unit is operated continuously at no load to permit instantaneous switching under automatic control in the event of an equipment failure.

This plant provides operating voltages for the main station repeaters and also provides power, over a high-voltage power loop, to auxiliary repeaters in the adjacent power sections. The lengths of the power loops are determined by many factors, but the maximum length is generally restricted by the voltage limitations of the cable. Voltages in excess of the maximum permissible value produce corona noise and, possibly, dielectric breakdown.

A power loop consists of a series loop of the center conductors of two oppositely directed coaxials routed through the primary winding of power transformers at the successive auxiliary repeaters on one side of the main station to the farthest office on

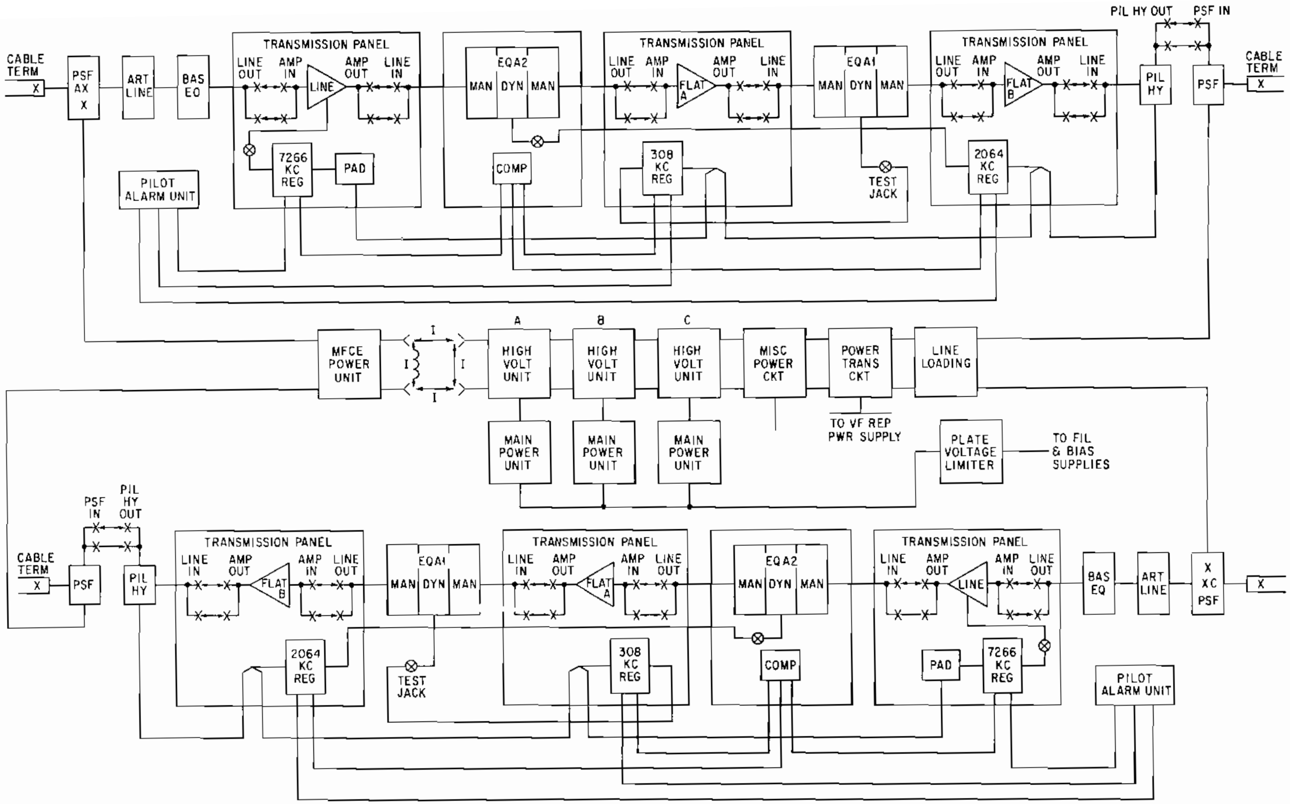



Fig. 1-17. Transmission schematic of an equalizing auxiliary repeater.

the loop where it is closed on itself through a power looping coil. At each auxiliary repeater the carrier and power frequencies are separated by power-separation filters. The power voltage is developed through a transformer at the main station, and a constant current is maintained in the loop by automatic regulators. The voltage is stepped down to the required value at each auxiliary repeater and rectified by bridge-type metallic disc rectifiers in a circuit designed to provide a constant resistance termination to the rectifier bridge. This provides almost unity power factor over the circuit and avoids the generation of harmful harmonics.

## *L-3 Amplifiers*

It has already been noted that the regulating repeaters in the L-3 system include a line amplifier and flat-gain amplifiers while auxiliary repeaters have only a line amplifier. Reference has also been made to the production and quality-control methods

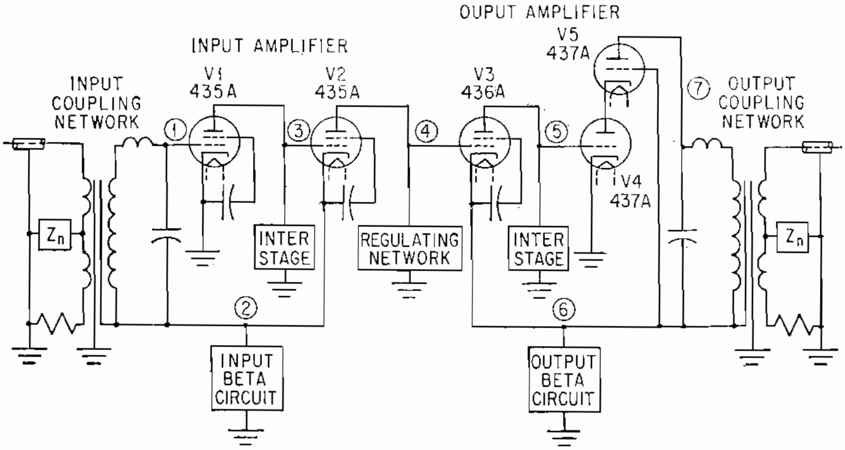



FIG. 1-18. Schematic of an L-3 line amplifier.

used in the manufacture of these amplifiers. The flat-gain amplifiers are essentially the same in design as the line amplifiers with only those changes necessitated by elimination of the interstage regulating network and some increase in feedback.

The basic amplifier configuration is shown in Fig. 1-18. It consists of two independent feedback amplifiers with a regulating network between them acting like a two-terminal interstage network. Each of the amplifiers is essentially a two-stage circuit, the input amplifier literally so and the output amplifier essentially so, since the double-triode output circuit acts like a single stage.

Each amplifier is connected to the coaxial through a coupling network which consists of a transformer plus gain-shaping and impedance-adjusting elements. Since there is no feedback around the coupling networks, they directly affect the insertion gain of the amplifier as do the two feedback networks and the regulating network. The required shaping of the insertion gain across the transmitted band is obtained and controlled by these networks, which constitute the first step of fixed equalization for the system.

## *L-3 Coaxial Video Terminal*

A set of video terminals that has been developed to operate with the L-3 coaxial-cable system includes several important departures in design from those of the L-1 system. These terminals operate in the frequency range between 3,639 and 8,500 kc above a telephone band carrying up to 660 telephone channels.

The method of producing the line-frequency signal from the video input to the L-3 terminals differs from that employed in the L-1 system. In the L-1, the video-frequency signal is first translated upward in modulation to a frequency range well above the final line signal. One sideband is then eliminated except for a vestigial portion, and the remaining signal is then translated back down to the line-frequency range. This is the time-honored method for avoiding interference effects, where the sidebands to be transmitted partially overlap the original signal band.

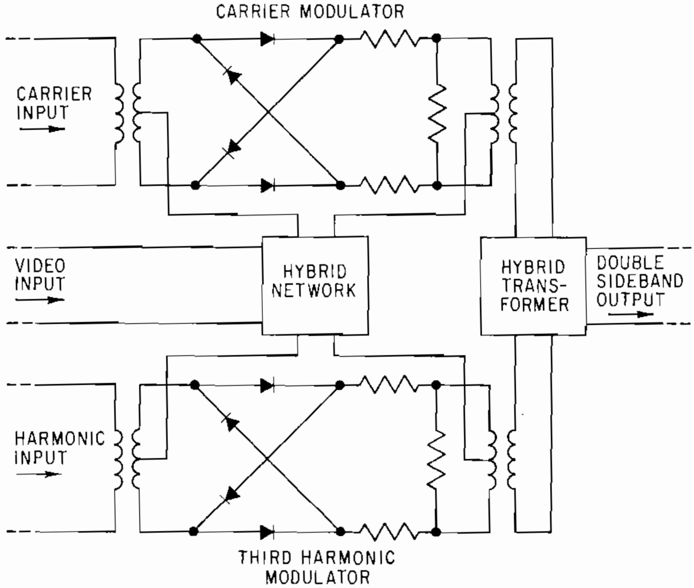



FIG. 1-19. Schematic of L-3 video modulator.

In the L-3 system, the sideband to be transmitted is produced by one step of modulation, and the products of the inevitable overlapping of fringe components of the original band and the sideband are suppressed by canceling them out in the modulator. Figure 1-19 shows a modulating arrangement employed which comprises two identical varistor-type modulators. The signal is fed to both modulators through the input hybrid network and modulates the carrier in the upper one. Some of the products of this modulation, lying in the lower sideband of the third harmonic of the carrier, overlap the upper sideband frequencies of the carrier and produce undesirable effects in the picture unless eliminated. A third harmonic of the same carrier is, therefore, supplied to the lower modulator and also modulated by the signal. This operation produces modulation products which can be made equal in amplitude and opposite in phase to the unwanted products from the upper modulator and thus made to cancel them in output. Great precision is, however, required in maintaining the necessary balance conditions in the modulator. Furthermore, a frequency stability of 2 ppm is required at this point to permit satisfactory use of carrier regeneration at the receiving terminal where product demodulation is employed. To accomplish this, a carrier oscillator with crystal-controlled frequency and thermistor-controlled amplitude is employed.

### *Excess-carrier-ratio Modulation*

Still another new feature of the L-3 system is the use of "excess-carrier-ratio modulation," which means modulation greater than what is commonly known as 100 per cent. In the L-3 system, the carrier amplitude is made one-half of the peak-to-peak modulation amplitude and a saving of several decibels in maximum carrier power is obtained. This affords an advantage in signal-to-noise ratio, as the signal carries greater information in proportion to its peak amplitude than one produced by the more usual modulation relationships. This modulation feature, however, requires special demodulating arrangements.

At the receiving point, demodulation is accomplished by the use of the "homodyne," or "product demodulation," method, since use of envelope detection would produce a distorted signal. Product demodulation accomplishes the additional end of effectively eliminating the quadrature component which is inherent in vestigial sideband transmission and which would otherwise be excessive in the L-3 system because of the use of overmodulation. This requires very close phase relationship between the demodulating carrier and the carrier that produced the signal.

The demodulator oscillator in the L-3 receiving terminal is synchronized and held in the necessary close phase relationship with the transmitting carrier by reference to the phase of the carrier components in the vestigial sideband signal received, averaged over periods corresponding to about a single frame.

Another feature of excess-carrier-ratio modulation, however, does introduce a complication at this point. The polarity of the carrier reverses as it goes through half-peak value, so it cannot be used directly in obtaining a regenerated carrier but must be put through a "square-law" circuit. This produces a result which is free of polarity reversals, but the ability to indicate proper polarity has now also been eliminated. This is regained at a later point in the demodulator operations, however, by a polarizer circuit which recognizes the polarity of the video output signal coming from the demodulator from the characteristics of the vertical blanking and sync portions which occur 60 times per second. From this it is able to maintain the proper polarity at its output.

### *Automatic Switching*

A standby high-frequency line is provided for either one or a group of working lines, depending upon the number of coaxials on the route. If only one working line is to be protected, both the standby and working lines are fed at the head end through a hybrid. Switching is thus required at the receiving end only. Where several working lines are to be protected, switching is provided at both terminals. The switches are controlled by an initiator which operates in response to a deviation in any pilot level.

When a 2-db deviation is registered in the initiator, it acts to cause a "slow" switch by:

1. Blocking the transmitting-switch control in the succeeding section for several seconds in order to prevent all switching sections from transferring.
2. Sending out an identification tone which initiates the switch transfer at the transmitting end of the section in trouble

When the transmitting switch transfers, a verifier tone is sent back which causes completion of the receiving-end switch.

When normal levels are restored, the control circuits operate to restore service to the working line and release the spare line for other switches.

The control system can be operated manually to release any line for maintenance work, or it can be disabled.

A "fast" switch is accomplished if the 7,266-kc pilot deviates from its normal range by $\pm 3.0$ db. This is accomplished by feeding the rectified 7,266-kc signal to an electronic control circuit which eliminates the delay feature.

### *TV Branching*

In its fundamentals, TV branching is relatively simple. At a TV service point the high-frequency line is passed throngh a receiving branching filter which separates the video and message frequencies. The video channel is then passed through the supplementary equalizers previously described and applied to the video terminal equipment. At a branching point where transmitting service is desired, the ontput of the video terminal is applied to a transmitting combining filter where it is combined with the message channel and fed to the line.

## Television Operating Centers

### *General Functions*

Network service is considered by the Telephone Company as a specialized service with respect to both operations and maintenance. For this reason all work incident to network service is concentrated in a single location in any city. These locations, designated program or television operating centers are normally in a telephone bnilding where long-haul communications facilities which serve that city are terminated. All the intercity network facilities and all the local facilities which provide the interconnections between the broadcasters' locations and the networks are terminated in these centers.

Since audio and video networks are derived from different facilities and are operated independently from each other, the program and the television operating centers are normally separate units, although they frequently are located adjacent to each other and are under the supervision of a single office chief. The functions of program and television operating centers are broadly similar.

The functions of a television operating center are briefly as follows:

1. To supervise the establishment and line-up of the network layout ordered by each customer on tbe facilities prescribed by the Engineering Department
2. To analyze customer service and operation orders and interpret them in terms of facility requirements and switching operations
3. To execute the switching operations incident to customer requirements from period to period
4. To keep informed of service conditions by frequent though not necessarily continuous inspection of monitors
5. To receive trouble reports from broadcasters in their local area and initiate appropriate action to clear trouble conditions
6. To make or supervise those routine tests which are necessary to ensure continuously satisfactory performance
7. To exercise general supervision over service in the area for which they are responsible

### *Control-office Plan*

The amount of work performed at the particular TOC in any of the general categories listed is dependent upon the responsibilities delegated to that office under a control-office plan. Under this plan, New York operates as the general control office with responsibility for the over-all network operations. Other offices located at strategic network points, such as Chicago, Atlanta, Los Angeles, and others, are designated as control or subcontrol offices with specific responsibilities for certain network sections. The office in or nearest to the city where a broadcaster takes network service is responsible for the service to that station and maintains contacts with the station. Some offices having no network operating responsibilities, as such, are responsible for the transmission performance of the systems routed through them. It is seen then that any control or subcontrol office, for example, Chicago, will have all responsibilities.

### *Layout and Service Orders*

As was outlined in the general section, customers' orders for network service are converted in the Engineering Department to terms of specific facility and equipment requirements, and orders are issued to all offices involved. The scheduling of the necessary facility changes and the testing and line-up of the new channels are coordinated by the control offices concerned.

Similarly, service orders and operation orders are transmitted to all offices involved. It is the responsibility of the control office, in consultation with other control offices when necessary, to make the specific facility assignments to meet the requirements and then to transmit this information to each office in his section. Each office, in turn, correlates the service orders he has received with the assignments and prepares his own detailed switching schedule.

### *Troubles and Maintenance*

Trouble reports can be originated at any broadcaster's location and referred to his local serving TOC. All reports are relayed immediately to the control office where the trouble-locating procedures are coordinated. The normal procedure is to establish a patch or reroute as quickly as possible and then to clear the trouble on the regular facilities. Maintenance responsibility, like the regular service responsibility, is delegated through a control-office plan to an office which is made directly responsible for the maintenance of the failed facility.

Routine tests are regularly scheduled during nonservice periods on all components and on over-all channels to ensure reliable service. The intervals during which facilities may be released for testing are scheduled by the control offices. Each office then makes local and sectional tests to coordinate with the over-all line-ups which normally follow the local tests.

### *Office-equipment Arrangements*

From the foregoing it is apparent that, aside from the clerical work of the operating center, the layout must be designed to permit two basic functions: switching and testing. Also, since the load varies among all offices, operating centers are not standardized but vary in size and equipment. Basically, however, a TOC provides a point where all the channels in the intercity networks and all the local channels which may be interconnected with the networks are brought to a common voltage and state of equalization. The inside cables by which the channels are extended from the carrier terminal room, the radio terminal room, or the local facility terminals are all equalized and, in the case of radio facilities, also include one or more knob-controlled variable equalizers. At the TOC, therefore, all channels look alike at the switching point and hence can be interconnected by video switches.

In an office where only one station is fed and there is no requirement for switching, the incoming channel is connected directly to distribution amplifiers. The distribution amplifiers have high-impedance inputs which are arranged so that several can be bridged across a terminated incoming line and provide unity gain which is nominally flat over the video band. In the one station office, two distribution amplifiers are bridged on the line with negligible effect on transmission. One output is used to feed the customer, and the second to feed the office video monitors.

### *High-impedance Switching*

In an office that feeds two or three stations and where switching is necessary, the incoming lines are connected to the horizontal, terminated busses of a manual push-button switch. The inputs of the distribution amplifiers from which the outgoing lines are fed are connected to successive verticals of the switch. The operation of a push button connects the input horizontal to the output vertical at the particular cross point.

Through mechanical interlock, any other switch in that vertical is disconnected so that an outgoing line can be fed from only one source.

The basic push-button video switching panel consists of ten inputs and six outputs and is provided with push buttons at the 60 cross points. For larger requirements panels can be multiplied horizontally and vertically. When it becomes necessary to feed more than three outgoing lines on a high-impedance basis, special measures are necessary to maintain high-frequency equalization and the switch flexibility is seriously impaired. For this reason the use of the push-button panel is limited to the smaller offices where the number of outgoing lines connected to any incoming bus is less than four.

In both of the foregoing arrangements testing equipment is normally provided on a portable basis and is moved to the patching bays on tea wagons when in use.

### *Low-impedance Switching System*

In the larger television operating centers the manual push-button switch has been superseded by a low-impedance switching system. Any new installations will be on this basis. The more important features of this system are:

1. Switching is done on a 124-ohm balanced basis rather than on a high-impedance bridging basis.
2. The control panel actuates only d-c control leads. The actual switching is done by wire spring relays in the equipment bay.
3. The basic building block is a 10 by 12 unit which can be used in various combinations up to 30 by 36.
4. All unused inputs and outputs on the switch are terminated so that the load on any input circuit is constant.
5. Switch operations can be preselected, checked, and then operated when required.
6. Individual switches can be operated, or groups of switches can be transferred to one of four "salvo" controls. Operation of a salvo causes rapid sequential operation of each switch transferred to that group.
7. The condition of any switch is indicated at all times by signal lamps on the control panel.
8. The control panel can be adapted to remote-control systems to control video, audio, or IF switches.
9. The cabling and circuitry of the switch are capable of flat transmission through 10 Mc, but the amplifiers presently installed are limited to 4.5 Mc.

### *Switching Plan*

The principle of the switching system is illustrated in Fig. 1-20, which shows the plan of a 10 by 12 unit.

Each incoming line is connected to a 1 by 12 resistance splitting pad. The through loss of this pad is about 27 db, and the loss between any two outputs is 54 db, which is sufficient to prevent interaction between output circuits. Figure 1-21 shows the physical structure of the splitting pad. One incoming line is reserved for a test trunk whose function is described later.

Each output branch of each splitting pad is cabled to the 10 by 12 switching unit as shown in Fig. 1-20. This unit consists of 12 blocks of 10 wire-spring relays which perform the actual video switching. Each of the 10 relays in a block connects to the same output channel, and the 12 blocks care for the 12 outputs. One relay in each block connects with one branch of each input splitting pad, so that every output circuit has access to any input circuit.

When it is desired to expand the switch capacity, a 1 by 3 splitting amplifier is connected to the input of each splitting pad so that each incoming line now can be connected to a maximum of 36 outputs. On the output side of the switch a 3 by 1 relay is added to permit the selection of one of a group of three 10 by 12 units and thereby to increase the input capacity to 30 lines. This is the present design maximum. The cabling arrangement is shown in Fig. 1-22.

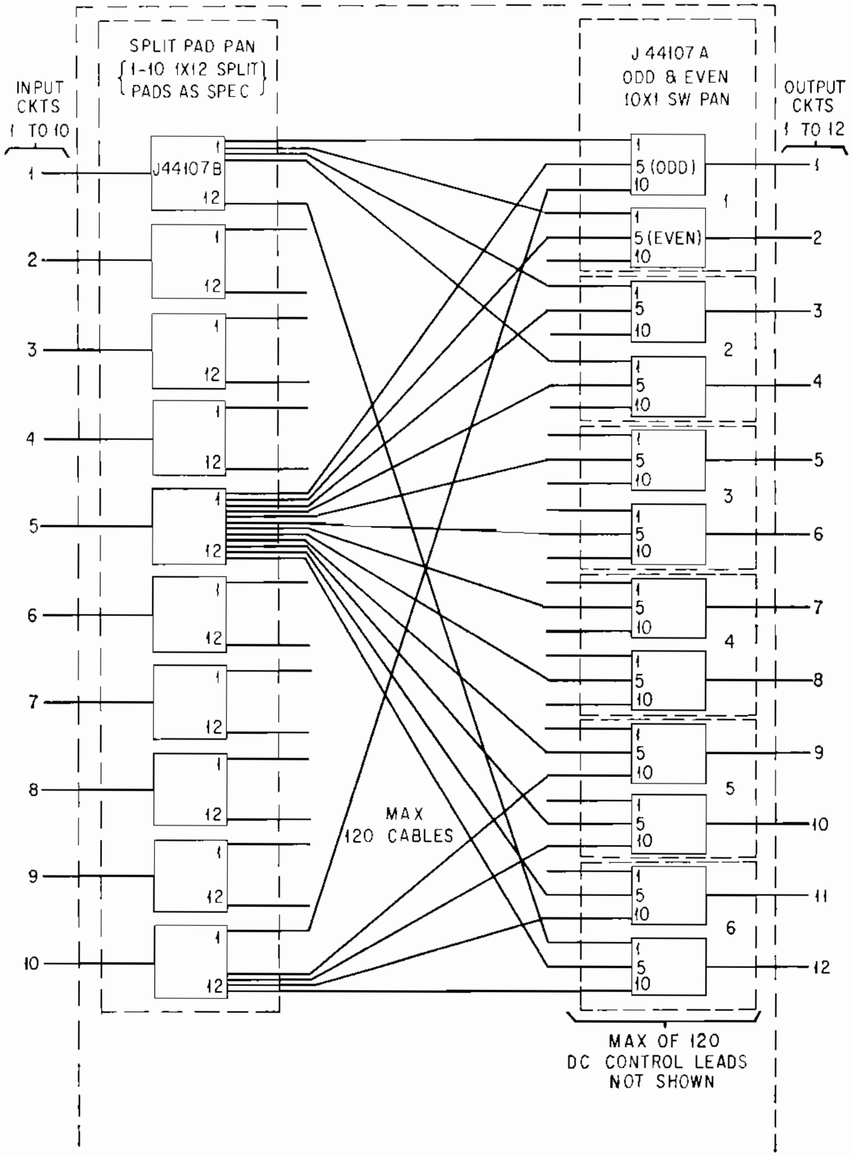



Fig. 1-20. Basic 10 by 12 switch unit.

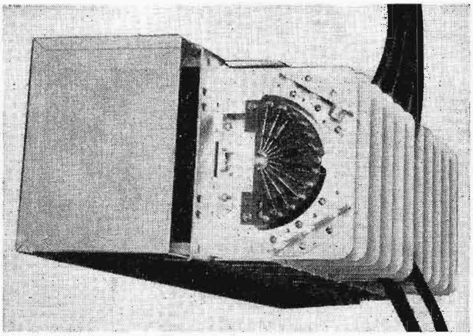


FIG. 1-21. Mounting arrangement for 1 by 12 splitting pads.

## *Switching Equipment*

The wiring and cabling for each switching system are laid out and installed to meet the anticipated ultimate requirement for an office but are not necessarily fully equipped initially. Careful control is exercised to ensure that all cables between common points in all switching paths are cut to uniform lengths and within definite limitations. By this means uniform transmission is assured between any switch input and any switch output. It is also the reason for installing cabling initially to meet the ultimate requirement.

The transmisison losses in the switch are compensated by an amplifier in each output circuit. This amplifier is identical with the receiving terminal amplifier used in the A2A system and is therefore designated an RTA. The 1 by 3 splitting amplifier does not provide gain with respect to the over-all switch but provides zero loss between the amplifier input and each of the three outputs. All switch components are designed for 124-ohm balanced interconnection.

Transmission loss through the switch from the input-video patch-bay jack to the output-video patch-bay jack is not flat but is designed to have a cable shape roll-off characteristic which can be compensated by variable cable equalizers associated with the channels connected to the switch. Channels connected to the switch are equalized flat only to a point $X$ internal to the switch at the 10 by 12 switching units where the channels are actually switched. Access to point $X$ is obtained only through input and output test trunks. Interconnections of facilities at points other than point $X$ will not be properly equalized unless special steps are taken.

## *Test and Monitor Trunks*

Depending upon the size of the switch, one or two inputs and outputs are designated as test trunks. Each of the test trunks can be equalized to be perfectly flat from point $X$ to its termination in a "test" bay. Input and output switch-control leads are also extended to the test bay so that the input test trunks can be remotely switched to any outgoing channel or any incoming channel can be switched to an output test trunk. Since the switched connection is made at point $X$ and the test trunks are maintained at zero flat loss, all testing equipment is effectively connected to point $X$.

From each 10 by 12 switching unit two output trunks are connected directly to monitor and control positions. These trunks are also carefully adjusted to zero flat loss from point $X$ to their termination. Switch-control leads are extended to the monitor positions so that the video monitors can be connected to monitor any incoming channel. Voice communication circuits which parallel the routes of the channels controlled by a particular office and direct talking circuits to local broadcasters' locations and to other terminal rooms in the building are also terminated in the monitor positions. An attendant, therefore, has immediate access, through automatic signaling, to all points in his control section for directing trouble-locating activity, arranging temporary reroutes, and all other functions incident to video-network operation.

Testing functions are concentrated at the test position(s) where access to all chan-

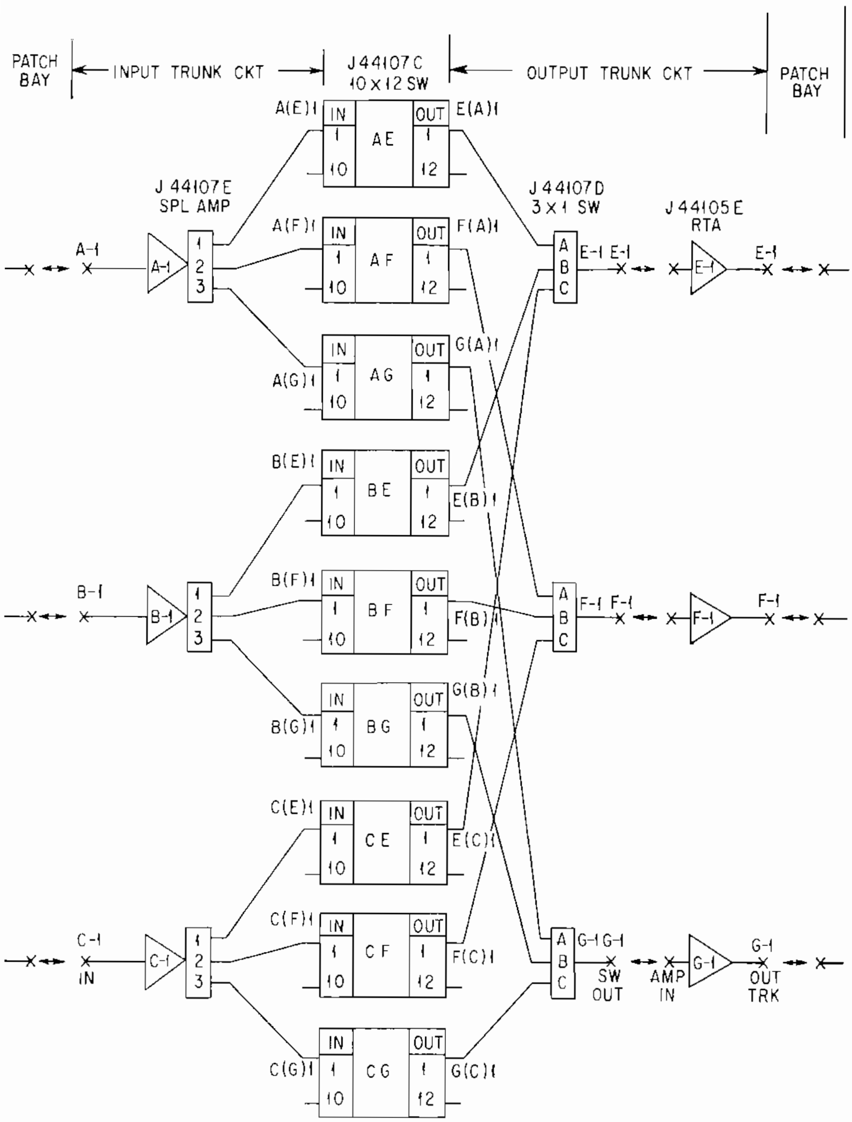



Fig. 1-22. Cabling plan of a 30 by 36 video switch.

nels is provided by the test trunks previously mentioned, and communcation is provided by multiples on the monitor position circuits. All the test equipment is mounted in these positions, and any unit can be connected to the test trunks in a small patching jack field where the units are terminated through cables carefully cut to uniform length.

### *Switch Control*

Switching is controlled from the control panel where d-c control leads are terminated in a coordinate pattern. All incoming lines are arranged on the horizontal and all outgoing lines on the vertical rows. Signal lights are provided at each intersection.

Preselection is accomplished by simultaneously operating the buttons opposite the horizontal and vertical which represent the channels to be connected. This brings up a white signal light at the intersection. This preselected switch can, if desired, be transferred to a given salvo row, on a horizontal along with other preselected switches which must be made simultaneously. Four salvo rows can be provided, and any number of preselected switches up to the capacity of the switch can be transferred to any one of the salvo rows. Upon completion of preselection the entire board can be checked against the switching schedule by a second attendant by observing the condition of the signal lamps. Errors can be corrected by operation of an ANNUL button. Actual operation of the switches is completed on cue by simultaneous operation of a MASTER EXECUTE button and the appropriate individual vertical or salvo button. As mentioned previously, the control panel can be arranged to control remote video or IF switches as well as local video switches, and they can be assigned to the same salvo for simultaneous operation. Completion of the switch is indicated by a red signal lamp at the intersection which represents the connected channels.

The master control panel supersedes the switch controls at the test bay in that the test-bay switch controls will not function unless the switches at the master control have been operated to the NO SERVICE position. This makes it impossible for anyone at the test position inadvertently to open a channel which is in service.

## Objectives of Video-network Transmission

### *General*

It was pointed out in the general section that the video network provided for any broadcaster is not necessarily a permanent combination of facilities but rather is a variable combination of television sections (TVS's), probably combining several types of video facilities and provided from day to day as required. Because of these variations it is not feasible to specify transmission objectives for a network. Instead, the individual TVS's are lined up and adjusted within tolerances such that all normal combinations, including local interconnecting channels, will provide a satisfactory grade of transmission over all. When certain combinations of facilities, through daily use, become identified with one broadcaster and the pattern of operation is relatively fixed, over-all tests are made periodically to check over-all network transmission and particularly to verify that the deviations in individual TVS's are not adding cumulatively in the same direction to result in an unfavorable over-all characteristic.

Video-network facilities are provided for the transmission either of a monochrome signal or an NTSC color signal. The transmission requirements for both types of facility are essentially the same, with the exception that for color transmission the frequency response in the region of the 3.58-Mc color carrier must be more closely controlled and differential phase and gain must be kept within definite tolerances. A channel which has been lined up for color transmission will, of course, satisfactorily transmit a monochrome signal, since the measures taken to provide color transmission also enhance monochrome transmission.

### *Levels*

All telephone company video-transmission systems are designed to operate with a 1-volt peak-to-peak signal at those input and output terminals which are located either at customer locations or at TOC's. Different levels may apply at junctions of different types of facilities at points other than TOC's, but they are established with respect to the TOC reference level.

Transmission level measurements of single-frequency sine-wave signals are made with thermocouple-type instruments which are calibrated in decibels. Here, the

1-volt peak-to-peak signal is considered as the reference of 0 dbv and the decibel reading of the meters are based on the fundamental relationship

$$db = 20 \log \frac{V_2}{V_1}$$

where $V_2$ is the measured voltage and $V_1$ is the 1-volt reference voltage.

Single-frequency level measurements and adjustments are made only on an out-of-service basis. Adjustments are provided on all channels, either in the facilities or in the TOC terminating circuits, so that they can be adjusted within $\pm 0.5$ db of the required level.

In-service checks of levels are made with oscilloscopes equipped with IRE scales and with vertical amplifiers having a standard IRE roll-off characteristic. In this instauce the 1-volt peak-to-peak reference corresponds to 140 divisions on tbe IRE scale. When level variations occur during service, temporary adjustments can be made based on the scope reading. On all scopes used in the TOC's, the amplifier characteristic is switch-selected. It is important that all scopes used to determine where the level has varied and, hence, where the temporary adjustmeut should be made are adjusted to the IRE characteristic because use of a wideband scope characteristic could lead to errors. Whenever a temporary in-service adjustment is made to compensate for a variation in network facilities, it is followed up by single-frequency transmission measurements during the next out-of-service period in order the sectionalize and correct the cause.

### *Frequency Response*

The low-frequency-response characteristics, up to about 250 kc, of all video channels are maintained to very close tolerances in order to avoid streaking and smearing. The characteristics are measured by the use of single-frequency sine waves and power meters. Waveform transmission in the low-frequency range is checked by observing the transmission of a "window signal," which is a critical indicator of low-frequency-transmission impairment.

In the high-frequency range different tolerances apply to color and monochrome chanuels. Color facilities in general are equipped with special equalizers which operate in the range of the color carrier and its sidebands. These equalizers are used to adjust the high-frequency characteristics to close tolerances. Typical objectives for color aud monochrome channels on TD-2 facilities for single-frequency sine waves measured with power meters are shown in Fig. 1-23. It will be noted that the ob-

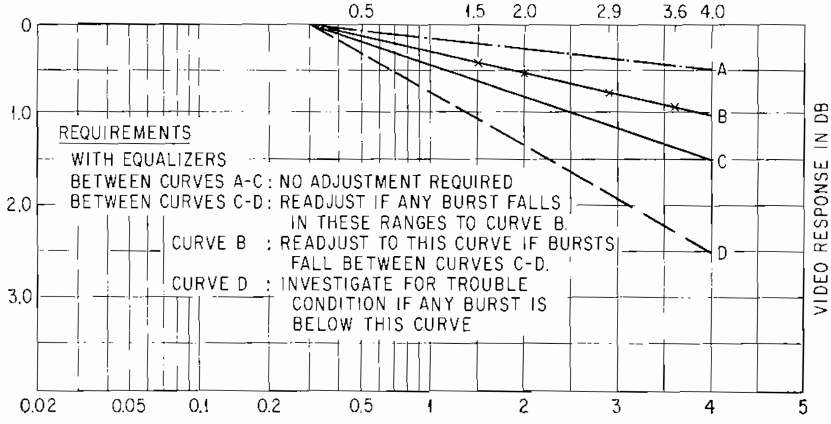



FIG. 1-23. Typical frequency-response objectives for TD-2 channels.

jective is to maintain a slight roll-off in order to minimize any tendency of the channel to ring.

Rapid checks of over-all channel characteristics are made using the multiburst signal. In addition to giving an indication of the frequency response of the channel at the burst frequencies, this signal also indicates sync compression or other distortions of the synchronizing pulses, video compression, harmonic distortion, and axis shift. Any of these impairments in the transmission of a composite waveform can be related to normal transmission parameters of the facility and can be sectionalized and cleared.

The tendency of a channel to ring, that is, to set up damped oscillations following rapid signal transitions of relatively large magnitude, can be checked by transmitting a sine-squared pulse and observing the magnitude of any oscillations.

### *Differential Phase and Gain*

Differential phase and differential gain, as defined in the IRE Standards, are not significant in monochrome transmission but require close control on channels for NTSC color transmission because of their effect on the hue and saturation of the color signal. All the facilities designed for video transmission, with the exception of the TD-2, exhibit satisfactory differential phase and gain performance without supplementary adjustment when all components are operating normally. Any deviation from the normal differential phase and gain performance on these systems can therefore be traced to some system irregularity, and no supplementary adjustments are necessary.

In the TD-2 system the video signal is converted to a frequency-modulated intermediate-frequency signal centered on 70 Mc. The negative and positive voltage peaks of the video signal thereby are shifted to positions at about 74 and 66 Mc in the IF band. The portions of the signal intermediate between maximum and minimum occupy positions between 74 and 66 Mc in proportion to the amount the rest frequency is shifted in response to the input voltage change. In the IF portion of the TD-2 system therefore, the relative phase shift of the carrier for different levels of the video signal is directly dependent upon the delay-frequency characteristic of the IF path. If the delay in this path can be made uniform, then video differential phase will be zero.

A series of IF delay equalizers has been developed, and all TD-2 channels are delay-equalized periodically on a switching section basis. The equalizers are placed in the main-line IF paths.

For color transmission the differential phase of a 3.58-Mc signal is of particular interest. The over-all delay equalization of the radio facilities is therefore supplemented by routine TOC-to-TOC measurements of the differential phase and gain at 3.58 Mc. When required, additional equalizers are placed in the IF side leg or dropping leg at each service point to reduce the differential phase to a minimum.

As in the case of other facilities, differential gain is not a problem when all system components are operating normally.

## AUDIO-NETWORK FACILITIES

## Local Audio Channels

### *Facilities*

Local audio channels include those provided between remote studios and master control, between studio and transmitter, and between master control and the point of interconnection with the intercity networks. These channels normally are concentrated in metropolitan areas and, generally, are relatively short. The wire facilities for these channels, therefore, are usually pairs in exchange area cables.

Whenever the length of the local channel is such that an intermediate amplifier is not required, nonloaded cable facilities are used in preference to loaded cable facilities because they can be equalized by relatively simple means.

If the length of the local channel is such that nonloaded facilities cannot be used without intermediate amplification because of noise or cross-talk considerations, loaded facilities of suitable bandwidth can be used in preference to providing an intermediate amplifier. However, when an intermediate amplifier is necessary, either loaded or nonloaded cable can be used as the wire facility.

### *Equalization*

Equalization is the process by which the loss of a transmission channel is adjusted to be approximately equal at all frequencies in the required transmission band. In the audio range this normally involves introducing low-frequency-loss components which complement the high-frequency loss of the cable facilities. Two methods are widely used to accomplish this on nonloaded local channels. One is to bridge across the receiving terminal of the channel an attenuation equalizer which is adjustable to meet the requirements of different lengths of facilities. The second is to apply 4-to-1 impedance-ratio transformers at the two terminals of the channel with the low-impedance side facing the cable. The transformers introduce mismatch losses at the low frequencies and can, thereby, equalize short lengths of cable depending upon the bandwidth desired and the gauge of the conductors. Transformers can be used alone for equalization, but when an adjustable equalizer is applied it is almost always used in conjunction with a transformer. Transformers alone can be used to provide transmission uniform to within about 1.0 db from 35 to 8,000 cycles for the cable lengths and gauges shown in Table 1-3:

**Table 1-3. Lengths of Nonloaded Cable Which Can Be Equalized by the Use of 4-to-1 Coils**

| *Gauge* | *Length, miles* |
|---|---|
| 16 | 5.0 |
| 19 | 2.3 |
| 22 | 1.5 |

Beyond these lengths an equalizer is required, either by itself or in conjunction with the 4-to-1 transformers. For those circuits involving the transmission of frequencies from 30 to 15,000 cycles, the equalizer and transformers are generally used together to provide a circuit whose transmission frequency response is uniform within about 1 db of the response at 1,000 cycles.

When facilities are specially constructed for long-term service, loading can be applied in the same pattern as is used on long-distance cables. For these facilities, type 17 equalizers, which are described later, can be used to secure the required transmission characteristic.

When equalized local channels are furnished and no special requirements are imposed as to the arrangements to be provided, equalizers and 4-to-1 impedance-ratio transformers are likely to be installed in combination. The same transmission characteristics on an over-all channel can be obtained when a 1-to-1 impedance-ratio transformer is used, by proper adjustment and choice of the equalizer, except in the cases of channels of irregular make-up or of lengths approaching the limits which can be equalized as one section. Other considerations, such as are involved in the use of volume indicators, may determine the more satisfactory arrangement.

Equalization is always applied at the receiving terminal of a channel in order to minimize the possibility of excessive noise and cross talk being experienced as a result of low signal levels. In those cases where a channel may be used for either transmitting or receiving, duplicate equipment is provided at each terminal which can be connected or disconnected readily to provide equalization at the receiving terminal in either case.

### *Transmission Objectives*

Channels for local service are provided to transmit the band of frequencies specified by the customer in his order. Within this band all frequencies are to be transmitted with uniform loss within abont 1 db.

The over-all noise on 5-kc local channels will not exceed 36 db above reference noise (program weighting) measured at the receiving end of the circuit with a 2B noise-measuring set and with tbe input terminated in 600 ohms, and no intelligible cross talk (words or syllables) will be audible. This will be equivalent to a signal-to-noise ratio of 62 db at the +8 VU transmission level points and will be adequate on all channels on which the equalized net loss does not exceed 12 db.

Signal levels in excess of +8 VU should not be transmitted over local channels in order to avoid the possibility of cross talk into other communications channels. Signal levels should be carefully checked and maintained by the proper use of standard volume indicators.

### *Volume Measurements*

It has been pointed out that audio program networks are frequently rearranged by switching operations and that the point of program origin is not always the same. Networks are not necessarily lined up as over-all entities but are lined up as sections in a manner such that normal switching operations and reroutes due to trouble conditions can be rapidly effected without transmission adjustments. In the over-all network, different levels may exist at different points at any one time, depending upon the types of equipment and facilities assigned and their operating requirements, but the over-all system is so adjusted that these levels will be correct when the input level is correct. It is obvious that an incorrect level at the input to a system which has been properly lined up will result in incorrect levels throughout the system. It is also apparent that an adjustment made in one part of a system to compensate for a variation in another part of the system can seriously interfere with the entire coordinated operation.

Excessively low volume levels at any point will result in objectionable noise being heard on the over-all system, and excessively high levels will result in undesirable distortion, particularly that which results from amplifier overloading. To ensure that neither of these conditions occurs it is essential, therefore, not only that all channels be correctly aligned in transmission tests but also that the volume level of the program material at the source be correctly maintained. The transmission line-up of network facilities is a telephone company responsibility, and the responsibility for maintaining correct levels at the program source rests with the broadcasters.

The local channel is the meeting point between the telephone company and the broadcasters, and it is at this point that the principal need for uniformity of thought and practice exists. For this reason the following discussion of volume measurements, although it applies to over-all network operation as well, is included in this section on local channels.

Transmission line-ups of program units are based on the use of a single-frequency signal at 0-dbm level at the +8-VU input point to the unit, and the levels at all points are adjusted with respect to this fixed level. It is the nature of program material, however, to vary considerably in volume, the range of variation and the maximum volumes being dependent upon the type of program. The operating conditions on a network, therefore, are vastly different from the line-up, so it becomes necessary to correlate the volume of program material with the level of transmission measurements. The standard volume indicator, having the characteristics prescribed in "American Recommended Practice for Volume Measurement of Electrical Speech and Program Waves," ASASPC 16.5, 1942, is accepted as the industry standard for this purpose, and it is used for the measurement and comparison of program volumes at all significant network points. The correct use and interpretation of the readings of these instruments are therefore of primary importance in proper network operation.

To maintain volumes which are satisfactory within the tolerances of network facilities, the technique of controlling volume at originating points consists of keeping the average maximum volume as close as possible to +8 VU without having to reduce too many volume peaks with a consequent loss of volume range. If this average maximum volume is maintained at the zero-transmission-level point at the input to the local channeel, then correct levels will obtain throughout the network. It also follows that the same volume should be read at all other network points which have been lined up to zero level on single-frequency line-ups. The readings at any other points can be corrected to an equivalent zero reading. Then by simultaneous readings at various points it is possible to verify that all network sections are operating properly or to determine in which section or sections deviations exist.

Information concerning the circuitry and calibration of the volume indicator is available in other literature. The following information relates specifically to certain conditions which may be encountered in network operation where the proper interpretation of volume indicator readings is dependent upon the manner of connecting the instrument to the circuit.

### *Methods of Connecting Volume Indicators*

In the methods of use of volume indicators illustrated in this section the use of amplifiers with 600-ohm input and output impedances is assumed and the gain of the amplifier is the gain measured with a 600-ohm measuring set.

Figure 1-24 shows two variations of a method of use of the volume indicator in which it is connected permanently across the circuit or loop on which the volume is to be measured.

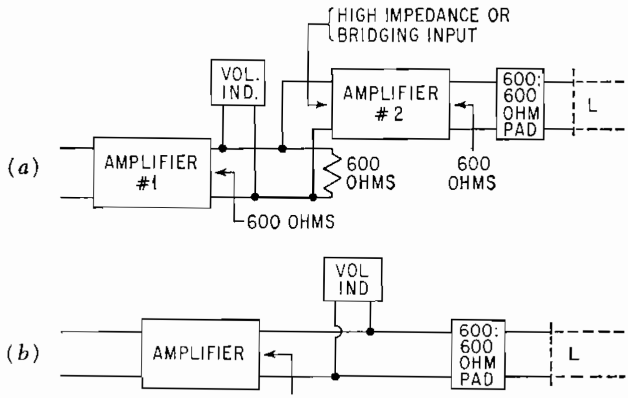



FIG. 1-24. Volume indicator permanently connected across loops.

In the arrangement shown in Fig. 1-24*a*, the indication of the volume indicator plus the gain of amplifier 2 minus the loss of the pad is considered the volume at point *L*.

In the arrangement shown in Fig. 1-24*b*, the volume indicator reading minus the loss of the pad is considered the volume at point *L*.

NOTE: In some cases the impedance of the loop or circuit may differ from 600 ohms by such an amount as to require a correction to the actual volume-indicator reading. This correction can be determined as given under the Correction of Volume-indicator Readings.

The arrangement shown in Fig. 1-25 is used by the Telephone Company at many network branching points where it is necessary to feed a number of circuits simultaneously. The resistance bridge has constant loss and impedance for all branches. Amplifier gains either are identical or differ by calculated amounts, depending upon the types of circuit being fed. The volume indicator is connected to one of the branches through its own amplifier. It does not, therefore, affect the power transmitted to the various branches.

With equal pad values and with amplifiers 1 and 2 set for identical gains, the indication of the volume indicator is considered the volume at point *L*.

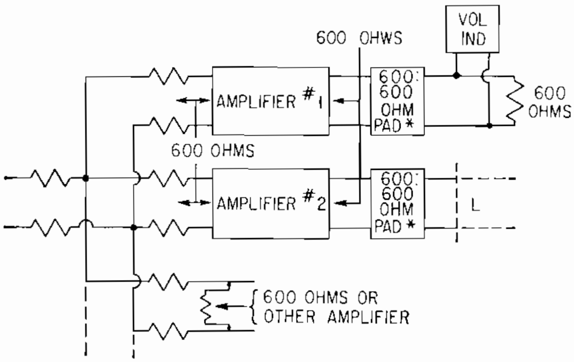



FIG. 1-25. Volume indicator connected across a bridge output.

The volume indicator in the arrangement shown in Fig. 1-26 does not take any power from the main circuit.

The volume-indicator reading minus the gain of amplifier 2 less the loss of the pad gives the volume at point *L* (see note regarding circuit impedances).

Figure 1-27 shows two ways of connecting volume indicators by means of bridge circuits.

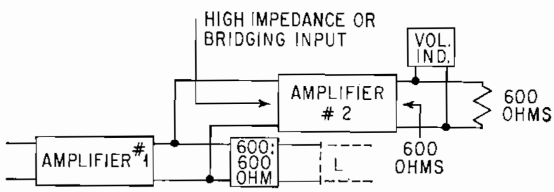



FIG. 1-26. Volume indicator bridged across a 600-ohm termination.

The volume-indicator reading, without any correction, is considered as being the volume at point *L*. The loss introduced between the amplifier and point *L* in either case is about 6 db. The balance obtainable with an amplifier of 600-ohm nominal output impedance should be sufficient (practically) to eliminate any effect of the loop impedance upon the volume-indicator readings. The entire wiring of the unbalanced circuit *A* should be shielded.

## *Transmitting Pads*

The readings of a volume indicator on average program material are influenced mainly by the energy in the frequencies below 1,000 cycles. The impedance below 1,000 cycles, presented by a local channel, therefore is of most importance in its influence on the readings and, consequently, on the amount of isolation needed between the volume indicator and the local channel for correct readings. For the usual channel of nonloaded cable this impedance varies with frequency, the range of variation depending upon the length, the gauge of the conductors, the equalizing arrangement applied, and, if a transmitting transformer be used, its impedance ratio. If this is a 1-to-1 impedance-ratio transformer or if the transformer is omitted altogether, a 6-db pad will normally be sufficient to make the readings of the volume indicator on average program material agree within 0.2 or 0.3 db with what they would be if the volume indicator faced a pure 600-ohm resistance in the direction of the local channel. If, however, a 4-to-1 impedance-ratio transformer is used at the transmitting point, as is done in most nonloaded cable equalizing arrangements, the impedance faced by the volume indicator will be much higher than with a 1-to-1 impedance-ratio transformer and the errors in the volume-indicator readings, even with a 6-db pad, may be

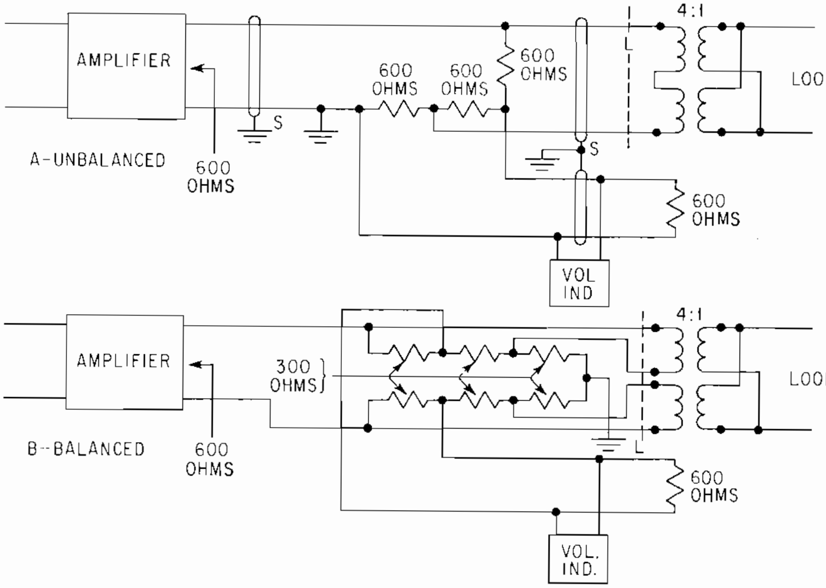



FIG. 1-27. Volume indicator connected by bridge circuits.

1 db or more. Use of larger pads will reduce these deviations, but this will increase the outpnt requirements on the amplifier, and alternative arrangements, as discussed subsequently, should be considered.

Most amplifiers now in use in broadcasting plants for transmitting into local channels have adequate output capacity to permit use of 6-db isolation pads and still apply a +8-VU level to the local channels without objectionable distortion.

Taking all the foregoing factors into consideration, 6 db should be the minimum value for an isolating transmitting pad where a transmitting transformer of 1-to-1 impedance ratio is used or where the transformer is omitted entirely.

### *Special Isolating Measures*

Where a transmitting transformer of 4-to-1 impedance ratio is used, other measures will be required for obtaining a correct indication of the volume being transmitted to the loop. Among these may be mentioned:

1. The use of pads larger than 6 db where practicable.
2. The application of specially designed impedance-adjusting pads.
3. The use of pads which provide isolation between two branches of a circuit by application of the Wheatstone-bridge principle.
4. The connection of the volume indicator to a paralleling branch of the circuit

having a separate amplifier, as is shown in Fig. 1-25. This arrangement is one used quite generally by the Telephone Company in its offices.

An example of a balanced-type output circuit is shown by Fig. 1-27*b*. The circuit in this case case incorporates a 4-to-1 impedance-ratio transformer connected to the local channel. The loss of this circuit is about 6 db, and the isolation of the volnme indicator will, as in the previous example, depend upon the match between the amplifier impedance and 600 ohms but will normally be several times the amount of loss introduced into the circuit by this arrangement.

### *Correction of Volume-indicator Readings*

Under Transmitting Pads, various measures are considered for reducing the influence of a nonuniform channel impedance on the accuracy of volume-indicator readings. Application of some of the arrangements discussed, particularly in the cases of Figs. 1-24*b* and 1-26, may still leave an objectionable residual error. The amount of this error at any given frequency (say 400 or 500 cycles) can be determined by comparing the volume-indicator reading (at that frequency) when the channel is connected in the normal operating condition with the corresponding volume-indicator reading obtained when a 600-ohm resistance is substituted for the channel.

In this test the transmitting transformer, if used, forms part of the channel and should be disconnected along with the channel when the 600-ohm resistor is substitnted. Tones of the frequencies mentioned can safely be transmitted at 0 dbm without danger of interference with neighboring circuits, and their effect on volume indicators compares closely with that of average program material for a test of this kind.

Where the difference between the two readings obtained in this test is not more than 0.3 db, it will usually be satisfactory to care for this by adjustment of the slide-wire resistor in the volume-indicator circuit. The procedure in this case is as follows: Make sure the volume indicator has been properly calibrated for use as in Fig. 1-24. Connect the 600-ohm resistance in place of the channel, and adjust the testing tone until the volume indicator shows the volume level to be transmitted (e.g., +14 VU with a 6-db pad). Disconnect the 600-ohm resistance, and reconnect the channel. Adjust the slide-wire until the volume indicator again reads +14 VU.

If the correction is found to be larger than 0.3 db, compensation by this method might disturb the dynamic characteristic of the volume indicator to an undesirable degree and other measures for reduction of the deviation, as discussed under Transmitting Pads, should be considered.

If a deviation of any appreciable magnitude is not to be corrected physically, the corrections should be applied algebraically in checking measurements with other points.

In the case of the method of use shown in Fig. 1-26, the correction can be determined by the same procedure as just described for Fig. 1-24. In this case, however, the gain of amplifier 2 is adjusted to obtain the desired compensation.

In the arrangements shown in Figs. 1-24*a*, 1-25, and 1-27, no deviations due to the effect of loop impedance will be involved.

### *Volume-indicator Scale for Peak Checking*

Peak checking between the Telephone Company and the broadcasters will normally be done by reference to the 0 to 100 scale on the volume indicator.

The broadcasters prefer the use of the 0 to 100 scale because it is applicable to direct indication of the per cent modulation of the radio transmitter or the per cent utilization of the facilities involved.

Differences in volume should preferably be discussed in terms of decibels. The justification for this lies in the relationship to the need for changing amplifier gains or pad values, which are designated in terms of decibels. The use of the term VU in this connection is permissible, although incorrect.

## Intercity Facilities—The B-22 Cable System

### *Cable Facilities*

The B-22 cable program system was developed to provide a high-quality network transmission system capable of transmitting a frequency band from 35 to 8,000 cycles. The wire facilities are 16-gauge pairs which are included in intercity cables along with other long-haul wire facilities which are normally quadded.

The designation B-22 relates to the pattern of loading of the facilities. Loading consists of connecting into each pair of wires in the cable lumps of inductance in the form of loading coils whose function is to counteract the distributed capacity of the pair. While this inductance does reduce attenuation, the combination of inductance and cable capacity creates a filter configuration which has a definite cutoff frequency. This is related to the amount of inductance added and the spacing between loading points. The B-22 system employed for cable program transmission facilities is based on the use of 22-mh inductance coils every 3,000 ft, or B spacing.

Intercity cables usually are composed of quads of wires. That is, two wires are twisted to form a pair and then two pairs are twisted to form a quad. The four wires of each quad are carefully balanced in order to permit the derivation of a third channel, or phantom, from each quad. For the B-22 program facilities single or non-quadded 16-gauge pairs are used which are laid up in the cable with the 19-gauge quadded complement. This cable make-up results in improved performance with respect to cross talk, babble, and other interferences. Connection from the cable facilities to office equipment is made through a lead-covered cable which connects the two units directly, bypassing office distributing frames. This cable is made up in quads, but only one pair in each quad is used, the idle pair providing separation to reduce cross talk.

### *Program Amplifiers*

Two types of program amplifiers are in general use on B-22 cable systems: the 12-C and 14-C. The 12-C program amplifier is a two-stage amplifier using W. E. Co. 101F and 102F tubes. It is designed for essentially flat gain from 35 to 8,000 cycles with an output level of +4 VU and a maximum gain of 36.5 db. On 5,000-cycle circuits it can be operated at +8-VU output level. The input and output impedances are 600 ohms.

The input circuit is provided with a shielded input transformer to prevent longitudinal potentials which originate on the line from acting on the amplifier circuits. Following this are two pads for coarse-gain adjustment and terminals between which any required gain- and delay-equalizing networks can be connected. The interstage is a resistance-capacitance network which provides satisfactory low-frequency delay distortion. Terminals are provided in the output circuit for connection of automatic-gain-regulating networks between the tube and the output transformer. The output transformer is essentially a hybrid coil which provides a monitoring or bridging winding. The level at the terminal of this winding is approximately 20 db down from that at the output terminal, and the gain-frequency characteristic is identical.

The 14-C amplifier is also a two-stage amplifier, but each stage is push-pull, and negative feedback is provided, derived from a winding on the output transformer. The amplifier provides a flat gain of 40 db over the range of 35 to 8,000 cycles to a 600-ohm load or of 34 db over the same frequency range through a bridging multiple to a +8-VU outlet. At 600 ohms, the output level may be as much as +20 VU. Unlike the 12-C amplifier, gain and delay equalizers are connected externally at the input of the amplifier and no provision is made for connecting automatic-gain-regulating networks. It cannot, therefore, be used as a regulating repeater.

### *Regulation*

In long-cable systems a considerable variation of transmission loss is encountered as a result of continuous changes in cable temperatures. This variation, which is not uniform over the frequency band, is of such magnitude that it must be continuously and automatically compensated. In intercity cable systems this process is designated regulation and is under the control of a pilot-wire regulating system. In this system, a loop of the two wires of one pair in a cable on either side of the regulator station is extended to the ends of the regulator section. A regulator section is usually three to four repeater sections long, and the regulating office usually is located near the middle. The pilot-wire pair is connected into a Wheatstone-bridge circuit at the regulating office so that any change in its resistance will unbalance the bridge. This unbalance is automatically compensated by the regulator circuitry, and the correction is transformed into mechanical movement of an arm which wipes successively over a series of contacts. As these contacts are made, other relays are actuated which in turn change the networks which are associated with regulating amplifiers. While the change in pilot-wire resistance is continuous, regulation is in steps, as contact is made at successive points. The regulating networks apply a gain correction which varies with frequency in a manner to balance the gain-frequency change which occurs on the cable as its temperature varies.

### *Equalization*

In the B-22 cable system, variations in the gain-frequency characteristic due to temperature changes of the cable are compensated automatically as just described. It is necessary, however, to provide equalization which is adjusted manually at certain intervals in order to remain within the operating range of the automatic system. This basic equalization is provided by a series of fixed and adjustable equalizing networks which are combined as required to complement the characteristics of various lengths of repeater sections. In general, a basic network is used which approximately matches the line section and supplementary networks are added as found necessary by measurements. The characteristics of each network are adjustable through the use of plug-in resistance pads. Delay equalization is provided by fixed delay equalizers which are assigned as required with the attenuation equalizers.

When used with 12-C amplifiers, the equalizing networks become a part of the amplifier circuit. With 14-C amplifiers the networks are electrically separated from the amplifier. In this application, transformers are used at the input and output of the equalizer network grouping to isolate the unbalanced equalizers from the balanced connecting circuitry.

### *Bridging*

A variety of bridging arrangements have been standardized for use in meeting various circuit requirements, as, for example, varying numbers of outlets, terminal or through transmission, in and out or bridged local channels, and the type of program amplifier used. A typical arrangement is described in the following section on Reversible Facilities.

### *Reversible Facilities*

In the general section it is pointed out that network operation frequently involves a change in the point of program origination. This can be provided for either by round-robin operation or by the use of reversible facilities. Reversible operation is obtained by the remotely controlled operation of relays which interchange the amplifier input and output connections at all repeater points. The operation can become quite complex and involve the switching of equalization when the cable lengths on either side of a repeater are markedly different and the switching of local channels from receive to transmit when a receiving point becomes the originating point. A single representative arrangement will be described.

Relay control at any intermediate point is extended to the control office over a control circuit which is obtained from the transmission pairs themselves by means of a resistance simplex bridged across the pairs in the station apparatus. The line relays are controlled by direct current transmitted over the simplex circuit from the control point. The arrangement is such that the circuit is set up by the control point to transmit away from that point; that is, the direction of the circuit is under the control of the transmitting point and cannot be set up to transmit toward the control point while that point retains control. Any control point, once having obtained control of the network, retains control until it is released. In other words, a station having control locks out the control at all other points. Upon release of control, the transmission path remains unchanged until reversed by control from some other point.

The control current is relayed at each nonbridging repeater point through the line relays directly, so +130 volts is supplied at each point to the next repeater section.

A control and reversing panel is provided at each point where transmission into the program network is to take place. This panel is equipped with the keys necessary to perform control and reversing functions on one system. Visual indications of the circuit condition are also provided.

Figure 1-28 represents a typical station arrangement at a bridging station employing a 14-C amplifier and associated G-type bridge. The G-type bridge shown is one of several of the general type of resistance-splitting devices designed to provide different numbers of outputs and levels (+8 VU for cable, +14 VU for open wire) from a single input fed by a 14-C program amplifier. Reference is also made to secondary and tertiary controls.

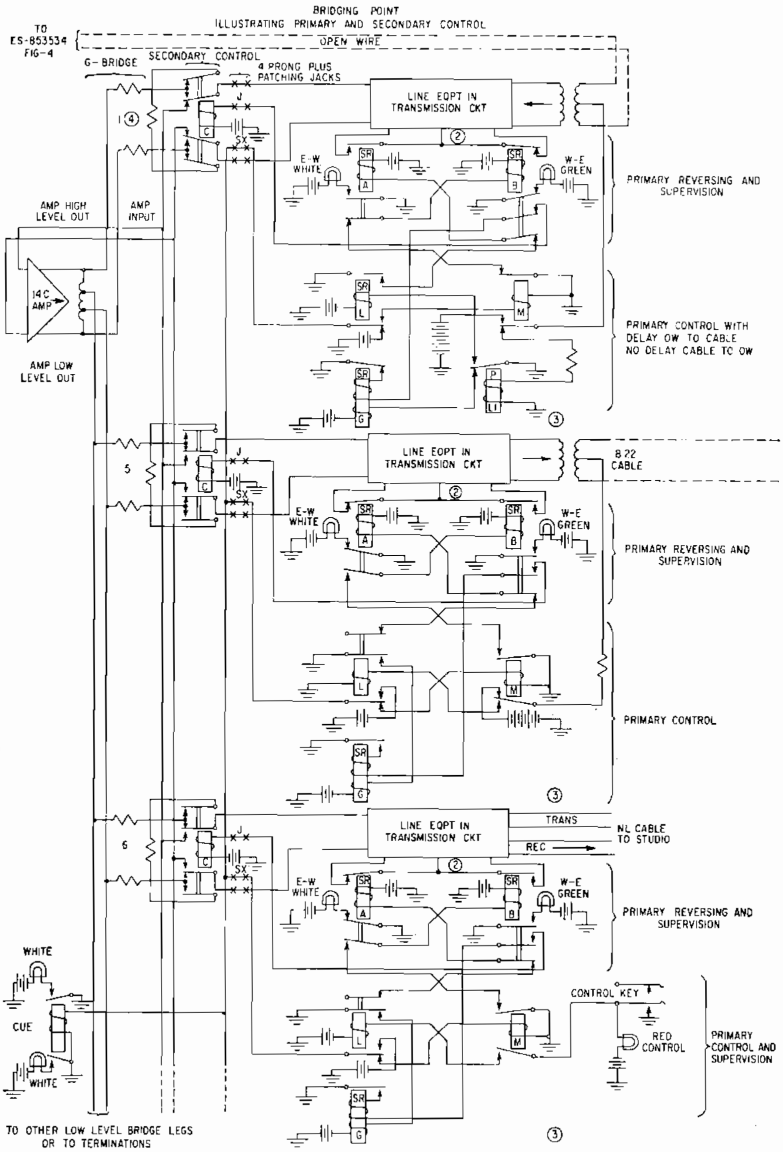
Secondary controls are associated with G-type bridges to transfer the line associated with a particular leg either to the input of the 14-C amplifier when the primary control is in one direction or to the output of the bridge when the primary control is in the opposite direction.

The function of the tertiary control is to provide switching at the input of the 14-C amplifier to connect or disconnect certain common equipment as required by the transmission path established.

The control current is taken from the program pairs through the simplex leg of the line repeating coil on the incoming program circuit and is relayed through the primary control to an Sx lead which parallels the bridging multiple and is connected to all the primary controls associated with this bridge. It is this Sx lead which ties all the lines together for this bridge as far as the control circuit is concerned so that a control signal coming in on any line can take the proper control and be relayed to all outgoing lines as desired. Delay is introduced in the release of the L relay associated with open-wire circuits connected to G-type bridges having both open-wire and cable facilities in order to prevent intermittent interference being imposed on the cable facilities.

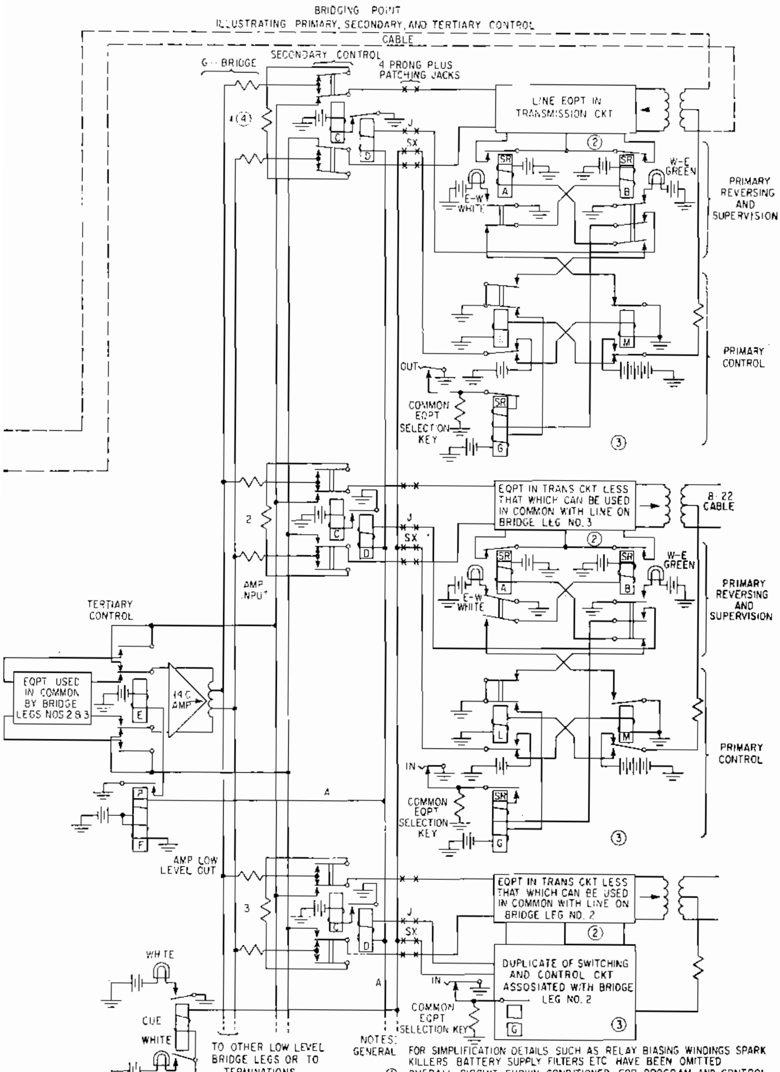
In some cases at a bridging point where several similar lines are associated with the bridging multiple, it may be possible that certain line equipment associated with each line is common for several lines, and so economy in equipment can be obtained if such equipment is installed at the input of the 14-C amplifier and used in this position, in common for all those lines. A case where some, but not all, of the lines use common equipment is shown by Fig. 1-28*b*.

In the drawing, the bridge is shown connected both to cable channels employing common equipment and to those having individual equalizers, so that the arrangements are the same as those described above except for this point regarding the common equipment. Here the secondary control is equipped with an additional relay *D* which is controlled by the *J* lead from the primary control. This *D* relay controls the *C* relay for switching at the output of the bridge. In addition, the "tertiary control" is controlled by the *A* lead, which is a continuation of the *J* lead beyond the *D* relay. This tertiary control controls switching at the input of the 14-C amplifier and determines whether or not the common equipment is in the circuit. The operation of the tertiary control is also controlled by means of the common equipment-




(*a*)

FIG. 1-28 (*a*) and (*b*). Typical B-22 reversing equipment.




(b)

NOTES:
GENERAL FOR SIMPLIFICATION DETAILS SUCH AS RELAY BIASING WINDINGS SPARK KILLERS BATTERY SUPPLY FILTERS ETC HAVE BEEN OMITTED

1 – OVERALL CIRCUIT SHOWN CONDITIONED FOR PROGRAM AND CONTROL BATTERY INCOMING ON BRIDGE LEG NO. 1 FIG 1 FROM FIG 4 OF ES-853534

2 – ONLY ONE OF SEVERAL SETS OF CONTACTS CARRYING TRANSMISSION SHOWN

3 – DIRECTIONAL KEY NORMALLY FURNISHED WITH EACH GROUP OF REVERSING AND CONTROL RELAYS KEY SHOWN IN FIG 4 OF ES-853534 ONLY

4 – ONLY ONE TERMINATION PER BRIDGE ACTUALLY FURNISHED FOR COMMON USE WHEN ANY LINE FEEDS INTO BRIDGE MONITORING CIRCUIT CAN BE USED FOR THIS TERMINATION SEE DRAWING ES-853539

selection key on the primary control. This is accomplished by controlling the amount of current sent from the primary control over the *J* and *A* leads. The *F* relay in the tertiary control is equipped with a biasing winding and is marginal in its operation. It will not operate when the 250-ohm resistance normally between the *J* lead and ground is in but will operate when this resistance is shorted out by the operation of the selection key when the common equipment is to be used. The *D* relay in the secondary control operates on either value of current. In Fig. 1-28*b* the arrangement shown is for the use of common equipment for the cable channels associated with legs 2 and 3 of the bridge while the cable channel associated with leg 1 does not use the common equipment and has all the necessary line equipment associated directly with the line itself.

## Intercity Facilities—Cable-carrier Systems

### *General*

It has previously been mentioned that the Bell Telephone Laboratories, in their development work directed toward producing ever more efficient communication-transmission systems, had concentrated much effort on carrier techniques. As more advanced systems were developed and placed in operation, each was assigned an alphabetical-type designation. Improved versions of the same general type of system were further identified by numerical additions to the alphabetical designation. Among the systems which are used to provide the long-haul backbone facilities, two types of cable carrier systems are in wide use:

Types K-1 and K-2 cable carrier systems which provide 12 two-way message channels on two cable pairs in separate cables, one for each direction, using the same line frequencies on each pair.

Types L-1 and L-3 cable carrier systems which use coaxial cables. These are described in the Television System section.

All these systems use basically the same terminal equipment (channel banks) to modulate 12 message channels into successive frequency positions 4 kc apart to form the basic groups. These groups are then further modulated as required by the particular system. The message channels thus derived have a bandwidth which extends from about 300 to 3,000 cycles and meet all transmission requirements for high-grade message service.

It is readily apparent that, by appropriate means, a band equivalent to three message channels would provide frequency space for an 8-kc program channel with adequate margin for filters on either side of the band to eliminate interference completely from or to adjacent message channels. In a similar manner a 5-kc program channel can be derived from the space of two message channels. The necessary terminal equipment has been developed and is in wide use in audio-network service, particularly for television audio service, where differential delay between the picture and the television sound is an important consideration.

A variety of equipment arrangements are available to meet the network requirements for flexibility; for bridging, dropping, or reversing; for occasional services and similar considerations. As a typical example the 5-kc system for application to K carrier will be described along with a representative bridging arrangement.

### *Terminal Equipment*

Five-kilocycle program-transmission channels (schedules A and B) are derived from K carrier systems by the application of C-1 terminal equipment. This equipment may be permanently associated with a particular channel bank, or it may be installed separately and so arranged that it can be associated with any channel bank in the station.

In either case, when it is in use, it occupies the frequency position of message Channels 6 and 7. When not in use, it can be remotely switched out and the message

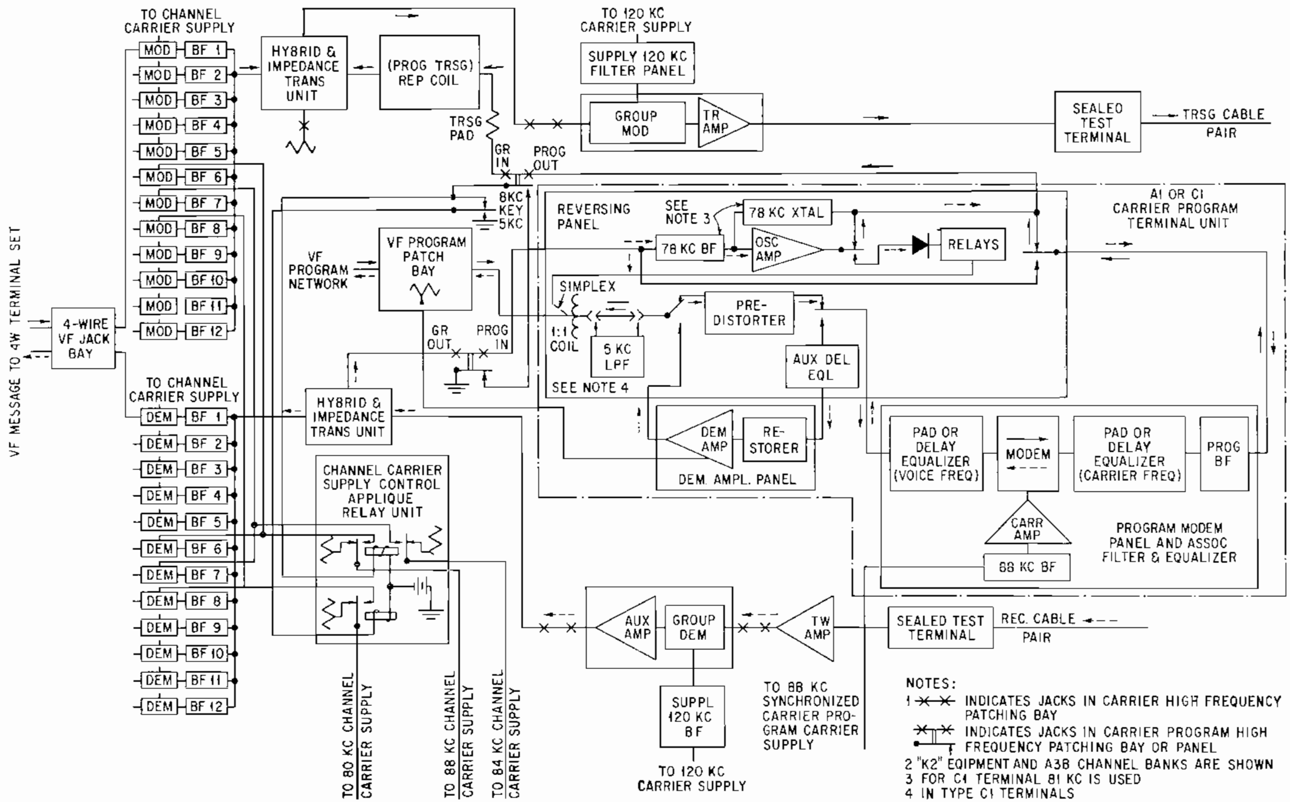



FIG. 1-29. Schematic of type C-1 program terminal.

equipment, which is always provided, put in use. A block schematic of the major features of the terminal is shown in Fig. 1-29.

The terminal is conditioned to transmit or receive by the presence of a control tone from either direction, as described later. In the transmitting direction, message Channels 6 and 7 are disabled and the program terminal is prepared for transmitting by d-c signals applied to the simplex channel at the high-frequency patch bay and the program control room, respectively. The voice frequency program material is received from the program control room and passed through a 5-kc low-pass filter and a preemphasis network to a modulator where it modulates an 88-kc carrier. The upper sideband and carrier are suppressed, and the lower sideband is combined with an 81-kc control tone and applied to a branch of a hybrid coil where the signal is combined with the working message channels in the range between 60 and 108 kc. The entire group is then again modulated with a 120-kc carrier, which produces frequencies in the range between 12 and 60 kc that are transmitted to the line.

At the receiving terminal the reverse action takes place. After the first stage of demodulation, the program and message signals are divided into two paths by the receiving hybrid. The 81-kc control tone conditions the program terminal for receiving, and the program material is passed through a filter to the demodulator and the delay equalizing networks. The voice frequency program signals are then passed through the restorer network and an amplifier and transmitted to the control room.

### *Bridging Arrangements*

Bridging and splitting arrangements can be provided at any amplifier point where the line characteristics have been suitably equalized. Several types of bridging and splitting arrangements are available for use in meeting different requirements. As an example, assume a bridging point which may receive program from the through line most of the time but is occasionally an originating point from which program must be fed in both directions.

To provide for receiving from a 5-kc program channel, blocking filters are inserted in the main line which pass the line-frequency signals of message Channels 1 to 5 and 8 to 12 and permit the line-frequency program signals to be picked off. The program signals are then passed to a receiving program channel which is conditioned by the control tone and delivers the audio-frequency material in the same manner as at a channel terminal. Normally program is received from only one direction at a time at an intermediate point. One reversible program terminal arranged for switching to the desired direction of receiving would meet the requirement. However, program branching points can be equipped with two reversible terminals for greater flexibility. With two terminals arranged for transmitting, program can be fed in both directions simultaneously by connecting one to each of the oppositely directed main line circuits. It is also possible to receive from one direction and transmit in the opposite direction on the same main-line channel. This is sometimes done to provide "in-and-out" service to the local station.

The filters which are used in the arrangement, however, introduce delay distortion because of their sharp cutoff characteristic. Tandem use of terminals is therefore avoided whenever possible, and at branching points arrangements are provided whereby the blocking filters are removed from the through line and the receiving terminals are bridged on. When transmission from the branching point is desired, the circuit is set up by manually controlled relays for transmission in either or both directions.

# *Part 2*

# TV MICROWAVE SYSTEMS ENGINEERING

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## INTRODUCTION

Microwave systems used by TV broadcast stations must be engineered to provide as high a degree of relability as other units in the television station. A microwave system is truly a link between the broadcaster's program source and his transmitter. Sometimes this reliability must be achieved with one or more microwave repeaters. The frequencies currently allocated by the FCC for television video use by broadcasters are those channels in the 2,000-, 7,000- and 13,000-Mc bands. These frequencies are so high that radio transmission in this spectrum behaves very much like light waves. Such waves are heavily attentuated when they travel over the ground. These frequencies, on the other hand, when traveling upward, are not reflected back to earth by the ionosphere, as are the VHF frequencies. As a result of discontinuities in the lower atmosphere (from ground to 2 miles up), they may, at times, be deflected upward or downward. These changes can occur very rapidly, sometimes in a matter of seconds.

In view of these and other factors, it is advisable to locate TV relays where a line of sight exists between the transmitting and receiving antennas. The actual amount of clearance for various conditions and techniques for overcoming various propagation difficulties will be discussed.

The TV broadcaster does not usually have a choice of sites for his microwave units. The positioning is usually dictated by the location of his studio and his transmitter, for studio to transmitter links, and the place of origination for remote pickups. It is up to the engineering staff of the television station to make the best possible use of these predetermined sites.

A microwave link, in order to operate satisfactorily, must have an overall system gain which exceeds the system attenuation by an amount necessary to provide high-quality video and a high order of reliability. In addition, if audio is multiplexed, its subcarrier must not degrade the video nor must the video degrade the audio program.

Through the use of sound engineering practices, excellent performance may be had in television microwave systems. Suggested specifications for performance requirements are set forth in Table 2-1. They apply to both short-haul remote pickups and studio-to-transmitter links (STL) as well. Studio-to-transmitter links up to 40 miles as well as multihop links should be capable of meeting these specifications. Engineering data and information are submitted to make possible such performance.

* No longer employed in this capacity.

Installed systems not meeting these specifications of performance can be improved by following the suggestions for improvement outlined in the last portion of this part.

**Table 2-1. Microwave Relay System Performance Specifications for STL and Remotes**

*Video performance* (with simultaneous single-channel audio):

1. Carrier frequency stability of transmitter to be $\pm 0.05\%$.
2. Amplitude frequency response to be within 0.5 db from 60 cycles to 5 Mc.
3. Differential gain from blanking level to peak white to be equal to or better than 0.5 db with 100% modulation.
4. Differential phase with respect to reference burst, to be equal to or less than $\pm 1°$ at 100% modulation.
5. Signal-to-noise ratio shall be better than 53 db, peak-to-peak video signal to rms noise, from 60 cycles to 5 Mc.
6. Sync compression shall be less than 10%.
7. Composite video input level to be 1.0 volt peak to peak.
8. Video output level to be 1.4 volts, peak to peak.
9. AFC system shall provide for unattended operation of system.

*Audio performance* (with simultaneous color video transmission):

1. Amplitude frequency response to be uniform within $\pm 1$ db from 50 to 15,000 cycles.
2. Distortion with sine-wave audio and EIA test pattern video shall be less than 1.5% from 50 to 15,000 cycles.
3. Audio signal-to-noise ratio to be greater than 58 db, with EIA test pattern video.
4. Audio input level to be $-5$ dbm minimum.
5. Audio output level shall be $+8$ dbm maximum.

## WAVE PROPAGATION

Attenuation may be defined as a decrease in the intensity of electromagnetic waves. There are a great many factors which cause microwave attenuation. The fundamental loss results from the spreading of energy through space. When microwave relay stations are installed, the distance between the transmitter and the receiver is of great importance. The attenuation of the transmitted signal will largely determine the maximum range obtainable for reliable reception of the signal.

Distributions of temperature, barometric pressure, and water vapor materially influence the propagation of radio waves in the troposphere. This is the area of the atmosphere from the earth's surface up to about 6 miles. The variations of the temperature, pressure, and water vapor are expressed by the index of refraction. This index decreases linearly with an increase in height in the standard atmosphere. The normal value of the refractive index is in the order of 1.0003. Most reference texts use a modified index of refraction which includes a term to compensate for the curvature of the earth, so that beam-ray diagrams can be plotted on the basis of a plane earth. Since the units are inconveniently small, a refractive modulus is used and defined as

$$M = \left(n + 1\frac{h}{a}\right) \times 10^6$$

where $M$ is the refractive modulus, $n$ is the refractive index, and $h$ is the height in the same units as $a$, the earth's radius. Thus, the normal value of $M$ at the earth's surface is approximately 300. A positive gradient of $3.6M$ units per 1,000 ft of height corresponds to a standard refraction.

Greater than standard refraction is caused by smaller positive $M$ gradients. Negative gradients cause superrefraction, or ducting. Upward bending of the transmitted ray, or substandard refraction, is caused by large positive $M$ gradients. In terms of dielectric constants, a uniform decrease with height results in standard refraction. Since the refraction normally decreases with height, the upper portions move with higher velocity than the lower portion. Thus the wave path can be represented by rays curved slightly downward toward the earth. As a result, the distance to the radio horizon is some 15 per cent greater than the geometrical line-of-sight distance from the transmitter to the horizon. This is the condition due to normal refraction of the atmosphere.

The signal at the receiver is the vector sum of the radio waves arriving at the antenna from the direct and any other path. Reflected rays are the result of the earth or large bodies of water acting as a reflecting body. Water and salt flats are very efficient reflectors, while rolling hills and terrain with vegetation may reflect only 10 per cent of the energy striking it at microwave frequencies.

The angles of harmful reflection in microwave propagation are very small. Therefore, it is not too important whether vertical or horizontal radiation is used as long as both the transmitting and receiving antennas are polarized in like manner. Since the reflection angle is very small, the phase lag is nearly 180° between the incident and reflected waves.

The wavefront may be arbitrarily divided into circular zones in the normal propagation of these frequencies. These circular zones are centered on the direct ray line such that the path-length difference from the transmitter to receiver will differ only by one-half wavelength for each zone. These areas are called Fresnel zones. Their radii vary from point to point along the path. Energy from alternate zones either adds to or subtracts from the wave in the first zone, which contains about 25 per cent of the total energy. Therefore, it is imperative that line of sight plus the first Fresnel-zone clearance be obtained between the transmitting and receiving antennas. Figure 2-1 shows the first Fresnel-zone radius at the center of the path for the three microwave bands allocated to TV broadcasters. It also shows the radius at various intermediate points.

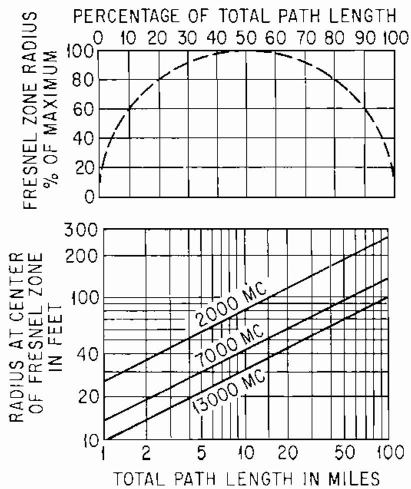

FIG. 2-1. Fresnel-zone radius.

## FADING

The path length, frequency, clearance above terrain, and the meterological conditions are the important factors in the consideration of fading. Data on 13,000-Mc fading is not conclusive but is known to be in excess of that occurring at 7,000 Mc.

The variable factor, the refractive gradient, affects the higher frequencies of propagation more than the lower. Fading depths and duration are greater on 13,000 than on 7,000 Mc; while 2,000 Mc, the lowest band available to broadcasters for video use, is the least affected.

Assuming first Fresnel-zone clearance, steady transmission occurs in a microwave link when the air along the path is well mixed or homogeneous. This excellent condition occurs during stormy, windy weather. The refractive gradient $M$ is then nearly standard.

Signal fading occurs in the presence of irregularities in the refractive gradient. A marked change in signal level invariably accompanies refractive gradient irregularities over non-line-of-sight paths or paths without full first Fresnel-zone clearance. For line-of-sight and Fresnel-zone clearance paths, the signal-level change is more diurnal in nature, indicating that fading is of the single-path variety. Generally, a diurnal signal changes from a steady condition at noon to a type characterized by pronounced fading within 2 hr after sunset. It occurs again within 2 hr before sunrise. Diurnal fading is more pronounced in summer than in winter because this type of fading is caused mainly by a change in the humidity gradient. This in turn is caused by temperature changes, also causing pressure changes. All three atmospheric factors are interrelated.

Extremely stormy conditions may seem to produce the effect of fading by causing antenna alignment variations, but these are not true propagation fades. Correlation between weather conditions and received signal on microwave circuits has been investigated.[*,4] It is interesting to note here that considerable change in refractive-

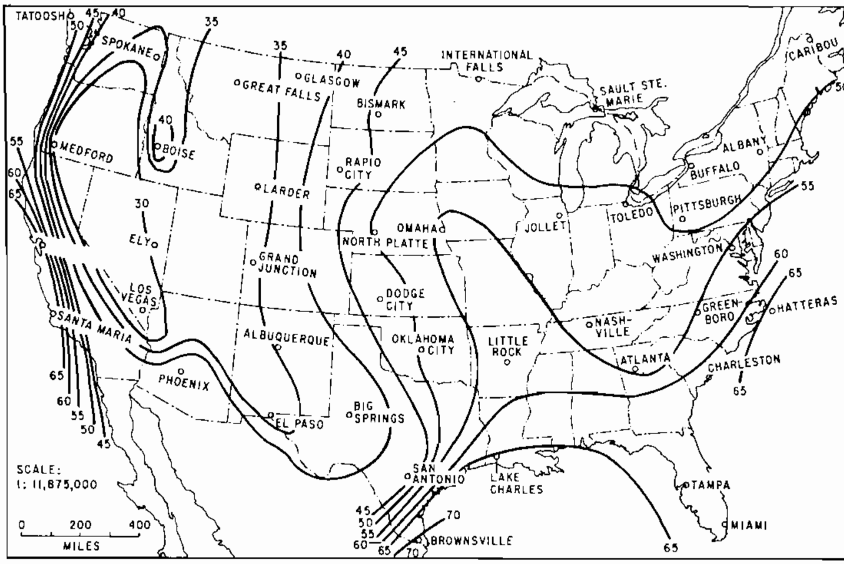


FIG. 2-2. Six-year average of monthly median values of $\Delta N$ taken from the surface to 1 km above the surface in August. (0300 GMT)

gradient structure exists at various parts of the United States. The West Coast and the southern Gulf Coast of Texas are areas where abnormal refractive gradients are the general rule throughout the year. The remainder of the United States as shown in Fig. 2-2 has very little change over short path lengths.[5] Delta $N$, as used in Fig. 2-2, is the simple difference between the value of refractivity at the earth's surface and at 1 km.

## Types of Fading

As pointed out earlier, the normal atmospheric conditions cause the microwave beam to be bent downward slightly. This downward bending of the line of propagation has a radius of approximately $\frac{4}{3}$ times the earth's radius, which corresponds to straight-line propagation on a fictitious earth with a radius of $\frac{4}{3}$ the actual earth's radius. Unfortunately, in actual practice, this so-called standard atmosphere varies with time. This in turn varies the downward bending, causing minor fading.

Lines of propagation plotted on true earth curvature paper is usually necessary in television broadcast station microwave siting, since even in long STLs, the receiving antenna, by virtue of the choice location of the TV station transmitter, is usually within line-of-sight. When doubt exists as to line-of-sight conditions, they can be checked out by means of 2-kw Fresnel spotlights, located at the height of the proposed antenna. Visual means of observation should be checked, with caution being taken to make such tests during periods of low humidity to avoid refractivity of the light beams.

[*] Superscript numbers refer to references at end of Part 2.

### Greater than Standard Refraction

· Sometimes called "superrefraction," this sort of fading is caused by meteorological conditions. The refraction of microwaves may increase until it is equal to the earth's curvature and the waves tend to follow the surface of the earth. This type of superrefraction fading is also called ducting and is common in areas close to large bodies of water. Evaporation of the water will cause an increase in moisture content and a decrease in temperature near the surface. This action then results in what is termed temperature inversion, the temperature being higher at the higher elevation. A quick check of this type of fading is to measure the temperature at the transmitter and the receiver. If the receiver is located at the higher altitude, the temperature should have a decrease of 3.6°F per 1,000 ft of elevation above the transmitter elevation. If this decrease in temperature with height does not exist, temperature-inversion fading may take place. The depth and duration of such fading will depend on frequency, path distance, and the extent of the refractive gradient. It is not only the temperature inversion which causes the abnormal bending but also the large increase in water-vapor content which accompanies the inversion and causes the dielectric constant to change. It is a well-known meteorological fact that the other basic characteristics of the air vary when one (the temperature, humidity, or pressure) varies.

### Substandard Refraction Fading

When heavy ground fog covers part of the path, or when the ray travels through fogs to mountain-top receiving sites clear of fog or clouds, substandard refraction fading is likely to occur. Under these conditions the dielectric constant is actually increasing with height. This causes an upward curvature of the microwave radiation. This has the same effect as tilting the transmitting parabola slightly upward. Less signal arrives at the receiver. Since the refractive index changes with time, the received signal varies or fades. In locations where heavy substandard refraction fading occurs, it is recommended that low- to medium-gain antennas be used. This procedure allows more signal during this type of fading because of the large vertical beam angles.

### Multipath Fading

It is also possible that the bending may be greater at some point *above* the direct-ray path. This may result in some free-space propagation taking place on two or more paths. Rays arriving at the receiver may have various phase relationships and thus may add or cancel. This multipath condition then will cause fading, even though the path is effectively removed from path obstacles.

### Reflected-ray Fading

Interference between the direct ray and the reflected ray must be considered where propagation takes place over smooth earth, a lake, sea water, or salt flats. Energy striking the earth or large bodies of water should be directed away from the receiving antenna, in view of signal cancellation. Another reason for avoiding reflected waves in microwave applications is the fact that this second ray may be subject to more fading because of proximity to the earth and subnormal refractive gradients. Thus, reflected waves may cause fading of the main ray by adding or subtracting in phase relationship.

If a microwave link operating over salt water varies in received-signal amplitude, such variance in signal level can be correlated with tide conditions. If this is found to be the case, then it becomes apparent that reflected-wave interference exists.

Corrective measures for this type of interference can often be devised by a judicious application of plane geometry. Adjustments of tower heights may be possible in some installations. Varying tower heights will place the reflection point upon a rough section of ground, or failing that, the reflection point may be brought as near as possible to either end of the hop. This latter procedure minimizes phase interference by reducing path-length differences.

Two other ways of avoiding reflected-ray problems have been found satisfactory in TV relay work. The receiving- or transmitting-antenna height can be varied so that an intervening hill or mountain acts as a shield to the reflected wave. The transmitting or receiving antenna or both can be tilted upward slightly in order that normal reflected rays to mid-point reflection points, for example, will be greatly reduced in amplitude.

Reflection coefficients have been measured from 0.2 for very low angles of incidence to 0.9 for angles of incidence of 0.5° over salt water.[6]

Another form of multipath fading or wave interference occurs in over-water TV links. When the transmitting parabola and the receiving parabola are located on land and a great deal of water lies in between, reflection off the water can cause either signal cancellation or addition. The result depends on the distances between dipoles, frequency, and angle of incidence and reflection. A reflection of energy from the surface of the water creates a vertical lobe structure in the antenna pattern. The number of lobes is proportional to the antenna height in wavelengths above the reflecting surface. The depth of the null between lobes depends on the magnitude and phase angle of the reflection coefficient of the water surface.

The gain pattern of the antenna usually makes only the first lobe and first null important. It should be recognized that this lobe shifts vertically only as the transmitting antenna height above the reflecting plane (water in this case) is varied. As pointed out previously, with either vertical or horizontal polarization, the reflection coefficient remains near unity with a phase angle of 180° for all grazing angles of 0.5° or less. Vertical polarization has a slight advantage, producing a somewhat lower reflection coefficient under such circumstances. Therefore, if grazing from water reflections is present, vertical polarization may reduce the effects.

Overland paths do not give reflection coefficients near unity because of the scattering and power-absorption qualities of the earth. Reflection at the right spot and right altitude is seldom encountered, and if it is, the scattering will diffuse the reflected wave.

Nulls can occur in over-water hops. In paths where sea-water tides are present, this cancellation, or nulling, will vary with the time of day at slow rates. Most troublesome fading occurs just before and after a high tide.[8]

Sea-water paths can be easily utilized, provided the usual precautions are taken with establishing first Fresnel-zone clearance throughout the path. In the 2,000-Mc band, the first Fresnel zone usually will not put the receiving antenna in a null point; therefore 4- to 6-ft variations in tides will not cause nulling. However, with 7,000- and 13,000-Mc systems, it is common to have more than first Fresnel-zone clearances. Here, then, lobes and nulls become common. A 6-ft tide will become a larger per cent of the Fresnel-zone radius, and nulling may take place more readily.

Nulling at the receiving antenna can be checked by varying the height of the receiving antenna and noting the received-signal strength. The antenna should be left at the lowest height consistent with satisfactory RF level. Polarization should be vertical.

Examples of different types of fading common in 2,000- and 7,000-Mc systems are shown in Figs. 2-8*a*, *b*, *c*, and *d*.

Determination of the absolute required path clearances for microwave propagation is a rather complex process. However, two important rules should be followed. In medium and long hops, where signal strength is a prime consideration, *first Fresnel-zone clearance should exist throughout the path.* The second rule is to maintain at least 25 ft of clearance between the beam center and any obstructions throughout the path from parabola to parabola. This means that the center of the antennas should be at least 25 ft higher than any immediate foreground obstructions. In fixed STLs, this procedure will minimize the effects of growing trees, new buildings, and moving vehicles.

## SIGNAL-LEVEL CALCULATIONS

In order to predict the performance of a microwave relay system, information is needed regarding the long-term median path losses and the characteristics of the fading to be expected. The median (average normal) path loss can be calculated between the two antennas to within 3 db. This information for the three TV microwave bands can be taken directly from Fig. 2-4. This chart shows the space loss

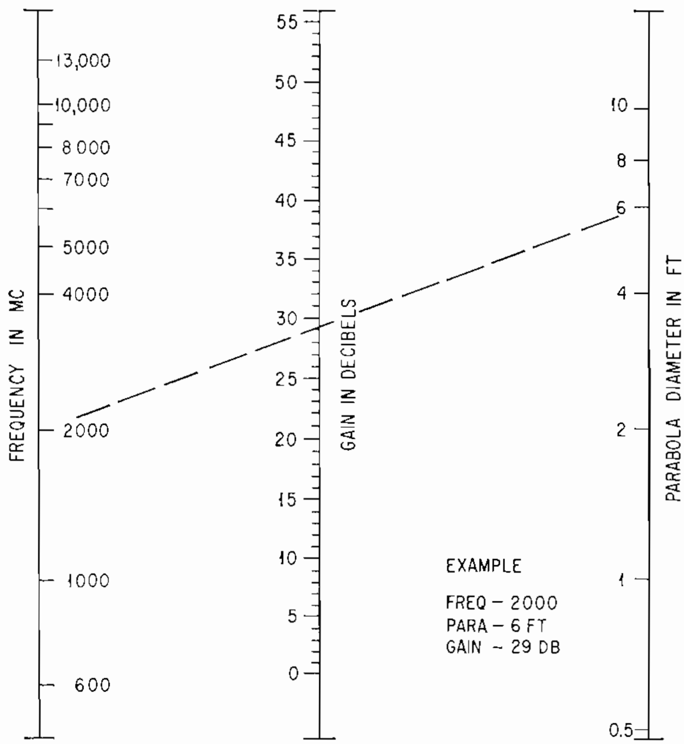


FIG. 2-3. Parabolic antenna gain over dipole.

between two dipole antennas as a function of frequency and the distance between the antennas. Thus the median space path loss can be determined with considerable accuracy. The principel need, therefore, is for statistics on fading depths appropriate to the location involved in a single-hop system or throughout the various legs in a multihop installation.

Free-space attenuation is the greatest loss item in a microwave link. This is the coupling loss between the transmitting and the receiving antenna. The energy radiated from a transmitting antenna is wasted unless it is directed toward the receiving antenna. To obtain this directivity a parabolic reflector, or dish, is ordinarily used to focus the waves. Horn antennas are sometimes used on 7,000 Mc and may become popular on 13,000 Mc because the gain varies directly with frequency. Figure 2-3 shows the gain in decibels of a parabolic antenna as a function of frequency and diameter for highest forward gain. Antenna gain is large in a normal system and tends to overcome part of the free-space loss.

In permanent microwave systems over 20 miles, it is well to make a signal-level calculation before purchase of equipment. The following factors should be considered:

1. Frequency
2. Power output
3. Antenna sizes
4. Reflector requirements
5. Performance expected
6. Fading margin and reliability

## Frequencies of Operation

There are currently allocated three microwave bands: 2,000, 7,000, and 13,000 Mc. These bands are for TV broadcast use for video transmission. Audio only can be transmitted in the 940- to 950-Mc band. Sound can be multiplexed in the three bands previously mentioned. Before signal-level calculations can be made, it is well to consider the main characteristics of these microwave bands.

**Table 2-2**

| | 2,000 *Mc* | 7,000 *Mc* | 13,000 *Mc* |
|---|---|---|---|
| Space attenuation, first 10 miles, db | 123 | 135 | 140 |
| Maximum transmitter power available, watts | 10 | 50 | 0.1 |
| Over-all receiver noise figure, db | 12 | 14 | 17 |
| Space attenuation per mile due to 0.5-in. rain per hour, db | 0.03 | 0.5 | 15 |
| Space attenuation per mile due to 2.3 gm/cu m fog (visibility 100 ft), db | None | 0.1 | 3.0 |

It can be seen from the table that there are certain physical limitations imposed by characteristics of the various frequencies that can be used. For example, the 13,000-Mc band would not be recommended for a 30-mile STL. Space attenuation plus variable attenuation due to the refractivity gradient, rain, and fog plus the stability required of the parabolas would preclude use of this band for a long hop.*

Signal-level calculations are rather simple. The gains and losses are totaled. Subtracting the losses from the gains gives the signal that is expected at the receiver end of the path. This received signal in an average system may be from 35 to 100 db below the level leaving the transmitter.

Although the normal level of the received signal can be predicted, this level is based on a condition of normal propagation, i.e., without any fading. In practice, only in short hops and in limited parts of the United States can ideal propagation conditions be found. In many parts of the country fading is minor and may go unnoticed, although it occurs throughout the year in various degrees.

Fading depths to be used in signal-level calculations cannot be determined in advance unless information regarding other systems in the area is available. Or it can be determined by setting up a temporary link over the exact path to be used and measuring the fades.

It is suggested that signal-level calculation sheets be used when surveying paths over 20 miles as well as on shorter paths where medium to heavy (10- to 30-db) fading is known to exist. These calculation sheets will give a first approximation of the results to be expected. It will also determine what frequency bands should be used, the size of the parabolas, and the transmitter power output required.

In the signal-level calculations, the margin required for fading should be at least 40 db. This will result in approximately a 53-db signal-to-noise ratio for video (peak signal to rms noise). However, when the received signal fades, say 6 db, the output video will be degraded approximately the same. This reduces the signal to noise in the output video to 53 − 6, or 47 db. To maintain a video signal-to-noise ratio of 53 db at all times, the received signal must be at least 40 db above the deepest fade encountered. This is difficult unless the system has been engineered with an adequate fading margin. It is very important in areas where atmospheric fading is prevalent to ascertain the depth of fades to be encountered and design the microwave

* Current developments are making use of these higher frequencies more feasible.

system to overcome it. This can be done by taking into consideration the following factors:

1. Choosing the frequency band that is least affected by fading
2. Using equipment in this band that has the lowest noise figure and the lowest threshold value
3. Using the largest parabolas consistent with structural limitations (wind, tower stability, etc.)

## Propagation-signal Calculations

Where nonstandard propagation conditions exist, a calculation of received signal levels is virtually impossible. Even a calculation of the required fading margin may be arbitrary. Therefore, actual performance measurements of microwave systems operating in the area are extremely helpful. Fading on existing links can be measured by calibrating the receiver limiter current with the aid of a calibrated microwave signal generator. This calibrated limiter current can be used to drive a chart recorder. Examination of these recording charts will reveal the maximum depth and duration of fades. For 100 per cent propagation reliability, the received signal should be 40 db above the deepest fade to be encountered.

Thus, if the deepest recorded fade was 23 db, adding 40-db signal required for 53-db peak rms video $S/N$ ratio makes the RF signal requirement 63 db above the threshold. This would provide 100 per cent propagation reliability. In practice, this signal level is not easily achieved at all times, thereby resulting in somewhat less than 100 per cent reliability.

Instances have been recorded where 43-db fades up to 23 min in duration have occurred in 7,000-Mc STL.[3] Where heavy fading of this nature due to refractive gradients exists, the 2,000-Mc band should be used, since it is less affected by the same conditions. In the case just referred to, a simultaneously operating 2,000-Mc link over the same path experienced a fade of 6 db for a period of 11 min. It has been concluded in tests and operation that the 2,000-Mc band is superior to 7,000 Mc, where heavy fading due to atmospheric refraction exists.[4-6]

## SYSTEM EVALUATION

The transmitter power and antenna gains are elements which contribute to the over-all system gain of a microwave link. The important elements that contribute to the over-all system loss are the transmission-line and free-space path losses. System evaluation starts at the video and audio input (if audio is being multiplexed) of the transmitter. It ends at the video and audio output terminals of the receiver.

Table 2-3 shows the no-loss maximum distance between a passive reflector and a parabola in the 7,000-Mc band, which will also serve as a guide for 13,000-Mc use, in the smaller antenna sizes.

**Table 2-3. No-loss Maximum Distance between Parabola and Passive Reflector**

($F$ = 7,000 Mc)

| *Parabola size, ft* | *Reflector size, ft* | *Max distance, ft* |
|---|---|---|
| 4 | 4 × 6 | 41 |
| 6 | | 65 |
| 8 | 6 × 8 | 82 |
| 6 | | 90 |
| 8 | 10 × 14 | 125 |
| 10 | | 150 |
| 8 | | 2,000 |

It is common practice to use large sheets to reflect energy from a conveniently mounted parabola in the 7,000- and 13,000-Mc bands. The reflector can be mounted at some distance away from the parabola before any coupling loss occurs. The allow-able distance is a function of frequency and reflector and antenna size. Distances up to 41 ft with 4-ft antennas and 4- by 6-ft reflectors can be used without coupling loss. See Table 2-3 for other antenna and reflector sizes.

Passive reflectors are not ordinarily used for 2,000-Mc systems. Low-loss coaxial cable in both rigid and semiflexible types is available for 2,000 Mc. The separation between transmitter and antenna on 2,000 Mc is limited only by the tolerable loss in the system. Oscillator pulling or nonlinear frequency swing with modulation can be overcome with the use of load isolators when long transmission lines are used with klystron oscillator systems. Load-isolator insertion loss can be kept to approximately 0.5 db or less. When it is desired to mount the antenna on top of the studio or transmitter building and locate RF heads in the normal operating areas, these load isolators can be used between transmission lines and RF heads. Thus oscillator pulling with coaxial or waveguide transmission lines can be reduced or eliminated by inserting these load isolators next to the RF heads in the lines.

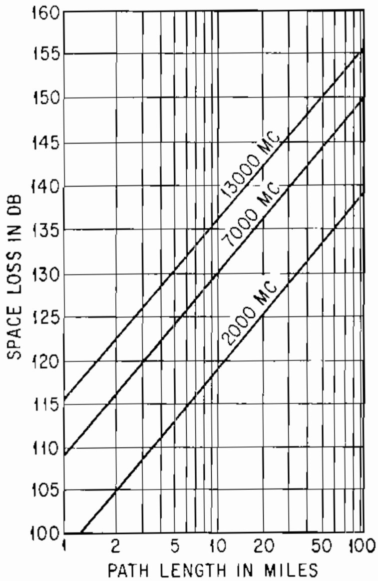


FIG. 2-4. Microwave space loss.

When system evaluations are made, transmitter power output should be converted into decibels above 1 mw (dbm). Dbm is a standard unit of signal level used in microwave engineering. Increases or decreases in power levels are referred to a 1-mw base. The dbm value should be used in the signal calculation sheets. Thus, when 1 watt of power is used in the transmitter, this power is converted into dbm, which would be +30 dbm. Putting this amount of power into an antenna with a gain of 32 db would then raise the radiated power to 30 dbm +32 db, or 62 dbm.

The loss in the antenna transmission line is also expressed in decibels. The actual amount of loss will depend on the line used. In present-day TV microwave relay systems operating on 7,000 and 13,000 Mc, the transmitters and receivers are mounted directly behind the parabolic antennas. Short waveguides used to couple the transmitter or receiver input circuits to the antennas have such negligible loss that they can be omitted in signal-level computations. However, when a waveguide is used to couple a distant antenna, then the length should be determined and the loss in decibels computed from the manufacturer's data.

The energy radiated from a transmitting parabola is wasted unless it is directed toward the receiving parabola. Very high coupling efficiencies can be obtained with carefully orientated large antennas. Table 2-4 shows the gains of typical parabolas and should be used when determining the signal gain in level computations. Figure 2-4 shows the free-space path loss for 2,000, 7,000, and 13,000 Mc as a function of path lengths from 1 through 100 miles. This graph should be used with the signal calculation sheet, a copy of which appears at the end of this part.

## Noise Factors in Signal-level Computation

In order to evaluate the performance of receivers and to determine their capability of handling weak signals, the concept of "noise figure" was introduced more than 25 years ago by Dr. H. T. Friis. This concept has been adopted almost universally and is used widely in connection with microwave receiver performance. No other one factor is so important a performance indicator of a TV microwave system.

**Table 2-4. Microwave Antenna Power Gains and Beamwidths**

| Parabola diameter, ft | 2,000 Mc | | 7,000 Mc | | 13,000 Mc | |
|---|---|---|---|---|---|---|
| | Antenna gain, db | Half-power beamwidth, deg | Antenna gain, db | Half-power beamwidth, deg | Antenna gain, db | Half-power beamwidth, deg |
| 2 | 19 | 18 | 30 | 5 | 36 | 2.5 |
| 4 | 25 | 9 | 36 | 2.5 | 42 | 1.5 |
| 6 | 29 | 6 | 40 | 1.75 | 46 | 0.875 |
| 8 | 31.5 | 4 | 43 | 1.25 | 48 | 0.65 |
| 10 | 33.5 | 3 | 44.5 | 1.00 | 50 | 0.50 |

In the microwave region external noise picked up by the antenna will usually be extremely low. Thus the noise level of the receiver can be determined by the thermal noise generated in the antenna and the noise generated in the receiver itself. This noise masks signals that are lower in level. Random-noise voltages are always present even in the most carefully designed and constructed receivers. These noises sound like hiss on a speaker and look like "grass" on an oscilloscope.

The probability of large noise amplitudes increases as the bandwidth of the receiver is increased. There is a definite rms and average value for all positive and negative noise voltages.

The thermal-noise level in a receiver is a function of the bandwidth of that receiver. It can be plotted from the conversion chart in Fig. 2-5, and is based on the following equation:

$$N_L = -174 + 10 \log_{10} B$$

where $B$ equals the receiver bandwidth in cycles per second.

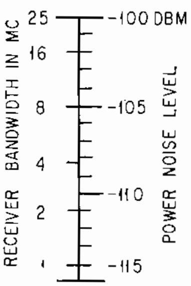


FIG. 2-5. Thermal noise as a function of bandwidth.

Noise fluctuation produced by the microwave receiver is given in terms of the receiver noise figure. The noise figure denotes the amount of deterioration of signal to noise which occurs while signal and noise pass through the receiver. The sensitivity of a receiver cannot be described in terms of thermal agitation noise alone because the receiver noise is several times the pure thermal noise.

The definition of noise figure by the Institute of Radio Engineers (IRE) is: [7]

> Noise factor or noise figure of a linear system at a selected input frequency is the *ratio* of the total noise power per unit of bandwidth available at the output terminals, to the portion thereof engendered at the input frequency by the input termination, whose noise temperature is standard (290°K) at all frequencies.

The method of actually measuring the over-all noise threshold of a receiver is described in this part under Equipment Tests and Measurements.

The over-all noise figures of two different receivers may vary as much as 15 db. This has the effect of requiring 15 db more power in the noisy receiver to get the same performance as the quieter receiver. In view of this, receivers with the lowest noise levels should be used in the longer paths and at all locations where the optimum in performance is required. At the present state of the art, TV microwave receivers with noise figures over 18 db for 2,000 Mc and 20 db for 7,000 Mc are considered poor.

Noise figures in receivers are kept low by utilizing low-noise mixers and low-noise first IF amplifier stages in either grounded grid or cascode circuits. A perfect mixer would have a conversion loss of 3 db. In practice, conversion-loss values from 4 to 9 db are common. This loss results in a reduction of the over-all noise figure.

Utilizing all the above data will give the level of signal required by the receiver.

The calculation sheets also indicate the amount of signal available for fading margins. The specifications for performance are based on a 53-db signal-to-noise ratio. Signal to noise deteriorates at the same rate as the RF signal deteriorates when receiver limiting is taking place. A 2-db fade will result in a 2-db reduction in signal to noise. If the signal is sufficiently strong to provide noise ratios in excess of 53 db, this may be of no concern. It is possible to develop a reliability ratio based on statistical fading amplitudes. This ratio holds for all properly engineered microwave systems where 40-db or more fading margin is available (see Fig. 2-6).

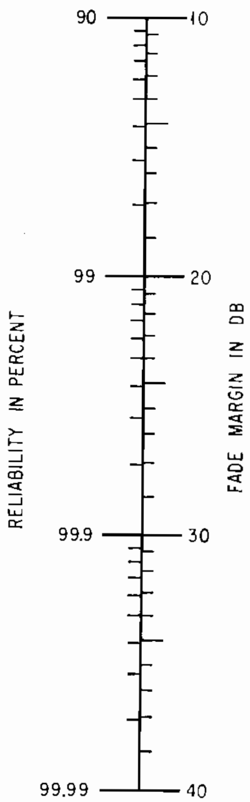


FIG. 2-6. Reliability factor vs. fading amplitudes.

The reliability factor indicates the percentage of time that the system will be normal in operation. If we assume maximum fades of 20 db in a system, Fig. 2-6 shows a reliability of 99 per cent. This means that over a period of, say, one week, the signal would be down 20 db 1 per cent of the time, or 1 hr and 40 min. If only a 40-db fade margin was available in the system, then for a period of 1 hr and 40 min scattered throughout the week, the signal would have a 33-db peak rms signal-to-noise ratio.

Unless a 40-db fade margin exists, the $S/N$ ratio of the video signal will be less than 53 db peak rms. Therefore the fade margin in a well-engineered TV relay link must be over 40 db. Experience will indicate how much over this value it should be. Fading-depth history, deterioration of the receiver and transmitter units, parabola wind stability, etc., are factors to be considered.

A microwave receiver in TV video service will produce a 53-db peak rms video signal if the incoming RF signal is 40 db above receiver noise level. Thus, in theory, if there were no fades in a system and the equipment did not deteriorate for any reason, a fade margin of 40 db would result in a reliability of 100 per cent with a video signal-to-noise ratio of 53 db. However, in practice this is not always possible. Therefore, the amount by which this standard is degraded depends principally on the fading encountered. Equipment failure and outages due to other than signal-level fading are not figured in these reliability-fade margin charts. If the installed system does not perform as calculated, then tests should be undertaken to determine the cause. These tests are detailed in this part under Equipment Tests and Measurements. The RF signal level should be checked. If it is not within 3 db of calculated, then Fresnel-zone clearance should be rechecked. If clearance is indicated but signal level is still low, then the power output of the transmitter, transmission-line losses, and antenna gains should be checked in that order. Where performance does not meet specifications, then detailed checks as indicated later will determine the probable cause of difficulty.

Fading margin as used in these level calculations is the usable signal above the receiver threshold. Fading margins in excess of 40 db raise the reliability of the systems. For example, if the received signal level was 85 db above the receiver threshold, then the system could tolerate a 45-db fade without the 53-db minimum noise value being degraded. Eighty-five-decibels less 45-db fade yields 40 db still above the threshold. This 40-db minimum signal allows the noise value to be met. More signal above this minimum design value will increase the performance, and the system will tolerate deeper fades. A system with a 48-db fading margin will tolerate an 8-db fade and still leave 40 db of signal to yield a 53-db signal-to-noise ratio.

## MULTIHOP EVALUATION

The previous discussion was based on single-hop systems. Where more than one hop is used or necessary, several other factors should be considered. The video and audio signal-to-noise ratios decrease with each hop. Fortunately this increase in noise is not destructive. The tendency for sync compression increases.

Off-the-air pickups for TV microwave relays may require as many as three hops. In such a three-hop system the average $S/N$ ratio will be 4.8 db poorer than a single hop, signal strengths being equal. This is shown in Fig. 2-7.

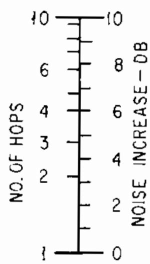


FIG. 2-7. Increase in noise for number of hops.

In this analysis the type of repeaters in a multihop installation using demodulated video and audio to modulate the next transmitter is considered. The video and audio signal level, receiver noise level, and threshold level in each repeater are considered to be the same throughout the multihop system. The video and audio noise levels will rise in each successive receiver, starting at the receiver nearest the beginning of the system. The increase in noise level is dependent on the number of hops.

In addition to noise, fading also should be considered. The multihop reliability compared with a single hop is lower. As the variation in the received signal level occurs in one repeater owing to fading, the automatic-gain-control circuit of the IF amplifiers tends to maintain a constant output level toward the next station in the system. A 20-db fade in one hop would not result in a reduction of total transmitted video in the next leg. Unfortunately, the IF amplifier gain would increase and both the video level and the receiver noise level would be increased by the amount necessary to bring the total up to the nominal level. The result is that the signal-to-noise ratio on the hop next to the low-signal hop is decreased not so much by reduction of signal as by an increase in noise.

For example, the signal-to-noise ratio for a 10-hop system, one hop of which is experiencing a 20-db fade, is only 1 db worse than the signal-to-noise ratio of the fading hop alone. Let us consider the example of a three-hop system when video $S/N$ ratio is being considered:

If the $S/N$ ratio of one hop is 53 db, then the $S/N$ ratio of three hops is 4.8 db less, or 48.2 db.

With a 20-db fade in one leg, the $S/N$ ratio of the hop is 33 db and the over-all three-hop system with one leg going through a 20-db fade will be 32 db.

If fading is occurring in two legs at the same time, there will be a further degradation of noise ratio. Simultaneous fading on two legs of a multihop system is rare except in heavy fading regions as shown in Fig. 2-2.

## EQUIPMENT TESTS AND MEASUREMENTS

TV microwave engineering tests can be divided into two parts; (1) tests to prove preliminary engineering in the installation of a system and (2) tests to determine causes of failure to meet predicted performance and reliability. Maintenance techniques can be applied to installed systems for improvement of existing day-to-day operation.

Testing and measuring TV microwave equipment are tasks requiring considerable skill and should not be attempted without proper test equipment and adequate knowledge of the subject. Good knowledge of the microwave equipment design and the use of systematic service methods with suitable test equipment will greatly reduce the possibility of error. Many types of test equipment have been developed for commercial and military microwave systems. Most of it is adaptable to TV microwave equipment.

Commercially available microwave gear for TV broadcast use generally employs unitized construction, permitting rapid and convenient replacement. If routine

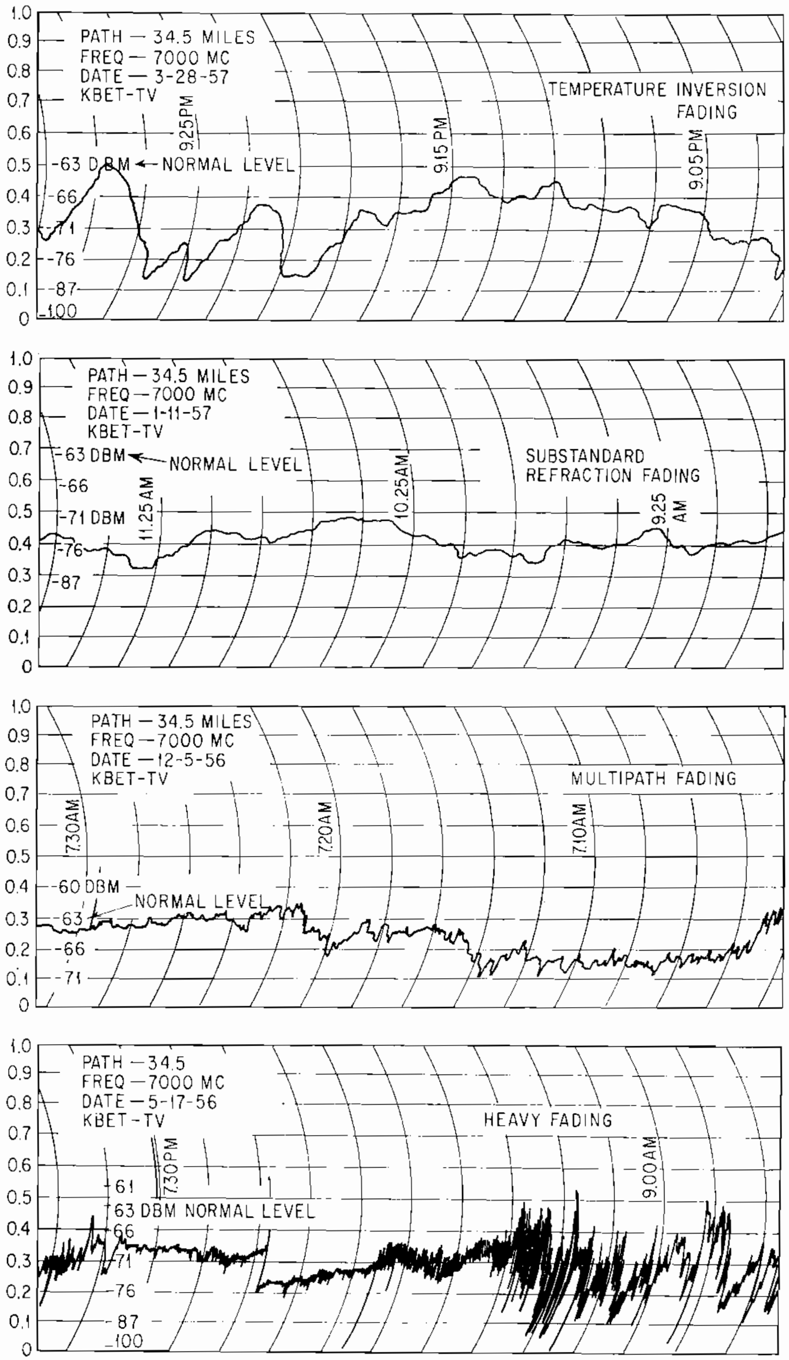


FIG. 2-8. Examples of different types of fading.

measurements are made of all important qualities, and if these measurements are logged, failure of tubes and components can be anticipated. Metering circuits and an ample number of test points strategically located permit checking of tube conditions, circuit voltages, and waveforms withont removing associated components.

Previous discussion has referred to planning of over-all microwave systems and methods of utilizing various microwave equipments. Certain guides were detailed which should be followed if the system is to meet performance requirements. In contemplated installations, it is wise to plan the procurement and installation of the several associated items. If the station engineer requires the installation of a complete system, extensive preinstallation planning is necessary and should be done prior tc ordering equipment. All supplier data on microwave and accessory equipment should be on hand. These data should include outline drawings with mounting dimensions, terminal connections, identification data, and electrical load requirement. Installation drawings of large items, such as towers and shelters, and of any special mounting and ventilation requirements are advisable. Detailed specifications can be obtained from the equipment manufacturer.

If the entire job is to be done simultaneously with the installation of a television station, elaborate preinstallation planning to the extent of drafting layouts is probably not feasible. The microwave installation is usually rushed along with the station installation. Although the engineer in charge may not actually detail in writing the several items, they can be used as a mental check list.

## Suggested Microwave Test Equipment

The average television station has several pieces of test equipment suitable for maintenance of microwave equipment. Other test equipment is unique in that it will be used only for testing and maintaining microwave gear. The following items should be available:

1. *Oscilloscope.* Usually available at any TV station, it should be a wideband unit with a vertical amplifier flat out to at least 6 Mc. It is a valuable tool for locating video troubles in the transmitter modulator as well as checking video in the receiver after demodulation. Scopes are valuable tools in locating sources of hum and distortion.

2. *Multimeter.* A 20,000-ohm/volt meter having various voltage, current, and resistance ranges is another popular item.

3. *RMS voltmeter.* A vacuum-tube voltmeter flat out to at least 6 Mc with 0.001-volt full-scale sensitivity. This is useful in measuring rms values of noise voltages.

4. *IF signal generator.* A variable-frequency signal generator capable of covering the IF of the receiver is recommended. In most equipments, this IF is 120 Mc, although there are some units that have 90 or 130 Mc IF. The frequency should be capable of being swept at least 20 Mc for IF alignment purposes. A signal generator with crystal markers is recommended.

5. *Grid-dip oscillator.* Useful for measuring transmitter deviation, it should be capable of covering the IF with good dial readability.

6. *Microwave test set.* This may be by far the most expensive single piece of test gear found in a TV station. Where outright purchase is not warranted, arrangements should be made to rent or borrow this item. This unit in its common form is a combination microwave RF power meter, frequency meter, and calibrated RF signal generator. It can be used for measuring the level of the received signal.

7. *Audio-signal generator and distortion analyser.* These two items are used to measure audio characteristics.

8. *Frequency meters.* Frequency can be measured with a microwave test set or with one of several types of wavemeters.

9. *Communication facilities.* Two-way radio or telephone facilities should be available at all times between the microwave transmitter and its receiver.

10. *Spare parts.* Needless to say, a certain number of spare tubes should be kept available at all times. Klystrons used in the transmitters and receivers can be pretuned and stored. In this way when a klystron is to be replaced, the time required

is cut to a minimum by inserting a tube already tuned for the proper frequency. Owing to the reliability built into microwave equipment by the manufacturers, spare parts can be held to a bare minimum. Where waveguide equipment is used, spare mica windows and Teflon screws should be stocked. O rings for waveguide and coaxial lines should also be stocked, since water damage to external components cannot be predicted. Mixer crystals, an item not normally stocked by wholesale houses, should be on hand.

## Microwave Tests

Before detailing actual tests and measurements, it should be pointed out that certain performance requirements of the system are desirable (see Table 2-1). A good monochrome system may not necessarily provide good color signals. This is because a color microwave system has much more stringent requirements than a monochrome system. The requirements for good color operation are associated with differential phase and gain and envelope delay. Equipment tests can be divided into propagation tests to determine signal levels and performance tests to determine the system characteristics with proper received-signal levels.

## Propagation Tests

Before a microwave system is installed, the expected signal level at the receivers should be calculated from the data given previously. After the system is installed, if it does not perform as expected, the received signal should be measured at the receiver input to determine if the measured level approximates the calculated. If the received signal is 3 db or lower than calculated, then the system should be checked out to determine where this RF loss is occurring. In long and medium hops and in multihop installations, less-than-calculated signal strength may be an indication that errors occurred in calculations of power output, line losses, antenna gains, antenna orientation, or Fresnel-zone clearances.

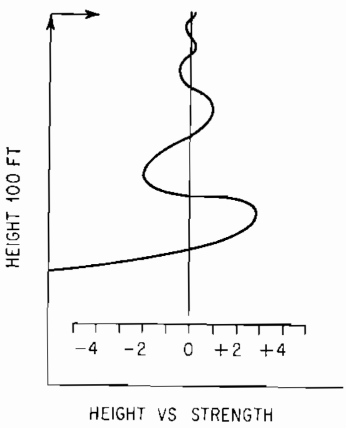


FIG. 2-9. Height-gain relation.

In long hops or in medium hops where low-power transmitters and small parabolas are used, 3 to 6 db of RF level can be gained by "height-gain" adjusting the antennas. This procedure is also helpful in extremely long hops or marginal systems. Height-gain adjustments are easy to make. Starting with the receiving parabola, the entire dish is moved in 12- to 18-in. increments vertically, and the received signal level is noted at each height. Over a vertical run of about 100 ft (for 2,000 Mc) and about 50 ft (for 7,000 Mc) the received-signal strength will usually vary and appear as in Fig. 2-9.

After the first maximum signal-level height has been found from the adjustments, the receiving antenna should be left at that position and secured. Then the transmitting-antenna height can be similarly adjusted vertically in the same manner while the received-signal level is noted. The transmitting dish should be permanently set at the first maximum when measured from the ground up. Since many television STL are located in metropolitan areas, these height-gain adjustments should be made during the months when trees are in leaf. Needless to say, these measurements should be made under steady signal conditions. To ensure that fading is not affecting the antenna being adjusted, it is suggested that another link be operating alongside the link under adjustment.* Then it can be determined that the increase or decrease in received signal level on the adjusted system is not due to fading.

* Usually not feasible.

If the signal strength is still appreciably below the calculated value, the output power of the transmitter should be checked. This can be done by using a microwave RF test set to measure power directly or by substituting for the output of the transmitter the known signal level of an RF test set. The test set is fed into a calibrated attenuation length of line (such as RG 21/U) if a 2,000-Mc system is under test. With 7,000-Mc transmitters, waveguide attenuators can be used while the receiver is used as a detector. Perhaps a simpler and faster way in some instances to check relative output from the transmitter is to change the transmitting klystron.

Another source of signal loss can occur in transmission-line connections. In 2,000-Mc systems where coaxial cable with type-N connectors are used, the actual loss of a male and female connector together could be as much as 1 db. The use of type-N connectors in 2,000-Mc systems should be kept to an absolute minimum. Seven-eighths- and 1⅝-in. flange couplings have lower loss and are suggested wherever usable in 2,000-Mc systems. In 7,000- and 13,000-Mc systems, care should be taken to ensure good physical mating of waveguide flanges in order to keep power loss at a minimum.

Apparent loss of signal from calculated values may result from the use of incorrect gain figures with certain parabolas. Not all parabolas have the same forward gain for a given diameter. Parabolas can be designed and manufactured for maximum forward gain or maximum forward gain consistent with minimum back lobes. The latter types are designed for use in multipath installations where back radiation may present isolation problems. It is advisable to use dishes recommended by the manufacturer for the particular use desired. The dimensions given in Fig. 2-3 are for maximum forward gain.

Polarization of radiation under normal circumstances is not a significant cause of propagation loss. However, cross polarization can be used to reduce cross talk between two links operating in the same band over the same path with isolation from 25 to 30 db.

In the final analysis of propagation tests, the actual signal level arriving at the receiver input terminals is all-important. The actual level of this signal can be determined by the use of a microwave RF test set. The received level as indicated by a meter in the first limiter grid circuit is recorded (under normal propagation conditions). Then the antenna transmission line or waveguide is disconnected and the output of the test set is fed into the receiver. The power from the test set is varied with the calibrated attenuator until the signal level from the test set equals that recorded from the antenna. The power level is read directly in dbm from the attenuator of the RF test set. Care must be taken to ensure that the test set is accurately aligned with the operating frequency of the receiver. Once the receiver is peaked on the received signal, it should not be adjusted when the RF test set is fed into the antenna input. Instead, the RF test set should be adjusted for maximum reading on the receiver. If a matching stub is used on the receiver input, as is sometimes provided in 2,000-Mc units, it should be left in the circuit and adjusted for maximum receiver limiter current under both conditions.

As pointed out previously, if the received signal is not within 3 db of the calculated value, it would be worthwhile to determine the cause.

## Equipment Testing

### *Transmitter Tests*

The transmitter should be tested for power output, operating frequency, deviation, noise, and differential gain and phase.

**Power Output.** The output power of the transmitter should be within 1 db of rated level. If it is not, then the klystron output should be checked by substitution of another tube. If the tube is not at fault, then the beam and repeller voltages should be checked. A good practical check on the power output of the transmitter is to nse a small power probe. This consists of a loop at the end of a PL-239 plug connected to a 1N21 crystal (2,000 Mc). 1N23 crystals can be used for 7,000- and 13,000-Mc systems. This loop is inserted into the antenna field by fastening it to the edge of the parabola. Orienting the loop will give changes in d-c rectified voltage from the power intercepted by the loop. The output current of the rectified crystal is connected to a 0- to 1-ma d-c meter. This meter reading will give an arbitrary power-level indication. Power variations are thus indicated. Aging klystrons and power-amplifier tubes will result in decreasing output power. This probe will also be helpful in peaking repeller voltages for maximum output.

**Frequency Measurements.** The operating frequency of the transmitter can be measured at the receiver by substituting the known frequency of a microwave test set for that of the transmitter. Operating frequency can also be measured with a calibrated cavity-type wavemeter. This is becoming a standard item supplied with most TV microwave units. Charts are furnished with each wavemeter which indicate the operating frequency corresponding to a given wavemeter dial setting.

**Transmitter Deviation.** The transmitting klystron deviation can be measured quite accurately with modulation. One method is to use a grid dip oscillator, or an IF signal generator. A sawtooth voltage from a built-in source in the transmitter or a sawtooth waveform obtained from a camera channel may be used as the test signal. This test sawtooth voltage is adjusted in level to approximate normal video modulation. A grid dip oscillator or the IF signal generator is loosely coupled to the IF amplifier of the receiver by removing a tube shield. When the video output is viewed on an oscilloscope, normal sawtooth voltage should be present. The transmitter should be adjusted to give maximum sawtooth voltage out of the receiver without compression. The receiver should be tuned for best signal, taking linearity into consideration. The grid dip oscillator or signal generator is then tuned through the IF of the receiver. A "birdie" will appear in the video presentation, running through the horizontal display. The frequency of the oscillator at the bottom of the sawtooth should be noted. Then the birdie should be run up the sawtooth and the frequency of the oscillator at the top of the sawtooth noted. The difference between these two frequencies is the deviation of the transmitter. If trouble is experience in first seeing the birdie in the scope waveform, the procedure can be practised with 60-cycle sine wave.

The sawtooth signal is then removed, and composite video fed into the transmitter. The video gain control on the transmitter is thus adjusted for maximum video deviation. In general, the amount of deviation is limited by the amount of sync or video compression that can be tolerated. The manufacturer's recommendations should be followed as to the amount of deviation. The noise-reduction qualities of the system are improved by increasing deviation, while extreme levels cause compression. Doubling the deviation yields a 6-db improvement in signal-to-noise ratio.

The deviation of a klystron is limited by several factors, the most important being the standing-wave ratio of the antenna and transmission line or waveguide. Since these loads for the klystron are reactive, they tend to change the oscillator tuning, resulting in the process known as "pulling." These outside reactive components can be isolated from the klystron to a great extent by inserting a load isolator between the klystron and its load.

Ferrite load isolators or gyrators are available for all three television STL bands. They are available in type-N connectors and waveguide flanges of various sizes. Insertion loss in several types is less than 0.5 db in the transmitted direction. Energy going from the load (antenna and coaxial or waveguide) to the klystron is attenuated from 25 to 30 db. In addition to permitting wider deviation of the klystron, these load isolators allow the transmitter to be mounted many feet from the parabola. On 2,000 Mc the parabola can be located as much as 150 ft away from the transmitter, using low-loss coaxial cable and a gyrator. Similar lengths of waveguide can be used to couple a 7,000-Mc antenna to its transmitter.

**Checking Transmitted Video.** The transmitter should be checked periodically for deterioration of video through its modulator. When a scope probe is placed at the plate of the modulator tube, composite video applied to the modulated klystron is observed. This signal can be checked for compression, noise, differential gain, and other qualities. One method for checking differential gain is to run 3.58-Mc subcarrier on a stair-step pattern through the modulator and check the linearity through a high-pass filter on the scope.

The modulator can be checked for proper clamping if a clamping circuit is used. The clamping circuit must permit the color subcarrier appearing on the back-porch interval to pass without degradation. This is usually accomplished by the use of a broadly resonant 3.58-Mc circuit in the clamping circuit. Clamping circuits are not usually adjustable, but some manufacturers make the balancing circuit variable. Improper operation of clamping circuits may be caused by defective tubes or changes in resistor values. Clamping circuits are very important to multihop systems in order to maintain proper level. Noise may also creep into the signal. Properly working clamp circuits will ensure proper black level without deterioration of the color subcarrier. Clamping on a line-to-line basis tends to clean up hum or noise appearing during the clamping interval.

**Measuring Video Signal-to-noise Ratio.** The signal-to-noise ratio of a microwave system, distribution amplifier, or nearly any video amplifier can be determined in the following manner. A video signal, preferably a standard EIA test pattern, is passed through the equipment under test with normal level. The amplitude of this signal is measured at the terminated output of the equipment. This voltage should be measured accurately, from sync tip to video tip, on a peak-to-peak device, such as an oscilloscope which is flat out to at least 6 Mc. The input to the equipment under test should then be terminated (in a microwave system check, the input to the video modulator). The gain controls or any other controls in the equipment should not be touched during this test. The output of the equipment is next measured, with the input thus terminated. The resulting signal is noise or hum. It can be measured on a peak-to-peak basis with the oscilloscope in the high-sensitivity position and then converted into rms values, or it can be directly measured in rms by the use of a sensitive rms voltmeter, flat out to at least 6 Mc.

The noise ratio can be determined by

$$\text{Signal-to-noise ratio} = \frac{\text{peak video voltage}}{\text{rms noise voltage}}$$

$$\text{Signal-to-noise ratio in db} = 20 \log \frac{\text{peak video}}{\text{rms noise}}$$

This, then, would be the signal-to-noise ratio in decibels where the noise voltage is standardized in rms values (normal practice). Unless there is 60- or 120-cycle hum in the equipment, the ratio should be quite large (over 100 to meet the microwave-system specifications set forth in Table 2-1 for video noise, 53db). By the use of the oscilloscope for noise measurements, the nature of the noise can be determined and suitable corrective measures can be taken.

An rms type of meter is recommended for measuring noise, since it is much more accurate than the visual method of reading noise peaks on an oscilloscope.

The noise appearing in most amplifying equipment and microwave systems is high frequency in nature. To evaluate the noise ratio properly, the rms voltmeter and the oscilloscope should have essentially the same high-frequency response. A flat response out to 6 Mc is recommended.

The receiver noise figure plays an important part in the resulting video signal-to-noise value. The signal at the output of the receiver results only from the signal which is applied to the input and is amplified and demodulated by the receiver. However, the noise at the output results from noise which is applied to the input and is amplified and demodulated by the receiver *plus* the noise which is generated within the receiver. The deterioration in signal-to-noise ratio suffered in passing through the receiver is defined in terms of available signal and noise powers at the receiver input and output. It is called the over-all receiver noise figure. Noise figures for individual stages or units in a system such as the transmitter modulator, mixer, first

IF, can be defined in the same manner, but the over-all noise figure is not the simple product of the component figures. The noise figure for an ideal receiver matched to the antenna is 2, and the noise figure for an ideal receiver with infinite input impedance is unity—an improvement of 3 db.

**Linearity Measurements.** The microwave system for television should be linear in its amplitude-transfer characteristics, especially near 3.58 Mc. Nonlinearity may occur from several causes. The most common are the operation of the transmitter into reactive loads and overdeviating the klystron. Modulated klystrons have limitations on deviation due to nonlinear output vs. frequency.

The recommended testing method and adjustment are the same for both a monochrome and a color microwave system. Test equipment consists of a sweep generator and an oscilloscope. It is suggested that the response of the modulator section of the transmitter be checked first. The sweep is fed into the modulator, and the video appearing on the klystron repeller checked with the scope. The video output level should be flat up through 6 Mc, plus or minus ½ db. The region around 3.58 Mc should be essentially flat without any peaks or dips. The video output level should be equal to that required for normal deviation.

Clamping circuits, if used, should be disabled, which can usually be done by removing the clamping diodes and substituting a suitable resistor. Preemphasis networks, if used, should be removed for this test. If the response is not as expected, then the scope probe should be moved back by stages to find the stage causing the difficulty. If peaking coils are used, these should be adjusted. It may also be helpful to study the suggested method of checking amplitude linearity in the equipment instruction book.

After it has been determined that frequency amplitude response of the transmitter with normal deviation is satisfactory, then the receiver can be checked. The video sweep can be fed into the detector circuits, and the scope connected to the receiver video output. Or the video sweep oscillator can be fed into the microwave test set, which in turn can be fed into the receiver-antenna input. The video section should be flat out to 6 Mc, within 0.5 db. Thus the video circuitry can be examined. The IF bandwidth should be checked and adjusted following instructions contained in the equipment instruction manual. Deemphasis networks should be removed when the receiver is checked and adjusted.

For routine checks on the amplitude linearity, a rapid method is to use a composite video test signal from a stair-step generator or from a slide source. The clamping circuits and the pre- and deemphasis networks should be left in operation. The signal from the stair-step generator is passed through the system and then through a high-pass filter into the scope at the receiving end. If the video is passed through the high-pass filter, only the subcarrier frequency at different amplitude levels appears. Variation in the subcarrier amplitude indicates nonlinearity.

A rapid and easy test for amplitude linearity is to use a sawtooth signal. If a built-in sawtooth signal is not available in the transmitter, a sawtooth waveform can be had from the shading signal output of a live camera chain. This sawtooth voltage is passed through the microwave system, and the signal at the receiver video output is observed for linearity. This method of testing is rapid but will not give the observer the actual linearity response in decibels. It is helpful as a rapid check for amplitnde linearity of the modulated klystron and video systems.

**Color Subcarrier Phase Shift.** There are two types of phase distortion to be considered in a color microwave system. Phase distortion that results in both color burst and color picture information being shifted together has a small effect in comparison with the errors in color reproduction caused by a variation in the phase of the subcarrier as a fnnction of its position in the amplitude range from burst toward white level. This sort of phase variation results in hue errors.

The phase of the color subcarrier should not be changed when passing through a system. Phase shifting with brightness causes the color signal to cange in hue and brightness. Several causes of phase shifts in a microwave system inclnde diagonal clipping, variable-impedance circuitry, and multipath transmission of a microwave signal.

Phase shifts or differential phase are measured with the aid of a vectorscope, or color-signal analyzer. The process is complicated and beyond the scope of this part. Information on the above test equipment is provided in the instruction books.

### *Receiver Tests*

**Measurements of Receiver Threshold Level.** The term *noise figure* is a figure of merit. It compares the actual noise threshold of a receiver under consideration with that of a hypothetical noise-free receiver with the same bandwidth and the same frequency of operation. The literature is complete with data on this subject. Here we are interested in the part this threshold level plays in the over-all sensitivity of the receiver. This threshold level largely determines the maximum usable distance of a microwave system. The required signal level at a receiver to provide specified performance can be determined in advance if the threshold level is known. Not all microwave-equipment manufacturers specify a threshold level for their receivers.

The threshold level, recorded periodically, can be used to predict deterioration of over-all receiver operation. Where identical receivers are used in a given location, the most sensitive receiver should be used in the hop where the lowest signal level exists.

Before a method of measurement is given, a brief explanation of how the threshold level is determined may be helpful.[13] A microwave receiver with an IF bandwidth of 16 Mc will be used as an example. The rms $KTF$ for such a bandwidth is $-132$ db. The symbol $K$ is the Boltzmann constant, $T$ is the temperature (290°), and $F$ is the bandwidth of the IF amplifier in cycles per second. Since the sync peak signal in the receiver has to override the peak noise, this rms $KTF$ is converted to peak $KTF$. The conversion value of peak noise to rms noise is 13 db. Thus the $-132$-db peak value $+13 = -119$ db. The excess noise figure of the mixer crystal in the receiver is approximately 13 db. This gives a peak noise level of $-106$ db. A 6-db difference exists between the FM threshold and the AM threshold, the latter being the lower. Thus the FM threshold is $-100$ db. This is the level, or point, where an FM signal would override the receiver noise and thus be detected.

At this FM threshold level, the video signal-to-noise ratio is approximately 20 db, which is an extremely poor signal. Video $S/N$ ratios of up to 25 db are classed as unusable. This is 5 db above threshold point. The noise content reaches a point at this level to be too objectionable to a viewer, and home receivers have trouble holding sync.

It might be well to point here how a 20-db rms peak video signal results from a RF signal that is at the threshold of the receiver. Three factors make up this $S/N$ improvement. They are the FM wideband gain of the received FM signal, the conversion from peak to peak to rms to peak, and the 6-db improvement from AM to FM conversion. The wideband gain (WBG) is a function of the modulation index of the transmitter. Six-megacycle video deviated 2-Mc yields about 1.3-db wideband gain. If the 6-Mc video is deviated 6 Mc, then the WBG improvement is about 5 db. The conversion from peak video to peak noise yields a numerical gain of 13 db when changed to peak video and rms noise voltages. The noise ratio isn't improved but the decibel numerical value is owing to the current standard practice of using peak signal to rms noise. Thus the peak signal to rms noise ratio at the threshold is $(\text{FM/AM}) + (\text{peak noise/rms noise}) + \text{WBG} = 6 + 13 + 1 = 20$ db.

This threshold level, then, is the level of input signal required to be detected or noticed in the output noise of the microwave receiver. It can be measured simply with a calibrated microwave signal generator, as shown in Fig. 2-10.

The receiver is tuned up for normal operation with its output connected to an oscilloscope and terminated. Deemphasis networks, if used, should be removed. The signal generator is fed into the antenna input of the receiver through either waveguide or coaxial. If tuning stubs are used, they should be left in. The signal generator is put into operation after careful output-level calibration. The signal from the generator is raised above the noise and carefully adjusted to the normal operating frequency of the receiver. The IF gain control, if variable, is set to normal operating level, since its position will somewhat affect the noise level. If the receiver has not been installed in a system, the IF gain control can be set at its midrange.

The signal generator should not have modulation on it, since the threshold level should be measured at its AM value. As the output of the signal generator is increased, there will be a decrease in the receiver noise as the limiter and gain-control circuits come into play. A point will be reached where the signal can just be seen in the noise. The dbm level of the signal from the generator is the threshold level of that receiver at the particular frequency and IF gain-control settings.

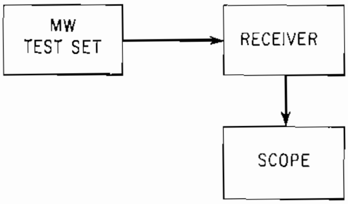


FIG. 2-10. Block diagram of test setup.

If the incoming signal in normal operation falls below the threshold level, then it is obvious that it will be lost in the noise. If the RF signal level is 40 db above the threshold, then in the average receiver, the performance specifications should be met as outlined in Table 2-1. If the signal is somewhat less than 40 db above the threshold, then the signal is degraded. The loss in signal below 40 db can be caused by fading, lack of RF signal due to overextension of paths, inadequate antenna gain, and other losses. It would be excellent practice in television microwave engineering to maintain the incoming RF signal at least 40 db above the threshold value.

## Improving the Performance of Older-type Links

If the received signal strength is adequate as specified by the microwave-equipment manufacturer or as determined by the use of the charts included herein, then the performance of the system should meet the specifications shown in Table 2-1. However, there are many instances with older equipment where performance is substandard even with what is considered and calculated to be an adequate signal level. During periods of steady level signals, the system may barely meet these specifications. When a 20-db fade comes along, the performance is subdstandard for the period of that fade. Therefore, improvement of the existing system is desirable.

There are some installations where the calculated signal level results in submarginal operation. For economic reasons it may be desirahle to improve the existing system instead of increasing the received signal by the use of larger antennas or an amplifier on the existing transmitter. As stated previously, it may also be desirable to build greater fading margin into a system.

Equipment improvement may be divided into the following methods of approach, without going into major modifications such as power amplifiers and larger size antennas:

Transmitter:

1. Increasing modulation deviation
2. Decreasing noise generated by the transmitter
3. Improving the modulator video characteristics

Receiver:

1. Improving the threshold level
2. Improving line match between antenna and receiver inpnt
3. Decreasing noise generated by the receiver local oscillator
4. Video preemphasis and deemphasis

It may be possible to incorporate all the above-mentioned improvements in an existing link that is not performing satisfactorily. Obviously there are some equipments where none of the above items can be improved upon. This information can be used as a check list in installations where there is unsatisfactory performance. Present-day equipment is well designed, manufactured, and checked before being shipped to the customer. It should function properly when installed under acceptable engineering conditions.

### *Increasing Modulation Deviation*

If the transmitter will not deviate more than 4 Mc, a worthwhile contribution to performance can be made by increasing this to 6 or 8 Mc. The cause of the deviation limitation should be determined first. It is suggested that the modulator be checked to ensure proper operation at the output level required for 8-Mc deviation. The modulator should be capable of providing the required voltage swing on the repeller for this deviation without degradation. The amount of this voltage can be obtained from tube data sheets for the particular klystron used, and the maximum deviation possible thus determined.

After the modulator has been checked, tests should be made on the modulated klystron. If a dummy load is available, it should be connected to the output of the klystron as closely as possible to eliminate any reactive waveguide or coaxial cable. The klystron deviation should be checked under these conditions. A klystron will deviate many magacycles more into a flat dummy load than into an antenna-line load. There is a natural limitation to deviation, due to the output vs. repeller voltage characteristics which are not linear with frequency. However, it should be possible to deviate up to 8 Mc with presently available klystrons on 2,000 and 7,000 Mc if the antenna is suitably flat.

The klystron should be checked and can be replaced if this amount of deviation is not possible into a dummy load. If this deviation is possible into a dummy but not into the waveguide or coaxial feeding the antenna, the VSWR can be checked to determine if the line is excessively reactive. If the antenna line limits deviation by being reactive, it is suggested that a load isolator be inserted between the klystron and the transmission line. This will prevent reactive components from being reflected back to the klystron. It should be remembered that if the deviation is doubled, the output signal will be 6 db better in signal to noise, assuming that limiting is taking place in the receiver.

### *Decreasing Noise Generated by the Transmitter*

Noise on the transmitter carrier can be caused by hum and noise voltages in the power supplies and in the modulator appearing on the repeller of the klystron. Thermal-type shot noise may also be present. A quick test to determine the presence of noise, as well as its type and magnitude, can be made by looking at the repeller voltage with a scope. The entire transmitter should be adjusted for normal operation with composite video. Then the input to the modulator should be terminated in order that the noise and hum are not masked by video. The noise voltages, including hum, should be at least 1/1,000 of the peak voltage required for normal deviation. Hum and noise can be tracked down with the use of the scope on a stage-by-stage basis.

In addition to checking the repeller, klystron-beam voltage should also be checked. Voltage-regulation circuits and tubes sometimes cause random-noise voltages.

The same technique for determining, measuring, and eliminating noise in the transmitting klystron should be applied to the local oscillator in the receiver. Hum and noise appearing from the receiver klystron can also cause performance impairment by mixing with the incoming signal.

### *Improving the Video Characteristics of the Modulator*

The modulator in the microwave transmitter is designed by the manufacturer to provide the necessary output video level for proper deviation. If the unit does not accomplish this, it probably needs maintenance. As pointed out previously, it should be capable of providing the necessary output voltage to deviate the klystron and still meet all the performance specifications for video. If it does not, a point-to-point check of the modulator circuit may be in order.

The modulator should be checked for differential gain and phase, signal-to-noise ratios, proper clamping, and output level for required deviation.

### *Video Preemphasis and Deemphasis*

Most TV microwave equipments now available utilize preemphasis and deemphasis networks in the video circuits. This scheme improves color performance and reduces video noise in the output of the receiver by approximately 6 db. These networks are now available in type BNC input and output terminals and can be readily inserted into the video line feeding the transmitter modulator and the output line from the receiver. They are passive networks with emphasis starting at about 2 Mc. Their insertion loss is approximately 6 db per unit. Distribution amplifiers are used to build up the video from the receiver, although in most cases the 6-db insertion loss in the modulator input can be overcome by the modulator gain circuitry. This is a very economical method of improving the noise problem in older types of microwave systems that do not have preemphasis and deemphasis circuits.

The theory of operation is the same as frequency-response improvement in FM operation. When the video is built up from 6 to 8 db from 2 to 6 Mc, the deemphasis network in the last receiver brings the *video and noise* down by the same amount. Since most video noise is above 2 Mc, this crossover point is quite effective. In multihop installation, only the first transmitter and the last receiver need have the emphasis networks.

These emphasis networks also improve sound subcarrier operation by increasing the amount of the subcarrier voltage available if the deemphasis network is inserted after the video goes through the subcarrier receiver.

### *Improving the Threshold Value*

Previously it was pointed out that the threshold level is the level at which a signal can be detected in the noise. If limiting in the receiver IF stages is taking place, an improvement of about 6 db can be obtained. If limiting is not taking place because of low signal level in the IF stages, the circuitry can be adjusted to cause signal-amplitude limiting at lower levels.

There are several factors which affect the threshold level of a receiver. In addition to limiting as described above, impedance matching between antenna and receiver, local oscillator injection power, crystal mixer current, the choice of a suitable mixer crystal, and low-noise IF amplifier design in the first two stages are all important factors contributing to the threshold level. Tubes used for the first two stages of the IF amplifier should be selected for low noise when necessary.

The mixer crystal determines requirements for the conversion gain, noise figure, and local oscillator excitation. These factors also determine, in turn, the threshold level. The noise ratio of commercially available crystals for TV microwave use (the 1N21 and 1N23 series) is usually measured at 30 Mc. The injection voltage frequency of the local oscillator has very little effect on the IF noise output resulting from the crystal when used as a mixer.

Currently available are mixer crystals in the IN2IE and the 1N23E series, which are picked crystals from the IN21B and IN23B types. These crystals have been selected for their high conversion gain, impedance match, and low noise figure. They may improve the threshold level from 3 to 5 db over the older types, and their use may be warranted to improve threshold levels.

Where balanced mixers are used in receivers, substituting matched pairs of these "low-noise" crystals may be warranted. RF and IF impedance of these crystals are held to closer tolerances, while the older types may vary from 340 to 460 ohms. The impedances are affected by the crystal holder, crystal geometry, and frequency and power level of the local oscillator.

The sensitivity of a crystal mixer is dependent on several factors. It should absorb all the signal power incident upon it, because any power reflected is lost. In order that the mixer can work properly, it is necessary that it have ample local oscillator power. This does not mean, however, that the more oscillator power applied to the crystal the better. Figure 2-11 shows the variation of crystal conversion loss in decibels and the over-all noise figure of a microwave receiver, as a function of the crystal current.[10]

Figure 2-11 was calculated on the assumption that the IF amplifier has a noise figure of 3.0 db. As can be seen, the best noise figure is obtained with this particular crystal at a crystal current of approximately 0.4 ma. This is a representative case with 1N21 and 1N23 types of crystals. If the crystal current is a little higher than this value, not much sensitivity is lost. If the crystal current is lower, there will be some loss in sensitivity and the noise level increases rapidly. The equipment manufacturer's instructions should be used to set the initial injection voltage from the local oscillator. Then if additional sensitivity is required, the injection level or crystal current can be varied as the noise is observed on a scope or rms voltmeter. The modulator feeding the receiver under adjustment should have its input terminated during this noise adjustment in order not to mask the noise with video.

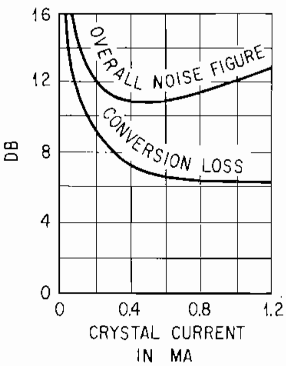


Fig. 2-11. Crystal conversion loss vs. over-all noise figure.

From Fig. 2-11 it can be seen that while the IF amplifier has a noise figure of 3.0 db, the crystal mixer increases this noise figure to approximately 11 db. This is, indeed, a good over-all noise figure and was calculated on a radar microwave receiver. TV video receivers require much more IF bandwidth than radar receivers. Thus the noise figure is higher on video receivers. It is possible to approach this figure with cascode input stages to IF amplifiers, low-noise crystals, and the use of balanced mixers.

## *Care and Handling of Mixer Crystals*

Currently available mixer crystals undergo rugged mechanical electrical and exposure tests in the manufacturing process. The mechanical test consists of a 30-in. drop onto a wooden block and mechanical twisting of the terminals. However, the crystal units can be easily damaged in handling, storage, and use. It has been found that the static accumulated by a person's body is sufficient to damage the crystal when it is inserted into its holder in the mixer. Therefore it is recommended that one's hand be grounded to the receiver chassis before inserting the crystal in or removing it from the receiver. A further step would be to use a well-insulated tool in removing or inserting the crystal in its holder. Crystals may also be damaged when stored in the vicinity of high-power transmitters. In transmitter areas it is advisable to keep the crystals in the metal shielding capsules when not in use.

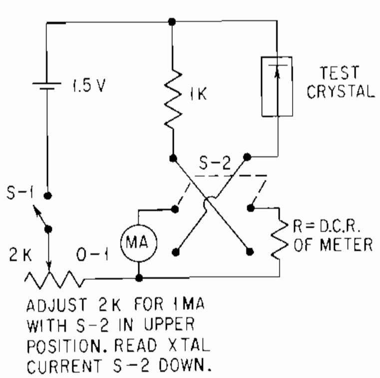


Fig. 2-12. D-c mixer crystal checker.

It is possible to build an inexpensive RF crystal mixer checker which will tell whether the crystal has deteriorated from the time it was known to be acceptable at the factory. The simplest way to check the crystal for deterioration is to measure its back resistance at the standard 1-volt value. A simple d-c mixer crystal checker is shown in Fig. 2-12. The 1N21 C and E series are acceptable if the back current at $-1$ volt is less than 0.100 ma. The 1N23 C and E series are acceptable if their back current is less than 0.125 ma. The results of a d-c check of this type depend on the particular crystal, not on the manufacturer. The currents can be logged when the crystal is received, and during routine maintenance checks it can be compared with its original value for deterioration.

**Table 2-5. Signal-level Calculation Sheet**

Signal path from Sacramento to El Dorado, Calif., Date 7/30/57

Path length, miles, 34.5 Calculated by FLO recommended band 2

| | 2,000 (example) | 7,000 | 13,000 |
|---|---|---|---|
| Transmitting antenna gain, db | +32 | | |
| Receiving antenna gain, db | +32 | | |
| Free-space path loss, db | −130 | | |
| Transmission-line loss, db | −13 | | |
| Other losses, db (isolator, etc.) | −2 | | |
| Transmitter power gain, dbm | +40 | | |
| Calculated RF signal level at receiver | −41 | | |
| Calculated receiver threshold level | −81 | | |
| Signal level above threshold, db | −40 | | |
| Converted into prop. reliability | 99.99% | | |
| Video signal to noise peak rms | 60 db | | |
| Fading margin, db | 40 | | |

Remarks:

NOTE: Calculated RF signal at the receiver is the difference between losses and gains between transmitter and receiver. Signal level above threshold is the difference between the RF signal level at the receiver and threshold level. In the above example, lines total 200 ft, power is 10 watts, receiver bandwidth 25 Mc, noise figure 19 db; 6-ft dishes, $S/N$ ratio is fade margin +20 db.

### *Transmission-line Tuning Stubs*

One make of TV microwave equipment currently available for the 2,000-Mc band utilizes coaxial tuning stubs at the input to the receiver and the output of the transmitter klystron. Adjusting these stubs tends to reduce the VSWR of the line. The matching of the antenna and line to the receiver input raises the received signal level. But what is perhaps more important, it improves the differential gain and phase response of the receiver. This is accomplished by the fact that the signal voltages as a result of FM deviation and demodulation are more nearly constant in level owing to the flatness of the antenna input circuitry.

## REFERENCES


1. Durkee, A. L.: Results of Microwave Propagation Tests on a 40 Mile Overland Path, *Proc. IRE,* February, 1948.
2. Miller, J. B., and L. A. Byam: A Micro-wave Propagation Test, *Proc. IRE,* June, 1950.
3. Onnigian, Peter K.: "Petition, 890 Mc and Above, FCC Docket 11866," Sacramento Telecasters, Inc., May, 1957.
4. Crain, C. M.: "Airborn Microwave Refractometer Measurements," U.S. Air Force Contract AF 18 (600)-113 Electrical Engineering Research Laboratory, University of Texas, Austin, Tex.
5. Bean, B. R., and F. M. Meany: "Monthly Median Refractivity Gradients in Propagation," paper presented at Conference on Radio-Meterology, University of Texas, Nov. 9, 1953.

6. Attwood, S. A.: "Radio Wave Propagation," Academic Press, Inc., New York, 1949.
7. North, D. O.: *RCA Rev.*, June, 1942, pp. 332–344, and Receiver Standards, *Proc. IRE*, December, 1952.
8. Wilson, E. F.: Planning An Overwater Microwave TV Link, *Electronic Ind.*, June, 1957.
9. Crosby, Murray G.: FM Noise Characteristics, *Proc. IRE*, April, 1937.
10. "Microwave Diode Handbook," Sylvania Electric Products Inc., New York, 1957.
11. Van Voorhis, S. N.: "Microwave Receivers," p. 18, MIT Radiation Laboratory Series, McGraw-Hill Book Company, Inc., New York.
12. Egli, J. J.: Radio-relay System Engineering, *Proc. IRE*, January, 1953.
13. Unpublished work of Jack Smith, dated June 24, 1957, TV Relay Engineering, Industrial Electronics Division, General Electric Company, Syracuse, N.Y.
14. Crosby, Murray G.: FM Noise Characteristics, *Proc. IRE*, April, 1937.

# *Part 3*

# ELECTRICAL PERFORMANCE STANDARDS FOR TELEVISION RELAY FACILITIES

PROPOSED EIA STANDARD

## INTRODUCTION

The intent of this standard is to specify the minimal electrical performance characteristics consistent with good engineering practice of radio relay equipment intended for transmission of NTSC color-television signals from a studio to its associated television broadcast transmitter or for similar applications. (For the purposes of this standard it is assumed that relay equipment meeting the stated requirements is also adequate for monochrome picture transmission.) Pertinent parameters are defined, and standards and methods of measurement have been established for each where practical to do so.

The EIA subcommittee (TR 4.2) responsible for this standard coordinated its efforts with those of the EIA subcommittee (TR 4.1) on Standards for Microwave Transmission Systems and the IRE Committee on Video Techniques to produce a standard of maximum usefulness.

## SCOPE

The radio relay systems covered by this standard will generaly be in frequency bands above 1,800 Mc. They will specifically be those used for transmission of TV signals from a broadcasting studio to its associated TV transmitter. The information provided should, however, be useful to a variety of TV relay purposes such as portable-mobile relays, intercity relays, off-air pickups, etc., particularly when the signal being relayed is intended for broadcast purposes.

The relay system may transmit the audio and video portions of the TV program on the same RF channel by any of several multiplexing methods, or they may be transmitted separately. Comment is made only on over-all performance requirements.

The video portion of the TV program may be either a color or monochrome signal. It is recognized that a monochrome signal does not actually require some of the specifications given in the standard. However, it is felt that with the imminence of increased color programming, only the one more rigorous standard should be provided.

## DEFINITION OF TELEVISION RELAY SYSTEM

A *television relay system* is a system of two or more stations for transmitting television relay signals from point to point using radio waves in free space as a medium, such transmission not being intended for direct reception by the public.

A *television relay signal* is a radio-freqnency wave modulated primarily by a composite picture signal and may or may not include the accompanying sound, auxiliary, and control signals.

The *composite picture signal* shall consist of the following individual signals:

1. Picture signal (including horizontal and vertical blanking signals)
2. Synchronizing signals (horizontal and vertical)

The *standard composite picture signal* is a composite picture signal having a waveform specified in TR-135 entitled "Picture Line Amplifier Output." This drawing shall be the latest revision of the standard.

*Television relay input signals* are signals consisting of a standard composite picture signal and, optionally, the accompanying audio, auxiliary, and control signals, available from separate circuits.

*Television relay output signals* are signals consisting of a standard composite picture signal and, optionally, the accompanying audio, auxiliary, and control signals, available to separate circuits.

### Studio-to-transmitter Relay System

A studio-to-transmitter relay system is a television relay system of one or more hops providing service from a television studio to its associated transmitter.

### Portable-mobile Relay System

A *portable-mobile relay system* is a system for the transmission of television relay signals from a portable or mobile program source to a fixed control room or a broadcast transmitter. This system may include more than one portable or mobile relay station. *Portable equipment* is defined as being readily transportable and operable in transit.

### Intercity Relay System

An *intercity relay system* is a system for the transmission of television relay signals by fixed stations from one metropolitan area to another.

### Intracity Relay System

An *intracity relay system* is a system for the transmission of television relay signals by fixed stations between two or more points within the metropolitan area for purposes other than those covered under Studio-to-transmitter Relay Systems.

### Off-the-air Pickup Relay System

An *off-the-air pickup relay system* is a system wherein the radiated signal from a television broadcast station is picked up by a suitable receiver and relayed to a point of utilization.

### Transmitting Terminal Station

A *transmitting terminal station* is part of a television relay system and is the specific assembly of apparatus which accepts a television relay input signal and radiates a television relay signal.

### Receiving Terminal Station

A *receiving terminal station* is part of a television relay system and is the specific assembly of apparatus which accepts a television relay signal and delivers a television relay output signal.

### Repeater Station

A *repeater station* is part of a television relay system and is the specific assembly of apparatus which receives and retransmits a television relay signal.

### Relay Channel

A *relay channel* is the band of frequencies used in transmission of a single television relay signal and normally includes both the frequency band for the transmission of intelligence and sufficient guard bands.

### Relay Band

A *relay band* is composed of a group of contiguous relay channels.

## OVER-ALL SYSTEM PERFORMANCE CHARACTERISTICS

This applies to the performance characteristics of a *studio-to-transmitter relay system* from transmitting-station input to receiving-terminal-station output.

### Input Impedance

#### *Composite Picture Signal*

**Definition.** The input impedance of a relay system is the complex ratio of voltage to current, expressed in rms, as measured at the input terminals of a transmitting terminal station.

**Standard.** The standard input impedance of a relay system shall be 75 ohms $\pm 5$ per cent and constant within $\pm 2$ per cent over a frequency range of 0 to 4.3 Mc. This impedance shall be connected for unbalanced line.

**Method of Measurement.** It is recommended that the input impedance of the relay system be measured by means of an impedance equipment having an accuracy of $\pm 1$ per cent in the vicinity of 75 ohms.

#### *Audio Signal*

**Definition.** The input impedance of a relay system is the complex ratio of voltage to current, expressed in ohms, as measured at the input terminals of a transmitting terminal station.

**Standard.** The standard input impedance shall be 600/150 ohms, nominal.

**Method of Measurement.** Standard audio-frequency impedance-measuring equipment shall be used.

### Input Level

#### *Composite Picture Signal*

**Definition.** The peak-to-peak voltage of a composite picture signal is the difference in level between its sync tip and reference white expressed in volts.

**Standard.** The input of the standard composite picture signal to the relay system across its standard impedance shall be a minimum of 0.7 volt and a maximum of 1.4 volts peak to peak. The standard level shall be 1.0 volt peak to peak.

**Method of Measurement.** It is recommended that the signal voltage input to the relay system be measured by means of an oscilloscope capable of measuring such a signal within an accuracy of $\pm 2$ per cent. The signal may normally occupy the band from 30 cycles to 4.3 Mc.

#### *Audio Signal*

**Definition.** The level of an audio signal is defined numerically as the power ratio in decibels between the audio signal working into a given impedance and a reference signal of 1 mw. It is commonly expressed in dbm.

**Standard.** The standard audio input level shall be a minimum of 0 dbm and a maximum of +20 dbm. The nominal operating level shall be +10 dbm.

**Method of Measurement.** The audio input level shall be measured directly across the input terminals of the relay system using a 400-cycle tone.

## Load Impedance

### *Composite Picture Signal*

**Definition.** The load impedance of a relay system is the complex ratio of voltage to current, expressed in ohms, as measured across the two-terminal network which terminates the output of the relay system.

**Standard.** The standard lead impedance for the relay system shall have a value at zero frequency of 75 ohms ±5 per cent. This impedance shall be connected for unbalanced line operation and shall be constant within ±2 per cent over the frequency range from 0 to 4.3 Mc.

**Method of Measurement.** It is recommended that the load impedance of the system be measured by means of an impedance-measuring equipment having an accuracy of ±1 per cent in the vicinity of 75 ohms.

### *Audio Signal*

**Definition.** The load impedance of a relay system is the complex ratio of voltage to current, expressed in ohms, as measured across the two terminal network which terminates the output of the relay system.

**Standard.** The standard load impedance shall be 600/150 ohms, nominal.

**Method of Measurement.** Standard audio-frequency impedance-measuring equipment shall be used.

## Source Impedance

### *Composite Picture Signal*

**Definition.** The source impedance of a relay system is a complex ratio of voltage to current, expressed in ohms, of the internal impedance as measured at the output terminals of a receiving terminal station.

**Standard.** The source impedance of a relay system shall be 75 ohms ±10 per cent over a frequency range of 15.75 kc to 4.3 Mc.

**Method of Measurement.** It is recommended that the source impedance of a relay system be measured by means of an impedance bridge having an accuracy of ±1 per cent in the vicinity of 75 ohms.

## Output Level

### *Composite Picture Signal*

**Definition.** The peak-to-peak voltage of a composite picture signal is the difference in level between its sync tip and reference white expressed in volts.

**Standard.** The standard composite picture-signal output from a receiving terminal station across its standard load impedance shall have a level of 1.0 volt peak to peak. The signal level shall be adjustable between the limits of 0.7 and 1.4 volts.

**Method of Measurement.** It is recommended that the signal voltage output of the relay system be measured by means of an oscilloscope capable of measuring such a signal within an accuracy of ±2 per cent. The signal may normally occupy the band from 30 cycles to 4.3 Mc.

### *Audio Signal*

**Definition.** The level of an audio signal is defined numerically as the power ratio in decibels between the audio signal working into a given impedance and a reference signal of 1 mw. It is commonly expressed as dbm.

**Standard.** The standard audio signal output from a receiving terminal station across its standard load impedance shall be 10 dbm ±2 db for 100 per cent modulation.

**Method of Measurement.** The audio output level shall be measured directly across the output terminals of the relay system using a 400-cycle tone.

## Polarity

### *Composite Picture Signal*

**Definition.** The polarity of a picture signal is the sense of the potential of a portion of the signal representing a dark area of the scene relative to the potential of a portion of the signal representing a light area. Polarity is stated as "black positive."

**Standard.** The standard polarity of the input or output of a microwave link shall be black negative.

**Method of Measurement.** It is recommended that signal polarity be measured by means of an oscilloscope of known deflection polarity.

## Amplitude vs. Frequency Characteristic

### *Composite Picture Signal*

**Definition.** An amplitude vs. frequency response characteristic is a description by means of a graph of the variation with frequency of the ratio of sine-wave output voltage applied to a four-terminal network.

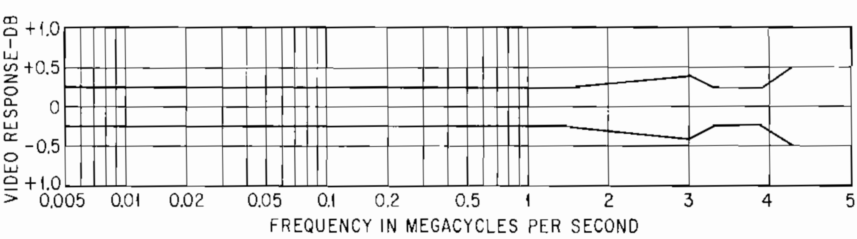


FIG. 3-1. Amplitude vs. frequency-response characteristic.

**Standard.** The amplitude vs. frequency response characteristics of a microwave link shall be within the limits specified in Fig. 3-1.

**Method of Measurement.** Deferred.

### *Audio Signal*

**Definition.** An amplitude vs. frequency response characteristic is a description by means of a graph of the variation with frequency of the ratio of sine-wave output voltage to input voltage applied to a four-terminal network.

**Standard.** The amplitude vs. frequency response characteristics of a microwave link shall be within the limits specified in Fig. 3-2. If preemphasis and deemphasis are used, it is recommended that it be in accordance with the impedance-frequency characteristics of a series *LR* network having a nominal time constant not greater than 75$\mu$sec.

**Method of Measurement.** The measuring equipment shall terminate the input and output of the equipment under test in pure resistances having values within 5 per cent of the rated source and load impedances. The condition of grounding or balance to ground normally used in operation shall be maintained. The standard input level and deviation to the transmitter shall be established at 400 cycles, and the receiver output

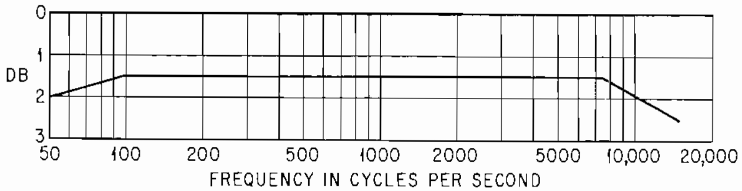


FIG. 3-2. Amplitude vs. frequency-response characteristic—audio signal.

control set for standard output. If *no* preemphasis and deemphasis are used, the frequency response shall be taken under these conditions, maintaining constant input to the transmitter and measuring receiver output variations. If preemphasis and deemphasis are used, after setting up as described, the input to the transmitter shall be dropped approximately 20 db and kept at this level during the frequency-response run. The receiver controls shall *not* be reset. This procedure is used to prevent overload of the audio system at higher audio frequencies due to the "boost" provided by the preemphasis network.

## Low-frequency Response

### *Composite Picture Signal*

**Definitiou, Standard, and Method of Measurement.** Deferred.

## Relative Envelope Delay vs. Frequency Characteristics

### *Composite Picture Signal*

**Defiuition.** Relative envelope delay is the variation in the first derivative of the phase shift, measured in radians, with reference to the frequency, measured in radians per second.

**Staudard.** Deferred.

**Method of Measurement.** Deferred.

## Step-function Transient Response

### *Composite Picture Signal*

**Definition, Standard, and Method of Measurement.** Deferred.

## Harmonic Distortion

### *Audio Signal*

**Defiuition.** The audio-frequency harmonic distortion is the change in harmonic content of the input signal as a result of passing through the relay system.

**Staudard.** The audio-frequency distortion, including all harmonics up to 30 kc, shall not exceed the values given in the following table at 25, 50, and 100 per cent of full modulation.

| *Distortion, per cent* | *Frequency range, cps* |
|---|---|
| 1.75 | 50–100 |
| 1.25 | 100–7,500 |
| 1.5 | 7,500–15,000 |

**Method of Measurement.** Standard audio-signal generating and distortion-measuring equipment shall be used. A resistor equal to the input impedance of the transmitter shall be connected between an audio oscillator (having less than 0.1 per cent rms distortion) and the transmitter input terminals. The audio-freqnency-level meter shall be connected across the output of the oscillator. The receiving end shall be terminated in a resistor equal to its rated load impedance, and the distortion-measuring equipment connected across this resistor. Measurements shall be taken on at least the following frequencies: 50, 100, 400, 1,000, 5,000, 10,000, and 15,000 cps. It should be noted that if the audio transmitting and receiving equipment employ preemphasis and deemphasis, constant modulation percentage is *not* obtained by constant input voltage but can be obtained only by dropping the transmitter input voltage with rising frequency as many decibels as the preemphasis curve rises. The receiver and transmitter gain controls shall not be readjusted during this procedure.

NOTE 1: Measurements of distortion in the range of 7,500 to 15,000 cps, at 25 and 50 per cent modulation, may not be possible with presently available measuring equipment if preemphasis and deemphasis are employed, and these measurements are not required in such a case.

NOTE 2: For the higher modulation frequencies, it is important to include in the measurements only harmonics of the modulating frequency and to exclude hum and noise components.

## Differential Gain and Differential Phase

### *Composite Picture Signal*

**Definition.** In a video-transmission system, "differential gain" is the difference in gain of the system in decibels for a small high-frequency sine-wave signal at two stated levels of a low-frequency signal on which it is superimposed.

NOTE: In this definition, level means a specified position on an amplitude scale applied to a signal waveform.

In a video-transmission system, "differential phase" is the difference in phase shift through the system for a small high-frequency sine-wave signal at two stated levels of a low-frequency signal on which it is superimposed.

NOTE: In this definition, level means a specified position on an amplitude scale applied to a signal waveform.

**Standards.** Maximum differential gain expressed in decibels relative to the maximum gain at 50 per cent average picture level (APL) sball not exceed 0.5 db; at 10 and 90 per cent APL it shall not exceed 0.8 db. Maximum differential phase between blanking level and any other level in the blanking to reference white range shall not exceed $+1.0, -1.0°$ at 50 per cent APL; it shall not exceed $+1.5, -1.5°$ at 10 and 90 per cent APL. The differential phase shall not exceed a total amount of 1.5° at 50 per cent APL and a total amount of 2.0° at 10 and 90 per cent APL.

**Method of Measurement.** The TV relay system shall be operated at standard input and output levels. A test signal consisting of the following components shall be applied to the transmitter input.

1. A low-frequency exploring voltage which varies from blanking to reference white.
2. Sync pulses at the nominal picture line frequency with an amplitude of 0.4 that of the exploring voltage and a nominal width of 5 $\mu$sec. Each sync pulse shall be followed by a nominal 5-$\mu$sec interval at blanking level.
3. A higher frequency sine wave having a peak-to-peak amplitude of 0.2 that of the exploring voltage. Unless stated otherwise, the sine wave shall he at a nominal frequency of 3.58 Mc.

4. The test signal may also contain such elements of a composite signal (additional sync pulses, color burst, etc.) as may be required for proper operation of clampers or other control devices in the specific equipment under test.

It shall be possible to make measurements at 10, 50, and 90 per cent average picture level. Average picture level is defined as the average signal level during active scanning time, i.e., excluding intervals at blanking and sync, integrated over a frame period. It is expressed as a percentage of the blanking to reference white range. Differential gain is measured by observing the variation in the amplitude of the high-frequency sine wave at the receiver output during a cycle of the exploring voltage at a given APL. Differential phase is measured by observing the variation in the phase of the high-frequency sine wave at the receiver.

## Signal-to-noise Degradation

### *Composite Picture Signal*

**Definition.** The video signal-to-noise ratio for the relay system is the ratio of the peak-to-peak signal voltage to rms noise voltage at the relay output terminals. Noise as referred to herein is random noise and does not include hum components or interfering tones.

**Standard.** The video signal to rms noise shall be 63 db weighted. The characteristics of the noise-weighting network are shown in Figs. 3-3 and 3-4 (63 db weighted corresponds to approximately 48 db unweighted).

**Method of Measurement.** The system shall be operated using a standard composite picture signal at standard input and output levels. The modulation shall then be removed, and the output disconnected from the 75-ohm termination and fed to the weighting network which shall be terminated with 75 ohms. The noise output shall be determined at this termination using an appropriate meter. The meter shall be of the rms or average (calibrated in rms) type with a frequency response that is flat $\pm 1$ db to 4 Mc relative to 10 kc.

NOTE: This standard is for nonfading conditions, and it should be noted that the percentage of time during which this standard is maintained is a function of the system fade margin.

### *Audio Signal*

**Definition.** The signal-to-noise ratio of the relay system is the ratio of rms signal voltage to the rms noise voltage in the relay output terminals. Noise is any extraneous output voltage in the frequency band 50 cycles to 15 kc.

**Standard.** The rms signal to rms noise ratio shall be at least 58 db.

**Method of Measurement:**

1. For an AM system the signal-to-noise ratio can be determined by power meters applied to the relay system output with measurements taken with carrier modulation at 100 per cent 400-cycle and at 0 per cent modulation.

2. For an FM system the ratio of signal to noise in the absence of modulation can be determined as follows: The carrier shall be deviated with rated modulation at 400 cycles, and the output determined with an rms indicator. The modulation shall be removed, and the noise output determined with an rms indicator. If preemphasis is used, deemphasis circuits shall be included ahead of the rms indicator.

3. Should the radio relay equipment utilize circuits that are common to the audio and video signals, the audio $S/N$ measurements shall be made while relaying a standard picture signal under standard input and output level conditions.

NOTE: Standard input and output impedance shall be used in all the above measurements. The audio test signal shall be sufficiently free from distortion and noise for the purpose of these measurements.

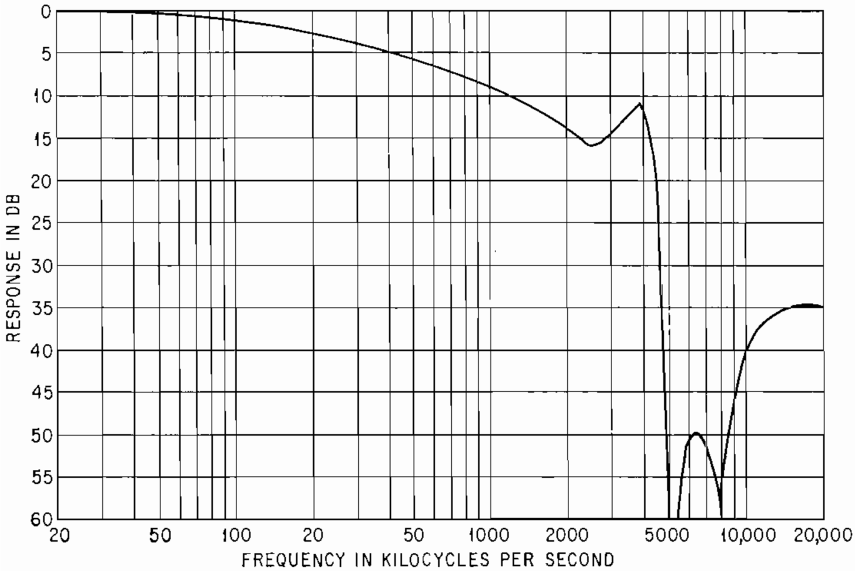


Fig. 3-3. Response of color-TV weighting network.

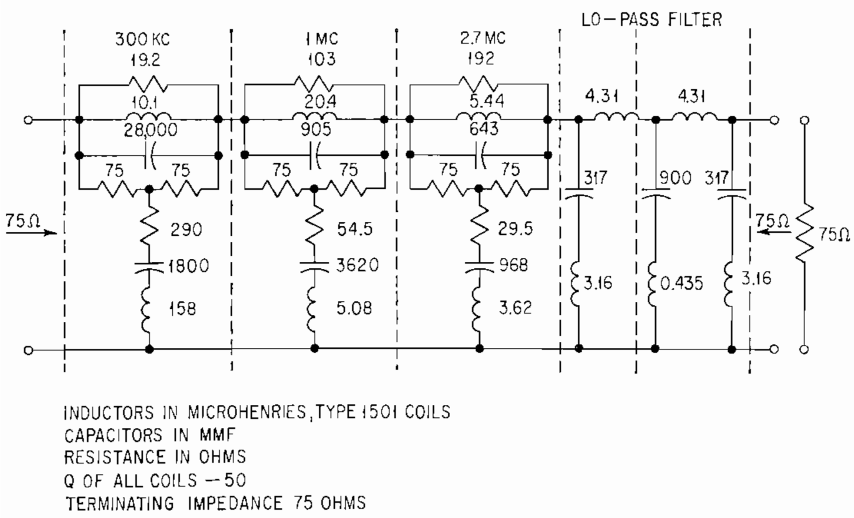


Fig. 3-4. Television weighting network.

## Signal-to-hum Ratio

### *Composite Picture Signal*

**Definition.** Video signal-to-hum ratio for the relay system is the ratio of the peak-to-peak signal voltage to the rms hum component voltage at the relay output terminals.

**Standard.** Deferred.

**Method of Measurement.** The system shall be operated using a standard composite picture signal at standard input and output levels. The modulation shall then be removed, and the hum output shall be determined with an appropriate meter. The meter should be of the rms or average (calibrated in rms) type with a bandwidth sufficiently narrow so that the random noise does not affect the reading.

## Power Supplies

### *Composite Picture Signal*

**Definition.** The rated power supply of the system is described by specifying the voltage, the number of phases, and the frequency of the supply with which the system shall be required to meet all performance standards applying to such apparatus.

**Standard.** The standard rated power supply shall be single-phase, 117-volt rms $\pm 5$ per cent, 60 cps, $\pm 2$ per cent alternating current.

**Method of Measurement.** Standard power-measurement practice shall be followed.

## *Part 4*

# PLANNING, CONSTRUCTION, AND OPERATION OF A REVERSIBLE INTERCITY MICROWAVE RELAY SYSTEM WITH AUTOMATIC FAULT-REPORTING EQUIPMENT

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### INTRODUCTION

Jefferson Standard Broadcasting Company owns and operates two television stations: WBTV in Charlotte, N.C., and WBTW in Florence, S.C. The airline distance between the two cities is 94 miles. Charlotte, N.C., is a metropolitan area with a population of more than a quarter of a million people and is the largest city in the two Carolinas. Florence, S.C., has a population of approximately 26,000. However, there are more than 800,000 Carolinians within the grade B contour of WBTW, which encompasses an area of some 12,292 square miles. Nearly 600,000 of these people reside on farms or in communities with populations under 1,000. Florence, with its population of only 26,000, is the largest community in the entire 12,000-square-mile area served by WBTW.

The Florence station is completely equipped to originate local live productions. However, because of the small population of Florence itself and the wide dispersion of the communities it serves, WBTW has had real difficulty in securing the suitable and salable talent necessary for successful local live productions. Charlotte, with its much larger population, has an abundance of talent which has built up a very high degree of popularity in the Carolinas over WBTV during the past nine years. Florence needed television talent—Charlotte had it—the problem was how to make this talent available to WBTW at a cost which would be compatible with the station's rate card. Economics, of course, ruled out the use of common-carrier facilities. Until recently, Part 4 of the Commission's Rules would not permit licensing of privately owned intercity relay systems where common-carrier facilities were available. In our case such common-carrier facilities were installed and were available. Thus, we were

* The author is deeply indebted to C. I. McDowell, C. A. Runyon, and J. B. Bullock of TCA and T. E. Howard for their valuable assistance in preparing this material.

stymied until the Commission recently relaxed its rules so as to permit privately owned and operated intercity facilities. We promptly applied for and received construction permits for the intercity system. The system has been constructed and has been in operation since Feb. 15, 1959. The system, which is designed to accommodate both color and monochrome programs, will also make available to WBTW the extensive color facilities installed at WBTV. The WBTV studios in Charlotte are equipped for the origination of local slide, film, opaque, and live color or color video tape-recorded programs. Origination of WBTW programs from one of the Charlotte studios enables WBTW to schedule local live color programs, which is not feasible from the Florence studios.

## DESCRIPTION OF SYSTEM

The WBTV-WBTW intercity system consists of two terminal stations and three repeater stations (see Fig. 4-1).

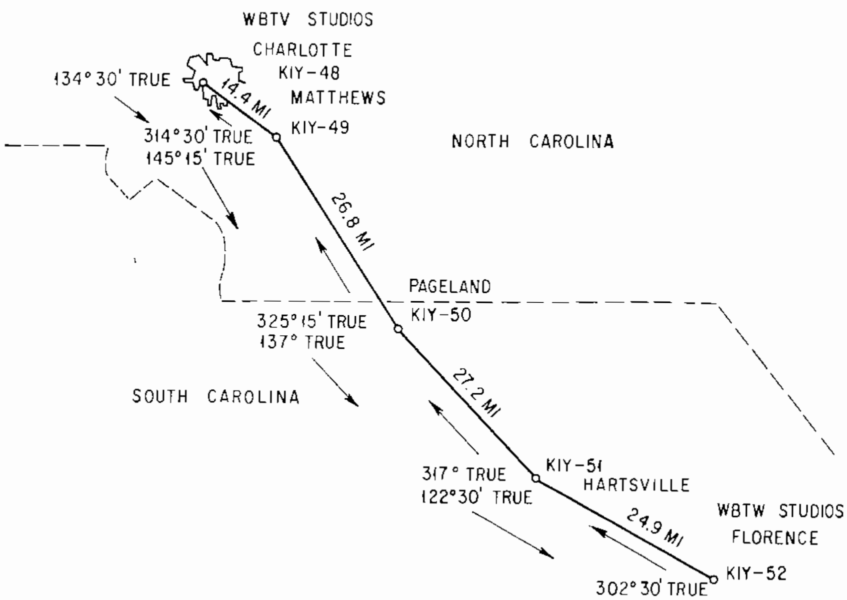



FIG. 4-1. WBTV-WBTW intercity microwave relay system.

The system was designed for remote control, reversible transmission, and automatic fault reporting, and the three repeater stations are unattended. A telephone line is used as the medium for switching signals and for reporting the status of each switched station as well as reporting faults existing at stations other than the controlling terminal. Separate private-line telephone-communication facilities are provided among all locations to facilitate maintenance and adjustments.

All transmitting and receiving equipment are housed in concrete block structures at the bases of the various towers. Plastic domed parabolic reflectors are mounted on these structures and are directed to passive reflectors mounted on the towers. The ground systems consist of 4/0 bare copper wire buried 15 in., extending from the tower base to each guy anchor, and bonded to each guy wire as well as to a copper-clad rod driven in the ground. A similar rod is used as a common-point bond to all three ground wires and connected to the tower and equipment racks to complete the system. A typical repeater installation is shown in Fig. 4-2.

The transmission system is capable of monochrome or color-television video-signal transmission in either direction, with television audio contained within the channel as a diplexed subcarrier signal. Audio diplexing is provided in both directions.

Automatic frequency control is provided at each of the repeater stations. Monitoring of the transmitter video modulation is also provided at each repeater, the RF signal being demodulated by sampling the same cavity used in the AFC circuit. Thus the output of each repeater transmitter can be locally monitored as an aid to inspection and maintenance of the unattended equipment at the repeater stations.

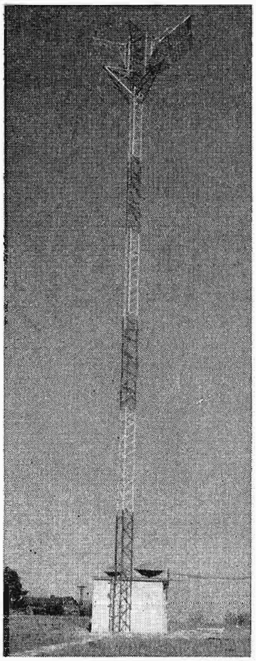


FIG. 4-2. A typical repeater installation.

Two RF channels are used in the system, thus avoiding problems of cross coupling between adjacent receiving and transmitting antennas and passive reflectors on the same tower. Sufficient frequency separation is used to provide adequate isolation between received and radiated signals. The use of two RF channels also minimizes possible problems of overshoot signals causing interference at subsequent receivers.

## Path Considerations

In the design of a microwave relay system two types of fading must be guarded against if the system is to have a predictable and a satisfactory propagational reliability. These two types of fades are recognizable by their duration and would be identified as due to what is called "inverse bending" and "multipath" reflection. A third type of fading, due to actual attenuation of the microwave beam by rain or snow, is generally negligible at 7,000 Mc and so will not be considered.

### *Inverse Bending*

The inverse-bending type of fade is prolonged. A fade of this type may last for from a few minutes to several hours as atmospheric conditions change. It is caused by the fact that the trajectory of the microwave beam from transmitter to receiver is not actually a straight line but is, in fact, curved, generally following a path similar to that shown in Fig. 4-3. The path departs from a straight line because the dielectric constant of air generally decreases with altitude. If the atmosphere were perfectly homogeneous, propagation would be along a straight line. If, owing to temperature

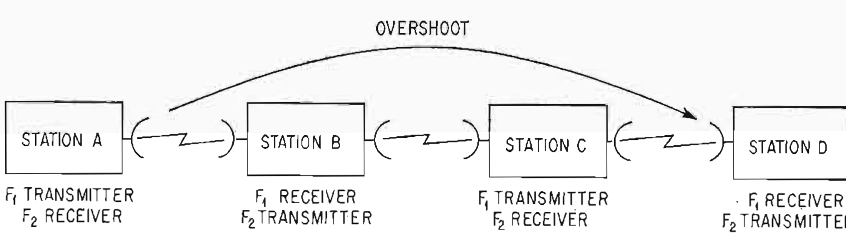



FIG. 4-3. Inverse-bending type of fade.

inversion along the path, the normal conditions become reversed, the beam may then have to follow an "inverse-bend" trajectory, which will result in its being blocked, unless sufficient clearance is provided.

The protection against inverse bending then is adequate clearance. Once this has been provided, the second type of fading, multipath, may be considered.

### *Multipath*

Multipath fading, as the name implies, is caused by the signal arriving at the receiver by two different paths, which become out of phase 180° or nearly so upon arrival. In a multipath fade, one of the paths is, of course, the straight-line antenna-to-antenna path. The second path may be from a ground reflection, from a layer of still air, or maybe from a flat, low cloud base. The second signal, if it is of equal strength to the direct signal and in phase with it, could add only 3 db to the receiver input. However, if equal and out of phase, it could reduce the receiver input to zero. Fortunately, the reflected signal is generally weaker than the direct signal and so reduces it only by some 30 or 40 db when arriving out of phase. Protection against multipath fade is afforded by adequate clearance plus providing sufficient fade margin to maintain the signal through those fades which come from reflections off atmospheric discontinuities. The multipath fade is always of short duration, only a few seconds at the most, but may take place in quick succession as a layer of air shifts so as to provide reflections in sequence.

Proper clearance on the microwave path is assured by providing clearance for the beam during conditions of the maximum amount of inverse bending expected. This varies with the type of terrain and with the generally prevalent weather conditions. Bending is always most severe over smooth earth and in regions where the air is often still and where temperature may vary widely in a short time.

These conditions are most conducive to the accumulation of layers of air in the path which can produce bending. On the other hand, a brisk wind blowing over a broken terrain will assure turbulence in the air which keeps it pretty thoroughly homogeneous, and the beam then tends to travel in a straight path.

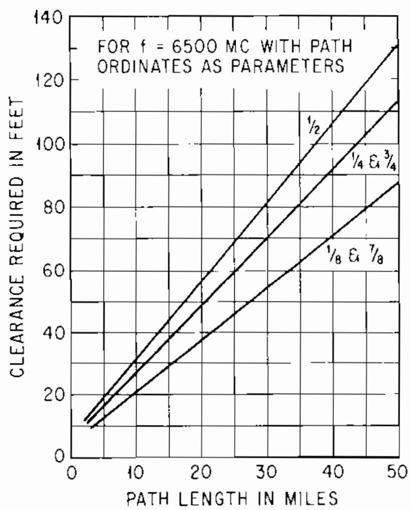



FIG. 4-4. Path-clearance curves.

### *Fresnel-zone Clearance*

For purposes of this part let us say that sufficient clearance protection against both types of fading is provided by allowing full Fresnel-zone clearance over a 4/3 earth on the terrain covered by the WBTV-WBTW system. This clearance is generally equal to about 0.6 full Fresnel zone over a true earth, depending on the distance involved. Figure 4-4 shows the required clearance for a microwave path.

With the use of this rule, antenna heights can be calculated for the case of terrain in which both ends of a hop are roughly equal. Antenna heights thus determined provide line-of-sight clearance *above* all obstructions along the path equal to 0.6 of the Fresnel-zone diameter. In all cases it is, of course, advisable to plot all this on profile.

The Fresnel zone is defined as a region bounded by a fictitious curved surface from which reflection traveling from transmitter to receiver will travel an extra 180° (one-half wavelength) compared with the direct path. Since there is 180° phase change upon reflection, any signal going from transmitter to receiver by this path will arrive as an *aiding* signal. A reflection from a point which penetrates well within the Fresnel zone, however, will not have the benefit of the extra half-wavelength of travel

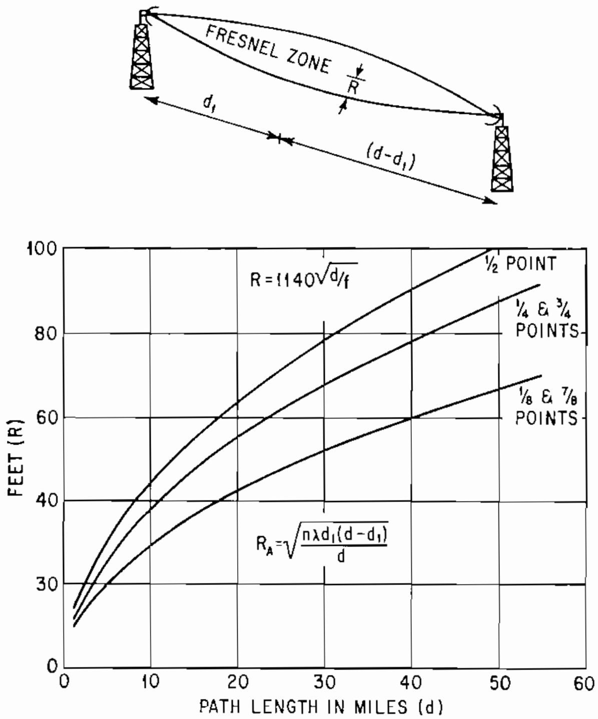



FIG. 4-5. Fresnel zone and radius vs. path length.

and would arrive at the receiver as a canceling signal. Figure 4-5 illustrates the Fresnel zone and radius vs. path length.

### *Fade Margin*

Proper clearance having been provided, it is now necessary to determine the fade margin for protection against those really unavoidable multipath fades which are statistically bound to happen.

In order to provide a fade margin, it is necessary to provide a nonfaded input signal to the receiver which is considerably greater than that required for a usable or even noise-free picture. The required fade margin for a given reliability varies with path length, and this is illustrated by Fig. 4-6.

The fade margin may be defined as the amount by which the nonfaded RF input to the receiver exceeds the RF input which is needed to provide a minimum usable signal out of the receiver. The minimum usable signal is defined—in view of the fact that expected fades are to be of short duration—as existing when the $S/N$ ratio is 28 db. This is a noisy picture. The peak-to-peak signal will be 2.5 times the peak-to-peak noise but by subjective tests is tolerable for short periods (seconds) of time by an average viewer.

Figure 4-7 shows that the RF power to the receiver to produce this minimum usable signal is minus 99 dbw. Every decibel of power above this level is considered fade margin.

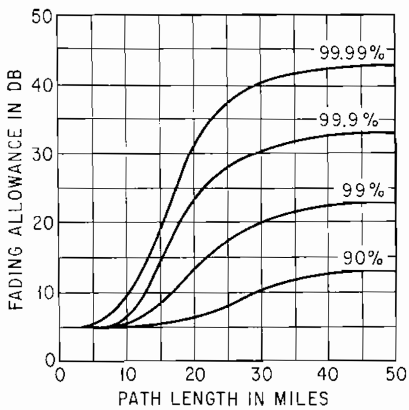



FIG. 4-6. Fading-allowance reliability.

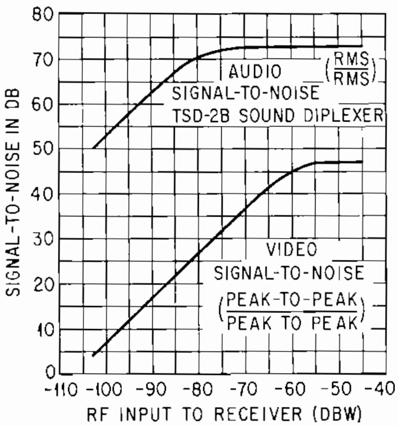



FIG. 4-7. Signal-to-noise ratio.

## Reliability Calculations

For example, let us take the Hartsville-Florence hop on the WBTV-WBTW system. The total free-space loss on this 25-mile path is 141.5 db. Figure 4-8 serves to illustrate. Allowing 2.5 db for waveguide losses, the total loss is 144 db. The antenna-reflector combinations at each end of the link have gains of 42.5 db, or a total of 85 db. This makes the net loss between transmitter and receiver 144 – 85, or 59 db, and the power into the receiver is minus 59 dbw (59 db below 1 watt). A fade margin of 99 – 59, or 40 db, has thus been provided. Figure 4-6 shows that the reliability will be slightly greater than 99.99 per cent.

A similar calculation on each of the other hops will also yield a reliability figure of 99.99 per cent.

The over-all reliability can be *conservatively* figured by assuming that none of the fades on the four hops will be coincident. Thus, if each hop is out for 0.01 per cent of the time, the total will be out 0.04 per cent of the time and the over-all reliability will be 99.96 per cent. Figure 4-9 shows the parameters of each path and the over-all system between WBTV and WBTW.

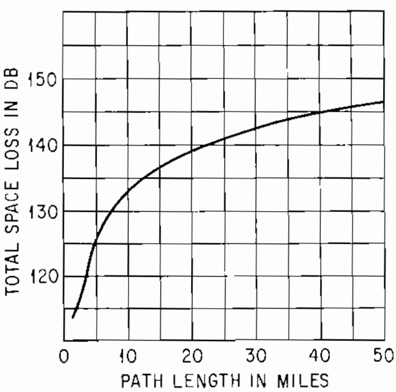



FIG. 4-8. Free-space loss at 6,500 Mc. $\alpha$ (db) = 37 + 20 log $f$ (Mc) + 20 log $d$ (miles).

## Equipment and Operation

A basic system diagram for a reversible, two-hop microwave system is shown in Fig. 4-10. There could be $N$ number of repeaters.

Comvor data-transmission and receiver terminal equipments are utilized for reversing control and fault reporting. For fault reporting, the Indicon coder and decoder with delay timer are required.

Fault sensing is accomplished through the use of the low-power–low-signal-level indicator and the video presence detector, while receiver AFC disabling and automatic shutdown is provided for by the application of the AFC radiation switch.

| Path Calculations<br>WBTV Five-Station Microwave Relay System | |
|---|---|
| Charlotte to Matthews | |
| Free-space loss, 14.4 miles, db | 136.0 |
| Waveguide loss, db | 2.5 |
| Total loss, db | 138.5 |
| Antenna gains: | |
| 4-ft dish and 8- by 12-ft reflector, 150 ft, db | 39.5 |
| 4-ft dish and 8- by 12-ft reflector, 150 ft, db | 39.5 |
| Total antenna gain | 79.0 |
| RF input to receiver, dbw | −59.5 |
| Audio $S/N$ ratio, db | 73.0 |
| Video $S/N$ ratio, db | 65.0 |
| Fading allowance, db | 39.5 |
| Predicted reliability, % | 99.99 plus |
| Matthews to Pageland; and Hartsville to Florence | |
| Free-space loss, 26.8 miles, db | 141.5 |
| Waveguide loss, db | 2.5 |
| Total loss, db | 144.0 |
| Antenna gains: | |
| 6-ft dish and 10- by 15-ft reflector, 150 ft, db | 42.5 |
| 6-ft dish and 10- by 15-ft reflector, 150 ft, db | 42.5 |
| Total antenna gain, db | 85.0 |
| RF input to receiver, dbw | −59.0 |
| Audio $S/N$ ratio, db | 73.0 |
| Video $S/N$ ratio, db | 65.0 |
| Fading allowance, db | 40.0 |
| Predicted reliability, % | 99.99 plus |
| Pageland to Hartsville | |
| Free-space loss, 27.5 miles, db | 142.0 |
| Waveguide loss, db | 2.5 |
| Total loss, db | 144.5 |
| Antenna gains: | |
| 6-ft dish and 10- by 15-ft reflector, 150 ft, db | 42.5 |
| 6-ft dish and 10- by 15-ft reflector, 150 ft, db | 42.5 |
| Total antenna gain | 85.0 |
| RF input to receiver, dbw | −59.5 |
| Audio $S/N$ ratio, db | 73.0 |
| Video $S/N$ ratio, db | 65.0 |
| Fading loss, db | 39.5 |
| Predicted reliability, % | 99.99 plus |
| Over-all predicted reliability, % | 99.96 |
| Over-all video $S/N$, db | 59.0 |
| Over-all audio $S/N$, db | 67.0 |
| Video $S/N$ is peak-to-peak signal to rms noise<br>Audio $S/N$ is rms signal to rms noise | Random noise only |

FIG. 4-9. Path calculations, WBTV five-station microwave relay system.

From the master terminal, switching is accomplished through the activation of a Comvor transmitter. A single Comvor transmitter is required for reversing. It is arranged for the transmission of a carrier-on, mark or space signal (raise-*off*-lower operation). A switching panel arranged to suit the system contains activating controls for the Comvor transmitter and an activating control for the local waveguide switch. Local fault indications appear on each of the units previously mentioned. An Indicon decoder and Comvor receiver are provided for the reception and display of remote faults and answer-backs.

A Comvor receiver is provided at the unattended repeater to receive reversing information. This receiver is equipped with the carrier detector accessory, enabling the receiver to operate in the raise-*off*-lower arrangement. The antenna reversing control provides a junction point for the Comvor receiver and waveguide switch wiring, as well as a remote and local answer-back. It also contains a local reversing control switch. Various fault-finding devices as previously mentioned are included. Remote contacts from the fault devices and the remote answer-back contacts are fed to the delay timer. A closed circuit initiates the timing cycle, and upon completion of the cycle, the Indicon coder transforms closed circuits into coded pulses which key the Comvor transmitter for reporting.

Fault sensing, reversing, and reporting from the final terminal is identical with that of the unattended repeater.

Switching control is shown at a master terminal with reporting to that same terminal. Modifications in arrangement and equipment are made to allow switching and reporting at both terminals.

### *Basic Reversible System*

Figure 4-10 is a block diagram of a basic reversible system with automatic fault reporting.

Operation of a reversing sequence is as follows:

1. To switch the system from that position shown (south-north), activate the system reverse switch at the attended master terminal to the north-south direction.
2. This turns *on* the Comvor tone generator terminal (frequency $F_2$) and may cause it to transmit a *mark* (or *space*) signal (*raise*).
3. This *mark* (*raise*) tone is then transmitted over the wire line to all unattended stations.
4. The Comvor tone receiver (frequency $F_2$) at each unattended station then receives the *mark* tone. The output relay and Comvor (tone) detector device will then move to that corresponding position.
5. The output relays of the Comvor tone receiver are then fed to the antenna reversing control.
6. This, in turn, activates the waveguide switch to the north-south position.
7. When the waveguide switch is placed in the north-south position, the microwave receiver and transmitter waveguide connections are reversed. The receivers are then placed on the opposite antenna to that shown in Fig. 4-10.
8. Similarly the transmitter antennas are reversed from the positions shown in Fig. 4-10.
9. Also, on the waveguide switches, answer-back contacts are provided to indicate the positions of the waveguide switches.
10. When the waveguide switches are activated by the antenna reversing control, the answer-back contacts are fed to the Indicon coders.
11. Taking first the unattended terminal, the answer-back contacts on the Indicon coder cause it to report.
12. When this Indicon coder reports, the coded pulses out of it are used to key the Comvor tone generator.
13. These audio tone pulses are then transmitted over the wire line to the attended terminal.
14. At the attended terminal, the audio tone pulses are received by the Comvor tone receiver.

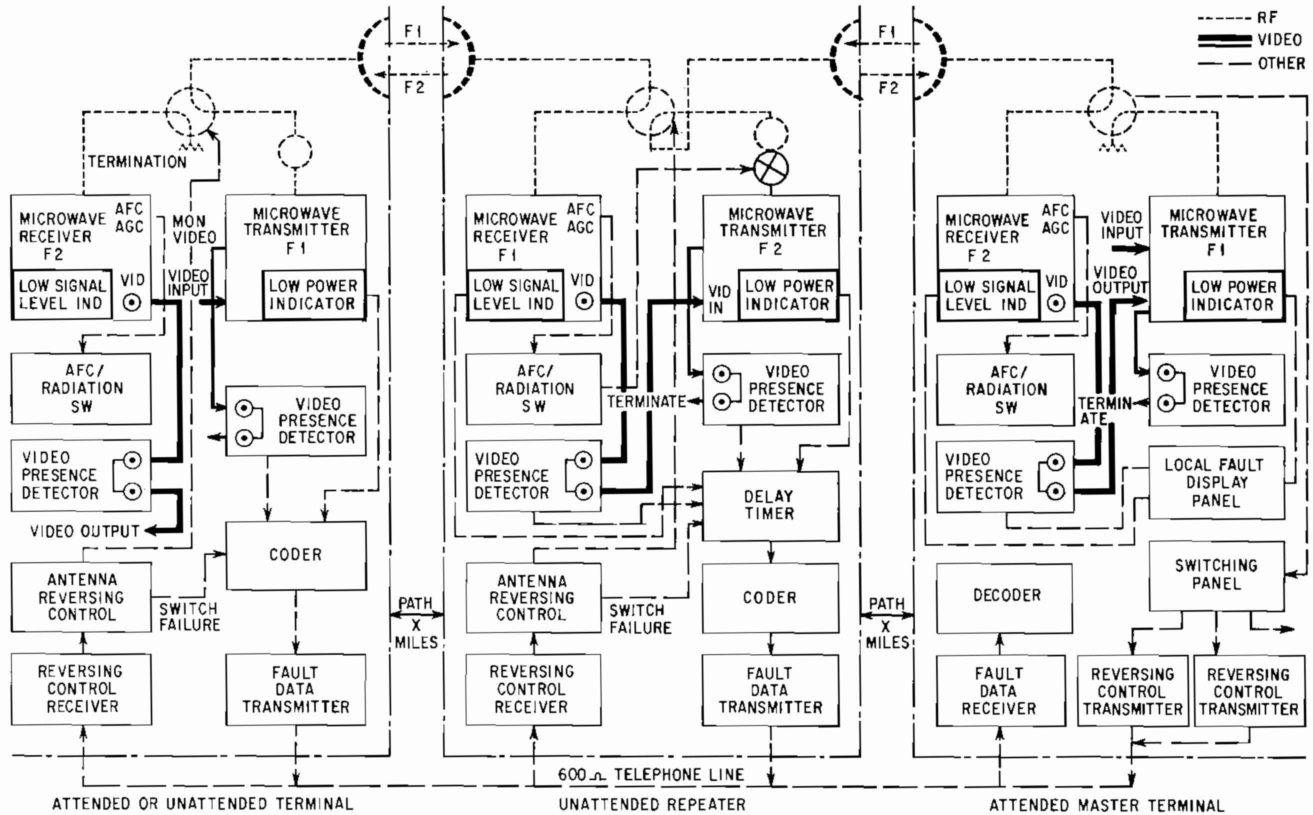



FIG. 4-10. Basic system diagram for a reversible, two-hop microwave system.

15. This tone receiver then keys the Indicon decoder in sequence with the reporting coder. Thus, the answer-back information is indicated on the decoder display. This answer-back information tells what station is reporting and whether or not the waveguide switch is in the proper position.

16. At the unattended repeater, the answer-back information is presented to the delay timer. After a prescribed time delay this station will then report just as the attended terminal did.

It requires about 15 sec for an Indicon coder to transmit its pulses. To arrange that the next station does not report simultaneously, it is necessary to create about 20 sec delay before the second station starts reporting. Similarly, if there is a third station, 40 sec would be required at that location and a fourth station would require 60 sec. This delay is provided by a delay timer at each location. Of course, all stations report in sequence with an arrangement such as this.

17. Thus, for a four-hop system, approximately 2 min would be required to obtain a complete report from all stations.

18. Once all stations have reported or allowing them to report twice, the reversing tone information is turned off. This is accomplished automatically by including a time-delay relay in the system reversing control panel.

When the reversing tone is turned off, the antenna reversing control is deenergized, which removes the answer-back information from the coder. This prevents further transmission of answer-back information and eliminates excessive wear on the coder and decoder equipments.

19. Fault reporting is accomplished exactly as the answer-back information.

When a fault occurs, the coder is activated and sends out pulses. These pulses key a tone generator. The keyed tone is transmitted over a wire line and received at the attended terminal by a tone receiver. The tone receiver keys the decoder, and the fault is thereby displayed.

Delay timers are included to eliminate garbling of fault reporting should simultaneous faults occur at different stations.

### *Indicon Coder*

The Indicon coder is a precision electromechanical device capable of sending 15 digits of binary code for indication purposes. A total of 10 faults or indications can be coded. The first five digits of the binary code are used to identify the reporting station. One of these devices is required at each unattended station. Figure 4-11 is a photograph of the Indicon coder unit.

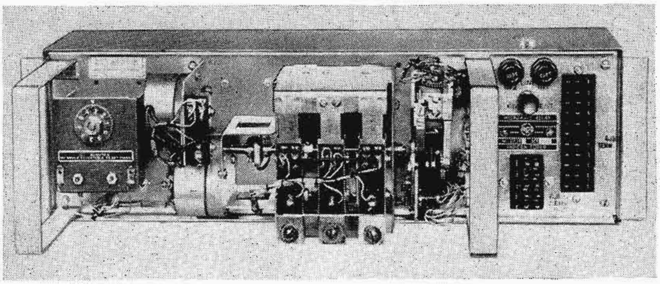


Fig. 4-11. Indicon coder unit.

Fault indications or other information are represented by *closed* relay contacts.

When any one or more of the fault-indicating devices present a closed circuit to the coder, the coding cycle begins.

As the coder is activated, it searches all 15 positions to determine whether or not there is a closure on the circuit. The closures on the first 5 positions are permanent and are so arranged that a particular code is transmitted for each different station. For the other 10 positions, if there is no closure, another type of pulse is transmitted. A pulse of 360 msec duration (*long*) will repreesnt a closure, while a pulse of 90 msec (*short*) represents no closure.

Assuming that faults 1 and 5 occurred at station 2, the sequence of pulses would be as follows:

Short-long-short-short-short
Long-short-short-short-long
Short-short-short-short-short

These pulses are actually a series of switch and relay contacts which provide a closed circuit to ground for 90 msec on a *short* pulse or 360 msec for a *long* pulse. Approximately 15 sec is required for the complete transmission of 15 digits. A transmission device such as an audio tone generator is then keyed, providing a duration of audio tone equal to the length of the keying pulse or zero audio tone if there is no pulse.

Once a fault has initiated the operation of the coder, it sends out the 15-digit code and then begins a timing cycle during which no code is transmitted. This timing lasts for 10 min, after which the coder again transmits the pulses providing the fault still exists. If the fault (faults) should disappear prior to the completion of the 10-min cycle, only the station identification would be reported and the coder would then rest in the home position. As long as the fault exists, the pulses will be transmitted every 10 min.

### *Decoder*

The decoder operates in response to incoming coded signals from the coder. A bank of five lamps is operated in response to the first five pulses of the coder pulse train for station identification. Ten other lamps operated from relays are used to display the received fault information. Figure 4-12 is a photograph of the Indicon decoder.

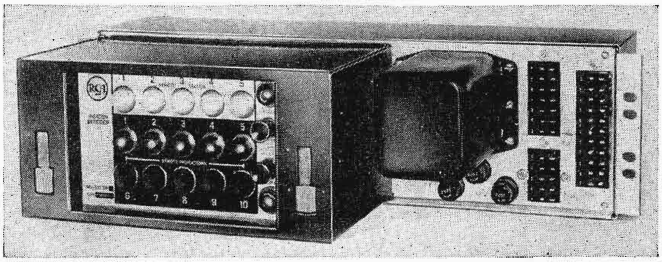


Fig. 4-12. Indicon decoder unit.

A detailed functional description of the decoder is rather laborious. A simple explanation would be to say that, when a long pulse is received, a lamp *is turned on* and, when a short pulse is received, lamps are not turned on. Each pulse as it is received (long or short) causes an "impulse" relay to step; thus the 15-count sequence is retained. If the decoder should receive an improper number of pulses (15 exactly) as a result of a fault in the fault-reporting system, then the information is cleared from the display of the decoder and it will await the second report.

As the fault information is reported, it is displayed on the decoder and the display is retained until another report is received. When the next report is received, the lamp display is automatically cleared before the new information is displayed.

The decoder is operated from closed contacts which are closed in sequence and for the same time duration as those of the Indicon coder pulse output.

A tone generator and tone receiver connected by wire line come between the coder and decoder. The tone receiver contains a relay in the output, and this relay keys the decoder. A description of the tone transmitter and receiver would be time-consuming and therefore would not be appropriate in this part. However, Fig. 4-13*a* and *b* shows a photograph and a block diagram of the model 912T (transmitter) and model 912R (receiver) used in this system.

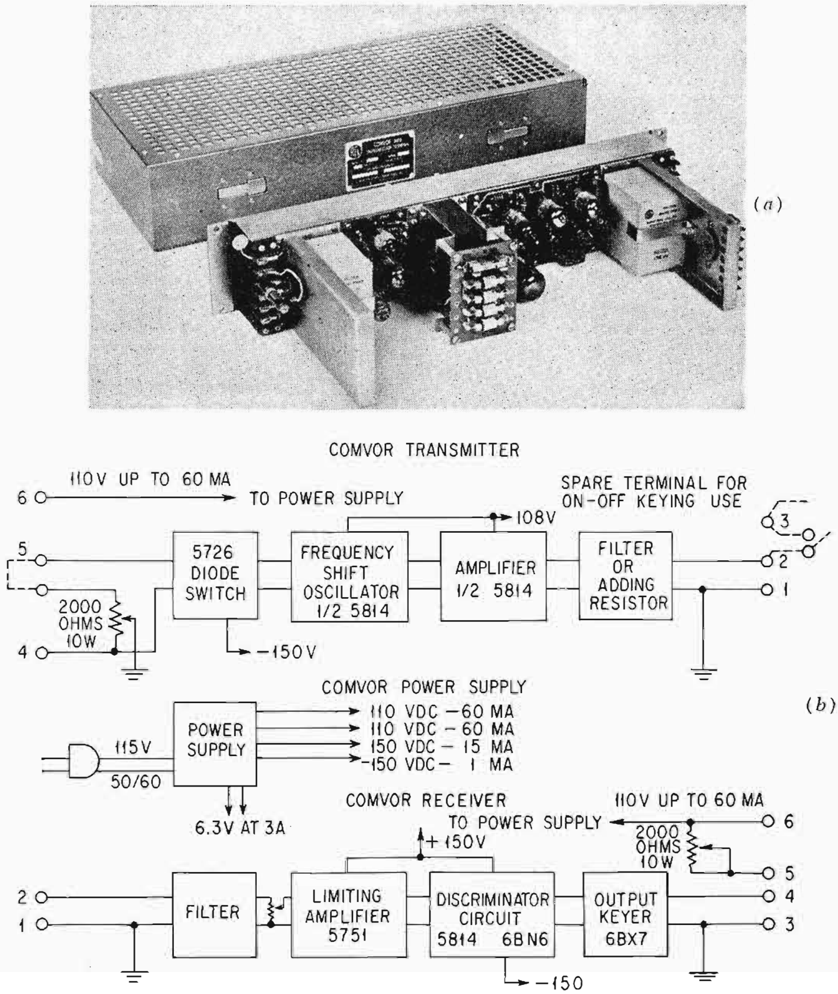



FIG. 4-13. Photograph and block diagram of model 912-T (transmitter) and model 912-R (receiver).

## Assembly and Installation

In order to minimize field assembly and installation time for this relay system it was felt desirable to install all equipment in the racks, together with required interunit cabling, at the manufacturer's plant. Figure 4-14 is a photograph of one unit. This procedure made it possible to accomplish all wiring and cabling more rapidly and uniformly and permitted complete system tests at a common location by engineering personnel familiar with system performance requirements. Thus, the equipment was delivered in this manner.

The equipment was given additional operating checks by measurement of video signal-to-noise ratio between transmitter and receiver pairs as they were to be installed in the actual system after delivery in Charlotte and Florence. This check was performed to ensure that all equipment was functioning normally after shipment; all equipment was, in fact, found to be functioning normally.

Upon completion of these checks the equipment was distributed to appropriate

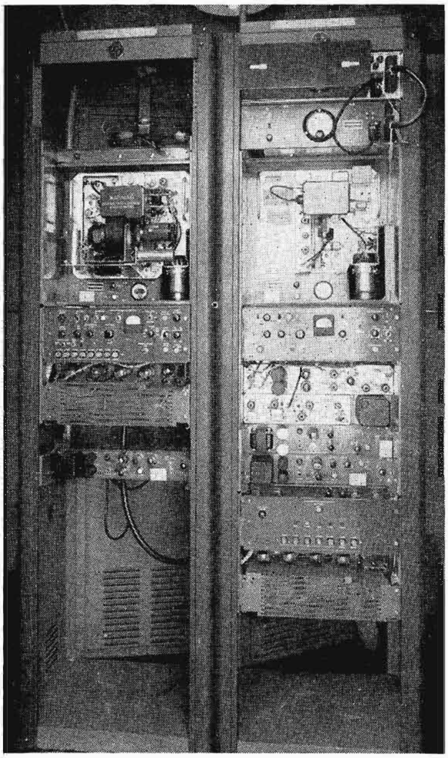


FIG. 4-14. Complete rack-mounted unit (receiver and transmitter).

locations, antennas installed, and the waveguide plumbing connections between equipment cabinets and antennas made. The towers had been previously erected, and passive reflectors installed and approximately oriented for path alignment.

Upon completion of all equipment, antenna, and waveguide installation, alignment of the four paths was begun.

In general, the antenna and reflector alignment proceeded rather rapidly and smoothly, since antenna sizes were such that the beamwidths are not unusualy critical and the terrain traversed is not unusually prone to ground reflection conditions. Typical terrain is shown in Fig. 4-15, which is a profile of the Pageland-Hartsville hop. The reasonably heavy stand of pine-tree vegetation in this area, together with the slightly rolling terrain, is not so likely to aggravate the alignment problem with ground reflections as in some geographical areas. However, even under these conditions considerable care was necessary during alignment to distinguish between maximum observed from direct main-lobe radiation and maxima which may be encountered owing to alignment on reflections.

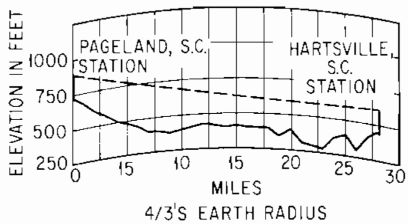
Upon completion of the over-all system the performance was found satisfactory, and program tests commenced on Feb. 15, which carried educational programs for broadcast by WBTW for use in the public school systems of South Carolina.

## Maintenance and Personnel

The problem of maintenance and technical personnel is of a twofold nature: (1) regular preventive maintenance and (2) emergency repairs.

One complete set of tubes, crystals, and fuses are kept at each station. A Lambda-Pacific model 7100 microwave test set, a Simpson model 260 Multi-Meter, a vacuum-tube voltmeter, and a tube checker are carried by the maintenance technician on all regular checks.

A regular weekly visit is made to each station to check the performance of all apparatus at that location. A thorough inspection is made of all components to detect excessive heating or other defective functioning. Tubes that are suspected of improper operation are checked and replaced where necessary. A check of the ventilating system is made for proper functioning. A Lambda-Pacific model 7100 test set is used to measure all pertinent characteristics of both transmitter and receivers.




| LOCATION | N-LATITUDE | | | W-LONGITUDE | | |
|---|---|---|---|---|---|---|
| | D | M | S | D | M | S |
| PAGELAND, S.C. | 34 | 45 | 16.99 | 80 | 25 | 11.971 |
| HARTSVILLE | 34 | 27 | 54.15 | 80 | 05 | 45.207 |

BETWEEN CHARLOTTE, N.C.
AND FLORENCE, S.C.

CONTOUR READING BY M. J. MINOR

DATE ________

FIG. 4-15. Profile graph for terrain between Pageland and Hartsville, S.C. (*Jefferson Standard Broadcasting Company: Television Intercity Relay System, Charlotte, N.C., to Florence, S.C.*)

Because of the use of fault-reporting equipment loss of air time will be minimized. Personnel holding first-class radiotelephone licenses are on duty at the terminal stations in Charlotte and Florence during all hours of operation of the system. In case of failure at one of the three unattended repeater stations it will not be necessary to search for the "needle in the haystack" because the location of the repeater in trouble together with an indication of the type of trouble existing is automatically sent to the terminal control station and an engineer can be sent from the nearest terminal.

# *Part* 5

## TELEVISION-SIGNAL ANALYSIS *

American Telephone & Telegraph Company
Long Lines Department
New York, N.Y.

### INTRODUCTION

Part 5 of this section was prepared as a general reference for telephone company employees who are concerned with the analysis of television signals transmitted over company lines. Such analysis has as its purpose a determination of the quality of the signal as received at various points along its transmission path and, if signal impairment appears, a diagnosis of its probable cause. This will naturally lead to the taking of such corrective measures as may be indicated.

It is clear that, to have any significance, the observation of signals requires the use of monitoring devices that are always capable of giving a faithful representation of the actual signal on the line. Correct adjustment and proper maintenance of these devices must, therefore, be assumed. Granting this, any observed deficiency in the signal must either be present in the output of the camera equipment or be the result of failure of the transmission system to carry the signal without distortion from its point of origin to the distant monitoring point.

Properly to discharge his responsibilities, the telephone technician must first know what the signal delivered by the camera looks like in comparison with the signal which he is receiving. If this comparison indicates that undue distortion is being introduced by the transmission system, he may wish similarly to compare his received signal with the signals received by other monitors back along the line in order to isolate the section of the transmission system that is at fault.

A single observer, of course, cannot make simultaneous observations of a signal at a number of different points. Comparisons, therefore, depend upon telephone communication among observers who may be located at widely separated points and who may be associated with entirely different communications or broadcasting organizations.

For such communication to be fully effective, it is necessary that the observing devices employed at all points be sufficiently alike to produce signal representations that are directly comparable in kind. It is also necessary that all observers have a common understanding of what constitutes the normal signal representation. Similarly, each should be able to recognize the appearance of the more usual types of signal impairments that may occur from time to time. In addition, skill in diagnosing the probable general cause of any observed impairment is highly desirable as a first step in facilitating the location and correction of the fault responsible.

It is obvious that effective communication among observers further requires that each use a language that is readily understood by the others. As in most new arts, the growing television vocabulary has tended to develop some coufusion, with several different words or phrases being used for the same thing in many cases. In this part, an attempt has been made to select in each case the particular words or designations that seem to have gained the widest acceptance at this time.

With the principal objective of promoting desirable common understandings of both signal forms and their nomenclature, the following pages first discuss satisfactory monochrome- and color-television signals as they appear in standard oscilloscope and picture-monitor representations and illustrate the generally accepted designations for their several principal components. Following this, various types of test signals are discussed. The major types of video-signal impairments are then listed, and each type is considered separately. Significant features, as they appear to the monitoring observers in both oscilloscope and picture-monitor representations, are illustrated and discussed. Finally, a glossary of video terms is presented.

Much of the photographic and descriptive material included has been prepared with the help of the engineering groups of the American Broadcasting Company, the Columbia Broadcasting System, the Dumont Television Network, and the National Broadcasting Company, all of whom have been extremely cooperative. This part, then, endeavors to represent the viewpoints of both the broadcasting industry and the telephone company.

## THE TELEVISION SIGNAL

A picture monitor in a broadcaster's studio or a telephone company television operating center might depict a test pattern as shown in Fig. 5-1. This picture is free of discernible defects as evidenced by the facts that straight lines are straight, circles are round, there is a complete range of grays, and there are no other obvious distortions.

The complete analysis of the picture signal, however, cannot be determined by the picture monitor alone. In the operation and maintenance of network television transmission, it is also necessary to analyze the signal using a cathode-ray oscilloscope (A scope). The A scope permits the display of the voltage-time characteristics of both the horizontal scanning interval and the vertical scanning interval.

### Horizontal Scanning Interval

Figure 5-2 is the horizontal video signal presentation of the monochrome test pattern of Fig. 5-1 as seen on the A scope with a sweep rate of about 7,875 cps (one-half the 15,750-cycle line rate). As shown, polarity of the signal generally displayed on A scopes used in broadcasters' master control rooms and telephone company television operating centers is "black negative."

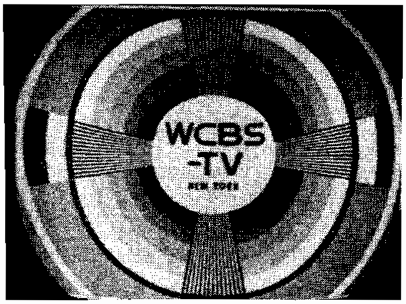



FIG. 5-1. Unimpaired video signal—pictnre-monitor presentation.

The complete video line signal for one scanning line, included between $E$ and $G$, requires a time interval of 1/15,750, or 63.5 $\mu$sec. The horizontal blanking interval nominally requires 10.05 $\mu$sec of this time as indicated between $E$ and $F$, and the picture information utilizes the balance of the time, or 53.45 $\mu$sec. The left side of the picture is indicated at $F$, and the right side at $G$.

The horizontal and vertical sync pulses, which synchronize the sweep circuits in the receiver with those of the camera, determine the timing of the scanning lines and thus permit accurate location of each element being scanned. The horizontal synchronizing pulse is shown in the blanking interval, with a voltage level corresponding to $D$.

The picture-brightness information is carried between $A$ and $B$, with the peak-white amplitude of the picture at *A* and the peak-black amplitude of the picture at *B*. In the case of test-pattern signals, these peaks correspond to reference-white and reference-black levels, in which range it is expected that normal program picture information will fall. Any video voltage less than that at *A* will produce an increasingly darker gray until black is reached at *B*. Thus the region between *A* and *B* carries the picture-brightness information in terms of voltage, the instantaneous level of the voltage corresponding to the brightness at that particular instant of time.

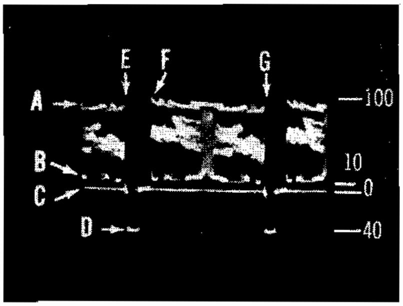



FIG. 5-2. Unimpaired video signal—A-scope horizontal presentation. *A*. White peak. *B*. Black peak. *C*. Blanking level. *D*. Synchronizing level. *E-G*. Complete horizontal interval = 63.5 μsec. *E-F*. Horizontal blanking interval = 10.05 μsec. *F-G*. Picture signal = 53.45 μsec.

The "setup" of the picture is the difference in voltage between the blanking and reference-black levels, as indicated between *C* and *B* in Fig. 5-2. On the IRE voltage scale, which has been adopted for industry-wide use, the setup value for network transmission is normally 10.

It can be seen that if a picture has no black but goes only from white to dark gray, the minimum video voltage will not approach blanking level as closely as it would if the picture contained full blacks. This picture would appear to have a high setup. On the other hand, the video voltage should not extend through reference-black level. Broadcasters attempt to maintain a reference black in all transmissions to obtain the most pleasing effect. Many of their studios are now equipped with electronic devices to maintain proper setup leaving the studio.

Typical proportions for a 1-volt peak-to-peak composite signal as displayed on an oscilloscope with an IRE scale are 40 divisions of sync, 10 divisions of setup, and 90 divisions of picture information, as shown in Fig. 5-2.

Figure 5-3 is an expanded view of the horizontal blanking interval with its component parts, including the horizontal synchronizing pulse and adjacent signal, identified. The nomenclature tabulated here, if universally used, will minimize confusion when a signal impairment is traced to its source.[1]

The front porch isolates the synchronizing pulse from transients or overshoots in the video signal at the end of the scanning line. This is done so that the synchronizing circuits in receivers or customer stabilizing amplifiers will not be triggered prematurely, thus producing a picture with successive horizontal lines displaced in a sporadic manner, which would result in jitter or possible tearing.

[1] The time intervals given in Figs. 5-2 and 5-3 for the front and back porches are approximately the minimum values set by the Federal Communications Commission for radiated signals. In practice, a 630-kc pulse generator frequently is used to time these signals so that the front porch equals one cycle, with the sync and back porch each equaling three cycles.

This basis currently is employed by CBS and NBC, and the nominal intervals become as below. ABC currently generates slightly different timing signals, also listed.

| | CBS, NBC | ABC |
|---|---|---|
| Front porch | 1.59 μsec | 1.3 μsec |
| Sync | 4.76 μsec | 5.0 μsec |
| Back porch | 4.76 μsec | 4.5 μsec |
| | 11.11 | 10.8 |

Since the total horizontal interval remains at 63.5 microseconds, the picture information interval varies according to the corresponding lengths of blanking interval.

The leading edge of the sync pulse is used to synchronize the horizontal-sweep oscillators in most monitors and receivers and to trigger some clamping circuits. Excessive slope or curvature of the leading edge of the sync pulse may cause erratic synchronization of a monitor or receiver or even complete failure of synchronization if sufficiently serious. It may also cause clamping failure in transmission equipment.

The tip of the sync pulse is used as the reference point in the d-c restorers of monitors and some oscilloscopes and in the d-c restoration or clamping stages of telephone company equipment.

A pulse derived from the trailing edge of the sync pulse is used to trigger the clamping circuits in most types of stabilizing amplifiers used by broadcasters. Serious slope or curvature of the trailing edge of the sync pulse will cause improper operation of these stabilizing amplifiers, resulting in tearing and rolling in the reproduced picture.

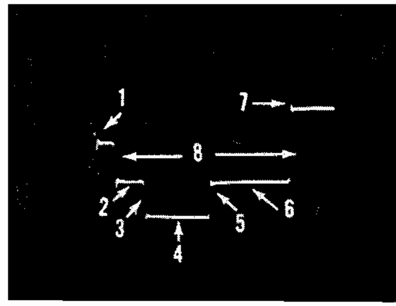



FIG. 5-3. Unimpaired video signal—A-scope expanded horizontal presentation. 1. Video voltages or right-hand side of picture. 2. Front porch = 1.25 μsec. 3. Leading edge of sync. 4. Tip of sync = 5.0 μsec. 5. Trailing edge of sync. 6. Back porch = 3.8 μsec. 7. Video voltages at left side of picture. 8. Horizontal blanking interval = 10.05 μsec.

The back porch completes the horizontal blanking interval. If the operation of the sweep circuits of a monitor or receiver is considered, it will be realized that when the electron beam has traversed the picture tube from left to right, it cannot return to the left side of the tube (retrace) instantaneously but requires a small amount of time to do so. If picture voltages were permitted to occur immediately after the horizontal sync pulse, the picture components they represent would be visible during retrace. The duration of the back-porch interval includes the time required for the sweep circuits to retrace completely prior to the occurrence of picture information.

While the broadcasters' stabilizing amplifiers are triggered by the trailing edge of the sync pulse, they clamp on the back porch. This type of clamper amplifier employs a time-delay *RC* circuit which is generally adjusted to delay the start of clamping action until sometime during the first quarter of the back-porch interval. The clamping or reference level is usually the average level over a 1-μsec (one-quarter) position of the back-porch interval. Therefore, if the back porch is seriously deformed or contains a large amount of noise, these amplifiers will clamp improperly, resulting in an impaired or useless picture to the customer, although the picture may appear usable at the serving telephone office.

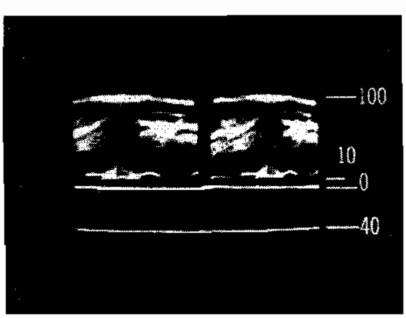



FIG. 5-4. Unimpaired video signal—A-scope vertical presentation.

## Vertical Scanning Interval

Figure 5-4 is the video-signal presentation of Fig. 5-1 as seen on the A scope during the vertical scanning interval, using a sweep rate of approximately 30 cps.

The levels of white peaks, black peaks, blanking, and tip of sync indicated in Fig. 5-4 are of the same value on the IRE scale as shown for Fig. 5-2. The vertical synchronizing pulse, with the associated equalizing pulses and blanking pulses, can be seen in the center of the picture. This presentation will reveal many of the common types of low-frequency trouble such as clamping failures, 60- or 120-cycle interference, or serious signal distortions.

Figure 5-5 is an expanded view of the vertical blanking interval with the component parts identified. Certain signal distortions that cannot be detected in the normal presentation can be seen in the expanded view.

The requirements imposed by interlaced scanning create the necessity for the equalizing pulses. The odd and even fields occur sequentially at the rate of 60 fields per second. The top line of an odd field starts at the top left side of the raster, and the bottom line ends at the bottom center of the raster, while the top line of an even field starts at the top center of the raster, and the bottom line ends at the bottom right side of the raster. Therefore, it can be seen that if the vertical synchronizing pulse occurred immediately following a horizontal scan, the vertical-pulse integrator capacitor in a receiver would have a different residual charge depending upon whether the vertical sync pulse followed an even or odd field. The fact that the vertical synchronizing pulse occurs one-half line nearer a horizontal sync pulse following an odd field than it does following an even field would result in imperfect interlacing if the first group of six equalizing pulses were not provided. The presence of these equalizing pulses preceding every vertical synchronizing pulse interval results in the vertical pulse integrator capacitor in a receiver having the same residual charge at the beginning of the vertical pulse, regardless of whether it follows an odd or even field. These six equalizing pulses occur at one-half horizontal-line intervals, which is at twice line frequency, or at the rate of approximately 31,500 pulses per second.

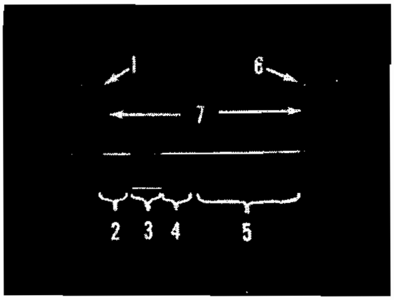



Fig. 5-5. Unimpaired video signal—A-scope expanded vertical presentation. 1. Picture voltages, bottom of picture. 2. First group of six equalizing pulses. 3. Serrated vertical sync pulse. 4. Second group of six equalizing pulses. 5. Horizontal sync pulses. 6. Picture voltages, top of picture. 7. Vertical blanking interval.

The serrated vertical sync pulse has a duration of approximately three full lines and has serrations occurring at the same rate as the equalizing pulses. These serrations are provided to keep the horizontal-sweep oscillators in receivers and monitors synchronized and running smoothly during the vertical synchronizing pulse. Alternate serrations function as horizontal sync pulses.

The second equalizing pulse group follows the serrated vertical sync pulse. These equalizing pulses also occur at twice line frequency. The first and second set of equalizing pulses, along with serrations of the vertical sync pulse, permit stable operation of the horizontal-sweep oscillator for the two different horizontal line conditions between the odd and even and between the even and odd fields.

The portion of the vertical blanking interval between the end of the second set of equalizing pulses and the first video information of the new field (4 and 5 of Fig. 5-5) is provided to allow time for the vertical sweep circuits in receivers to return the electron beam completely to the top of the picture tube before the video information of the new field starts. By adjusting the vertical hold control of the picture monitor and increasing the brightness, a presentation similar to Fig. 5-6 can be obtained. This shows the vertical blanking interval as a wide dark bar. The black bars represent equalizing and vertical sync pulses.

## NTSC Color

Figure 5-7 presents the horizontal display of an NTSC color signal on a wideband A scope. This particular signal is shown in black and white by Fig. 5-8. As can be

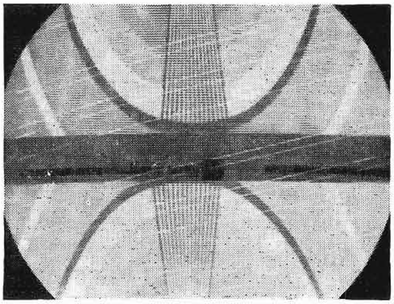


FIG. 5-6. Vertical blanking—picture.

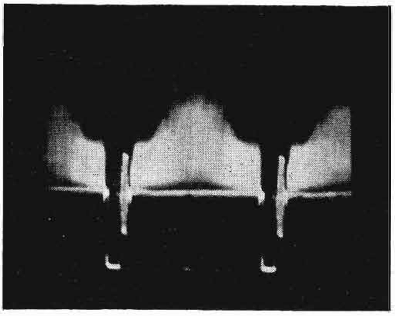


FIG. 5-7. Color signal—horizontal—wide-band.

seen, the A-scope presentation is similar in appearance to that of a monochrome signal in so far as horizontal blanking, sync, and picture information are concerned. The burst of high frequency during the back-porch interval represents the most distinguishing feature of the color signal observed on the A scope. This is the color sync burst, comprising 8 to 11 cycles of 3.6-Mc voltage. The peak-to-peak amplitude of the color burst should be the same as the amplitude of the horizontal sync pulse, i.e., 40 divisions on the IRE scale. The color burst is centered voltage-wise at blanking level, and time-wise it starts about one-tenth of the total back-porch interval from the trailing edge of the sync pulse. Another distinguishing feature is the presence of video information below black level, which varies with the hue and saturation of the colors being televised.

For color transmission the horizontal scanning frequency is 15,734.264 ± 0.044 cps rather than the nominal value of 15,750 cps; the vertical scanning frequency is 59.94 cps rather than the nominal value of 60 cps. The complete video signal for one scanning line requires a time interval of 1/15,734, or approximately 63.6 μsec. The horizontal blanking interval requires approximately 10.5 μsec of this time, and the picture information utilizes the balance of the time, or 53.1 μsec. This compares closely with the nominal intervals shown in Fig. 5-2 for the monochrome signal, the increase in blanking for the color signal being mainly in the back-porch interval.

If the picture content of the signal could be resolved, it would be seen that where color is scanned, the signal includes the 3.6-Mc color subcarrier varying in both amplitude and phase. When the A scope is operated using the IRE roll-off characteristic, the color signal appears as in Fig. 5-9, with practically all the color information removed. Now the scope presentation represents the luminance, or monochrome, portion of the signal only.

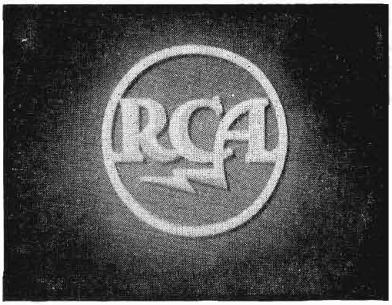



FIG. 5-8. Color signal—monochrome picture.

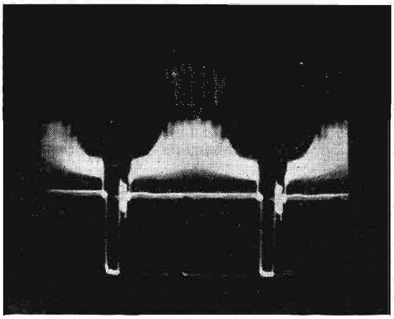


FIG. 5-9. Color signal—horizontal—IRE roll-offs.

A-scope presentations of color signals at vertical sweep rate, using either the wideband or IRE roll-off characteristic, do not differ from monochrome-signal presentations except for the presence of the high-frequency color information. Such a presentation is shown by Fig. 5-10, which was taken on a wideband scope.

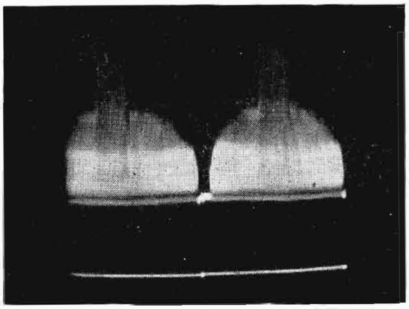


FIG. 5-10. Color signal—vertical—wideband.

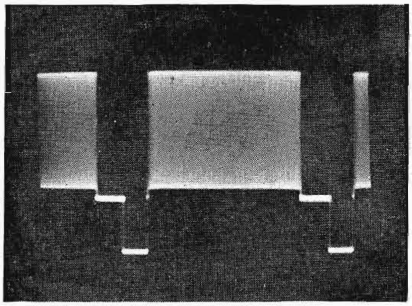


FIG. 5-11. Monoburst signal—horizontal.

## TELEVISION TEST SIGNALS

This section describes some of the test signals used in line-up and maintenance of television channels.

### Sine Waves

Sine-wave measurements are frequently used to determine gain-frequency characteristics of transmission channels. These signals generally are obtained from the 61B or 61C signal generator. The 70A or 70B power meter, a thermocouple instrument, is used for measuring. To provide accurate measurements at frequencies below 10 kc, clamping circuits along the transmission path must be disabled. Simple sine-wave measurements are not suitable where gating circuits are used, as in certain types of radio relay systems, to set the carrier rest frequency at the time of the horizontal sync pulse. In such cases, synchronizing pulses must be present for faithful reproduction of transmission conditions.

### Monoburst

The name "monoburst" has been applied to the resulting composite signal which is illustrated in Fig. 5-11. The complete monoburst signal consists of single-frequency sine waves plus sync pulses at the line rate, a blanking interval, and a means for varying the setup and the amplitude of the sine waves. The presence of the sync enables monoburst signals to operate gating circuits and clampers in normal fashion. Monoburst signals are measured and interpreted using a calibrated oscilloscope.

### Window Signal

As viewed on a picture monitor, the window signal is a large square or rectangular white area with a black background. Figure 5-12 is a typical window signal viewed on a picture monitor. Figures 5-13 and 5-14 show the horizontal and vertical presentations on an A scope. The picture signal has but two normal levels, reference black and white. The white level can be adjusted but is usually set at reference white. In order to locate the maximum energy content of the signal in the lower portion of the total frequency band, the white area is adjusted to cover one-fourth to one-half of the total picture width and one-fourth to one-half of the total picture height.

The window signal is useful for a number of checks and tests when observed on picture monitors or A scopes, including:

1. Convenient check for level or continuity. With the use of window of known white level, the peak-to-peak voltage of the signal can be read easily on a calibrated oscilloscope, using the IRE roll-off characteristic.

2. Measurement of sync compression or expansion. Comparison with the office transmitting the window signal of horizontal sync and white levels on calibrated scopes using IRE roll-off permits accurate evaluation of these linearity characteristics at the receiving point so that any necessary corrective action can be taken.

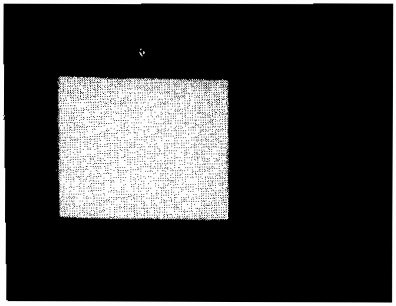


FIG. 5-12. Broadcaster's window signal—picture.

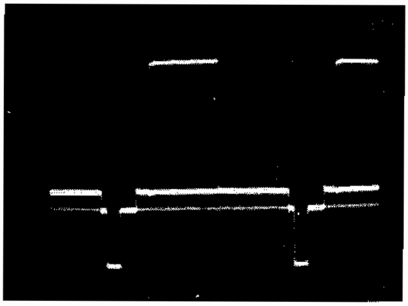


FIG. 5-13. Broadcaster's window signal—horizontal.

3. Minimizing streaking and smearing. Observation of this test signal on scopes using the IRE roll-off characteristic at both vertical and horizontal rates enables evaluation of streaking and smearing and adjustments to be made on clamper amplifiers and low-frequency equalizers to minimize these impairments. When a picture monitor is used for observation of streaking or smearing, it is essential to ensure that it is free from internal defects which might give false results.

4. Observation of ringing. The presence of ringing can be detected using wide-band scopes, properly calibrated, and expanding the horizontal presentation to a convenient scale. Ringing amplitude can be measured directly. Its frequency can be calculated by counting the number of ringing cycles occurring during a known time interval. Ringing also can be seen on picture monitors when receiving this signal.

The window signal generally used by the broadcasters contains both horizontal and vertical sync information, as in Figs. 5-12 to 5-14. In this type of signal, the white window is adjustable in size both horizontally and vertically and also is adjustable in position anywhere on the black background.

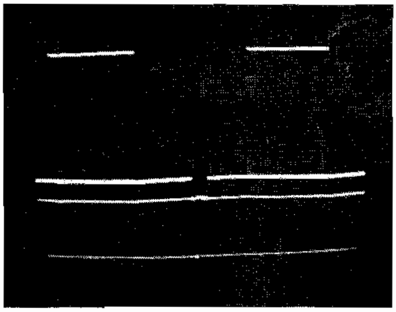


FIG. 5-14. Broadcaster's window signal—vertical.

The window signal provided by most telephone company generators, such as the 61C signal generator, provides a white area adjustable in width from the left edge of the raster, with a black area in the remaining portion as shown in Figs. 5-15 and 5-16. Sync pulses are provided at the horizontal rate (15,750 per second). The window signal provided by the earlier model signal generator (61B) is similar but not so suitable for streaking tests because the black and white areas are reversed, the white area being adjustable in width from the right edge of the raster. There is no adjustment of height for either the 61B or 61C white window, but if these signals are modulated at a 60-cycle rate by means available within the set, a window of approximately one-half the picture height can be obtained, as shown in Fig. 5-17. Horizontal and

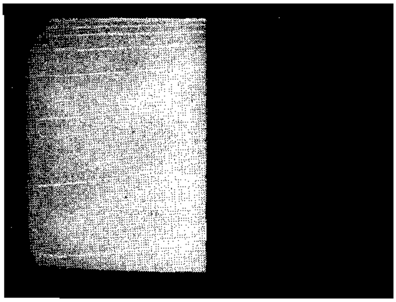


FIG. 5-15. 61C window signal—unmodulated—picture.

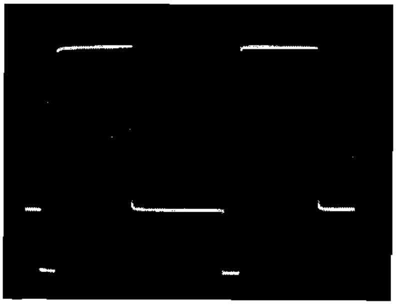


FIG. 5-16. 61C window signal—unmodulated—horizontal.

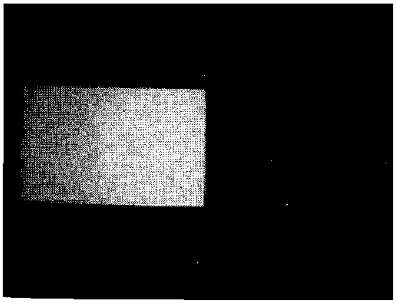


FIG. 5-17. 61C window signal—modulated—picture.

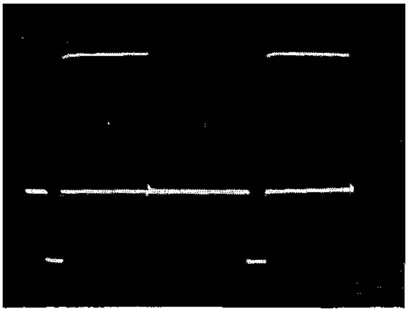


FIG. 5-18. 61C window signal—modulated—horizontal.

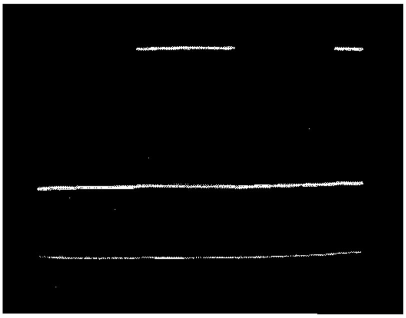


FIG. 5-19. 61C window signal—modulated—vertical.

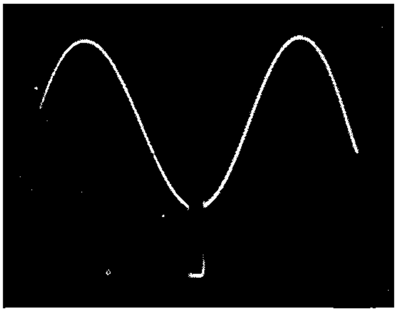


FIG. 5-20. 47A TMS—test signal—unmodulated—horizontal.

vertical presentations on an A scope are shown in Figs. 5-18 and 5-19. Since none of these signals have vertical sync information, the vertical retrace of the monitor is not blanked and the retrace lines are visible. This does not interfere with observation.

## 47A Transmission-measuring System

The 47A transmission-measuring system is nsed for measurements of differential phase and differential gain of facilities used for color-television transmission (change in phase or gain at 3.6 Mc as level is varied from black to white). The test signal

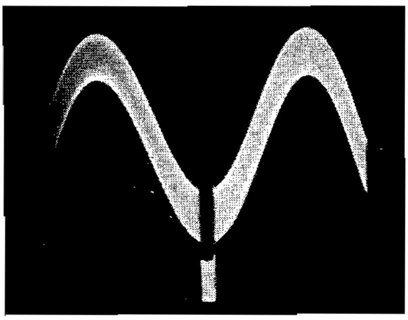


FIG. 5-21. 47A TMS—test signal—modulated—horizontal.

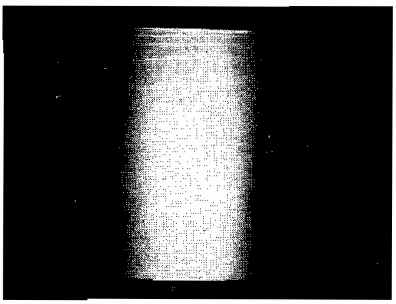


FIG. 5-22. 47A TMS—test signal—picture.

FIG. 5-23. 47A TMS—receiving-unit presentation—minus 27° differential phase.

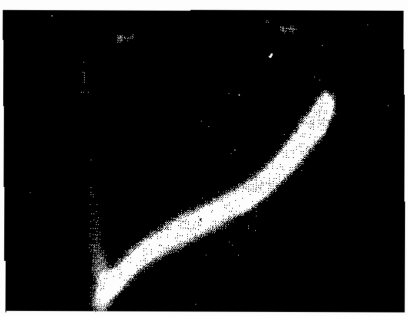


FIG. 5-24. 47A TMS—receiving-unit presentation—plus 27° differential phase.

consists of a 15.75-kc sine wave with positive peaks at reference-white level and negative peaks at blanking level, plus horizontal sync pulses inserted at negative peaks. On this sine wave, which corresponds to the luminance signal, there is superimposed a lower level 3.6-Mc (3579.545 kc) sine-wave signal corresponding to the chrominance signal. The 3.6-Mc signal is thus periodically raised and lowered through the region between blanking and white levels. At the receiving locations, instantaneous differential phase or differential gain at 3.6 Mc is displayed and measured on a low-frequency high-gain oscilloscope.

The 47A system consists of a transmitting unit (47B) and a receiving nnit (47C). Test signals and presentations on receiving sets are illustrated by Figs. 5-20 through 5-25.

For comparison, Fig. 5-26 illustrates a staircase signal transmitted over the layout having a 2-db differential gain.

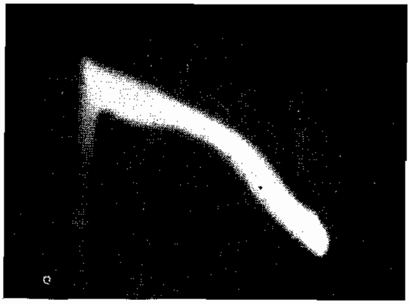


FIG. 5-25. 47A TMS—receiving unit presentation—2-db differential gain.

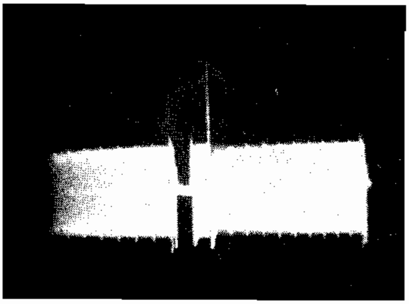


FIG. 5-26. Staircase signal—horizontal—2-db differential gain.

## Multiburst

A multiburst signal is used for rapid measurements of gain at a few predetermined frequencies.

One form of multiburst signal, illustrated in Fig. 5-27, consists of a burst of peak white (white flag) followed by bursts of six sine-wave frequencies from 0.5 to 4.2 Mc, plus a horizontal sync pulse, all transmitted during one line interval. The white flag provides white level reference signal. Figure 5-28 indicates the burst frequencies normally used, but these may be varied. Vertical sync information is also provided in some types of multiburst generators.

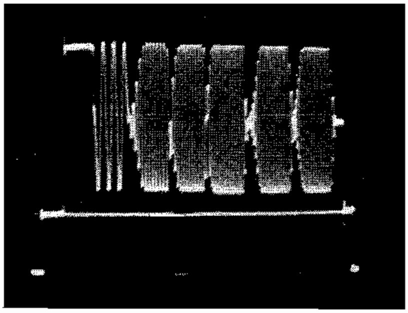


FIG. 5-27. Multiburst signal—horizontal.

Some of the earlier models of multiburst generators do not include the white flag; that is, six sine-wave bursts occupy the entire interval bethween sync pulses.

At the receiving point the signal is observed on an oscilloscope. For gain measurements, the peak-to-peak amplitudes of the individual bursts are measured and compared. The accuracy of measurement is subject to the limitations of the oscilloscope. The principal uses are to observe:

1. Quick check of amplitude-frequency response
2. Changes in setup
3. Black or white compression
4. Compression which may be selective with frequency

Figures 5-29 and 5-30 illustrate, respectively, gradual dropping and rising gain-frequency characteristics. These figures should be compared with the normal signal illustrated in Fig. 5-27. For information, the picture-monitor presentation is shown in Fig. 5-31 and the A-scope vertical presentation is shown in Fig. 5-32.

## Test Pattern—RETMA [2]

Standard test patterns are valuable in determining the performance of video systems because the distant viewer knows what the original picture looks like and can therefore readily detect distortions. The test pattern illustrated in Fig. 5-33 is a reproduction of a test chart developed by the RETMA Data Bureau. It is used mainly as source material for local test of broadcasters' equipment, such as cameras, etc.

The following is a description of the use of the pattern in checking the quality of

[2] Now Electronic Industries Association (EIA).

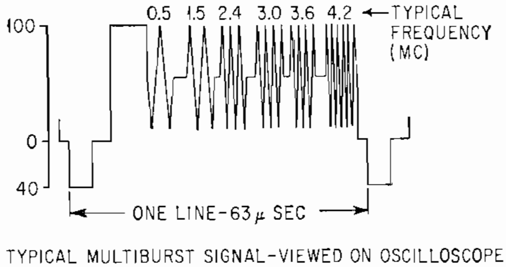



FIG. 5-28. Multiburst signal–frequencies normally used–horizontal.

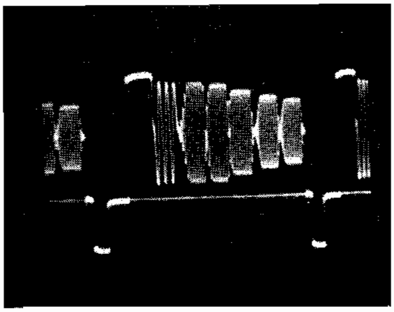


FIG. 5-29. Multiburst signal–gradual loss –horizontal.

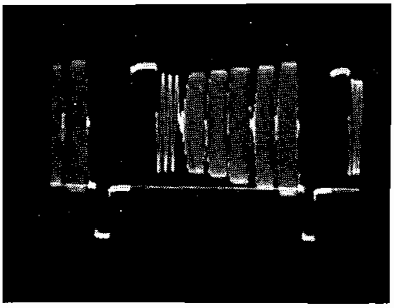


FIG. 5-30. Multiburst signal–gradual gain –horizontal.

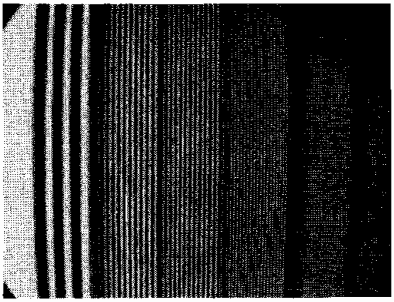


FIG. 5-31. Multiburst signal–picture.

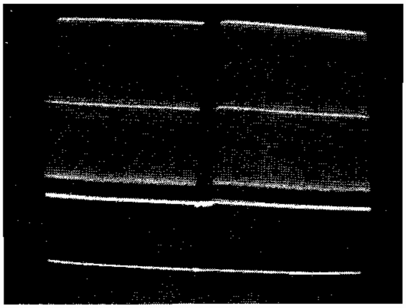


FIG. 5-32. Multiburst signal–vertical.

the picture and interpreting the results. In all cases it is assumed that the picture monitor has been properly adjusted.

**Horizontal Linearity.** This can be determined by checking the large circle, the four corner circles, and the three squares of "200-line" vertical bars, one on each side of the picture and one in the center. The circles should show no distortion, and the horizontal length of all squares should be equal.

**Vertical Linearity.** The circles plus the six sets of short "200-line" horizontal bars can be used to check linearity of the vertical sweep. The circles should show no distortion, and the over-all height of the sets of bars should be equal.

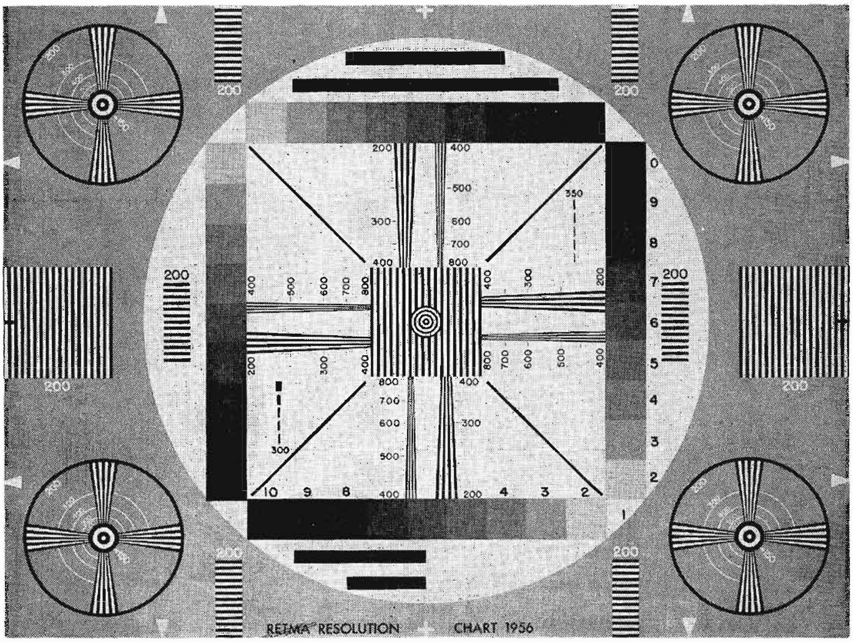



FIG. 5-33. RETMA test pattern—picture.

**Contrast.** The four bars at the ends of the central wedges are the gray scales. Each is composed of 10 squares varying from maximum white brightness to approximately one-thirtieth of this value. If the received signal has the proper distribution of grays, it will be possible to distinguish all squares in the scales. Loss of distinction among the individual squares is an indication that the gain of the over-all system is not constant over the full range of the input voltages.

**Aspect Ratio.** The four gray-scale bars should form a perfect square.

**Interlace.** The quality of interlace can be checked by noting the condiiton of the four diagonal lines in the center. A serrated or jagged line indicates pairing of the interlace lines.

**Streaking.** Streaking following any one of the two horizontal black bars, at the top and bottom of the large circle, indicates low-frequency phase and/or amplitude distortion. The bars represent half cycles of square-wave signals ranging from about 30 kc for the longest to 100 kc for the shortest. They help to locate the frequency range within which the phase distortion takes place. For instance, if it is near 100 kc, the short bar will have more intense streaks than the others.

**Ringing.** The vertical wedges and the short vertical lines or ringing bars, marked

50 to 300 in the lower left quadrant of the circle along with those marked 350 to 600 in the upper right quadrant, are used to check ringing. The frequency of the ring will be indicated on the vertical wedges by the vertical position at which the strongest ring is indicated to the right or left of the wedge. Similarly, the short vertical line that gives the strongest ring will also indicate the ringing frequency.

**Resolution.** Resolution is measured in terms of "lines."

Vertical resolution, the resolution from top to bottom of the picture, is expressed in the number of horizontal lines that can be resolved. Therefore, the horioznta1 wedges in the test pattern are used to measure vertical resolution. Vertical resolution depends primarily on the size and shape of the picture-tube scanning beam spot rather than the high-frequency response or bandwidth of the receiver or transmission path. Therefore, vertical-resolution measurements are omitted from network operating tests.

Horizontal resolution is based upon the number of distinct black and white dots (vertical lines) that can be reproduced by the picture monitor in three-quarters of the usable (visible) length of a horizontal scanning line. This length of three-quarter width is selected because it equals the height of the picture and, therefore, gives a basis for direct comparison between horizontal and vertical resolutions. The vertical wedges are used to determine horizontal resolution.

Vertical or horizontal resolution can be measured in terms of lines by determining the point on the horizontal or vertical wedges, respectively, up to which it is possible to distingnish distinct lines.

The wedges in the center and the four corners are calibrated in lines. They all vary from 200 at the large end to 600 at the small end. The vertical and horizontal linearity bars are all spaced for 200-line resolution. The concentric circles in the centers of the corner circles are at 150-line spacing. Those at the center of the large circle are at 300-line spacing.

## Test Pattern—Typical Broadcasters

Various types of test patterns are employed by the different broadcasters for alignment of their circuits and monitors and for use by servicemen in the adjustment of home receivers. The test pattern illustrated in Fig. 5-34 is a typical pattern and employs many of the features included in the standard RETMA pattern.

The following is a description of the use of this test pattern:

**Linearity.** The circles and the horizontal and vertical wedges can be used to check both the horizontal and vertical linearity. The circles should be round, and the wedges of equal length.

**Contrast.** The five circles extending from black to white offer a check of the grays in the received signal. If the signal has the proper distribution of grays, all circles will be seen in varying shades of gray from black to white.

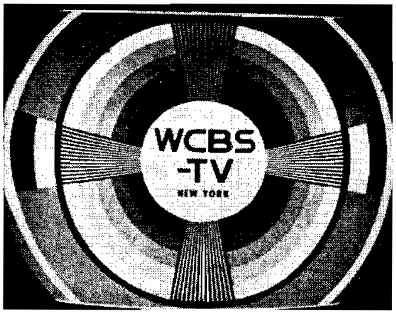



Fig. 5-34. Unimpaired picture—typical test pattern.

**Streaking and Smearing.** Streaking following any of the letters in the center of the test pattern indicates low-frequency distortion. Echo, smear, following whites, etc., can also be noted at these points. Streaking can also be seen at the right outside edge of the horizontal wedge.

**Resolution.** Resolution can be determined by noting the point to which the lines can be distinguished on the vertical and horizontal wedges. The resolution of the vertical wedges on the test pattern illustrated extends from 150 to 320 lines and on the horizontal wedges from 150 to 350 lines. This value will differ among the various broadcasters' patterns, depending upon the width of the wedge lines.

**Ringing.** Ringing can be noted on the sides of the vertical wedges. Ringing frequency will be indicated by the vertical position at which the strongest ring is observed.

## Color Bars

The broadcasters use various color-bar signals for the adjustment of their equipment including color monitors. They may also transmit this signal over transmission facilities for test purposes.

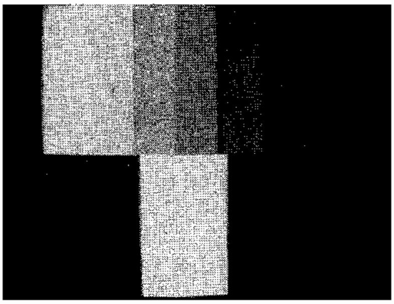


FIG. 5-35. Color-bar signal—monochrome picture.

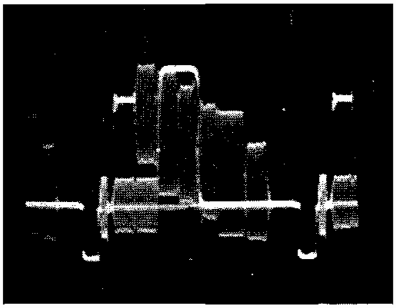


FIG. 5-36. Color-bar signal—horizontal—wideband.

As shown in Fig. 5-35, on a monochrome picture monitor, the color-bar signals will appear as corresponding bars in various densities of gray, the densities depending upon the individual values of luminance. The wideband A-scope horizontal presentation can indicate whether or not the white reference of the luminance signal and the color information have the proper amplitude relations. Figure 5-36 illustrates a typical presentation, the colors for this particular pattern being identified in Fig. 5-37. For this color-bar signal, if the color burst signal is of correct amplitude, and if the positive excursion of the cyan bar is at 99 per cent of white level, with the negative excur-

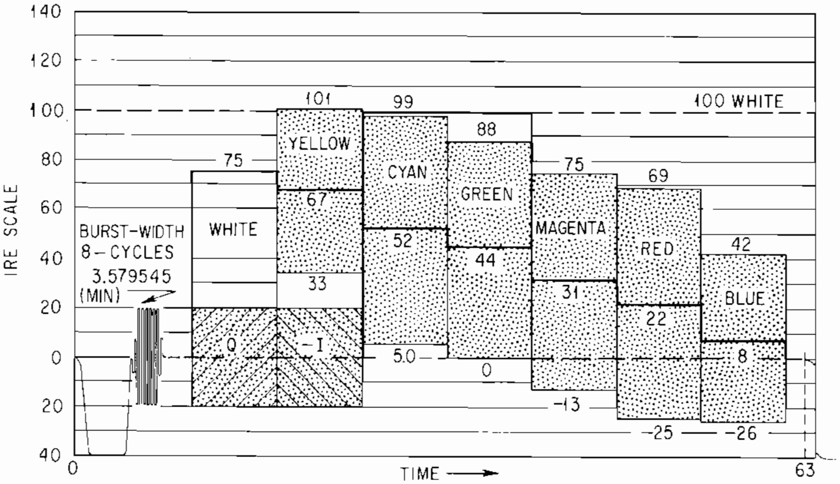



FIG. 5-37. Color-bar signal—typical color information.

sion of the green bar at black level, it can be assumed that the over-all signal is in good condition from an amplitude standpoint. Figures 5-38 and 5-39 show vertical and expanded horizontal presentations of this signal.

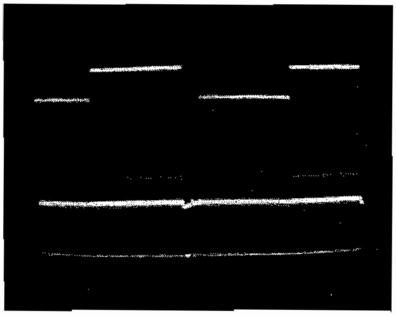


FIG. 5-38. Color-bar signal—vertical.

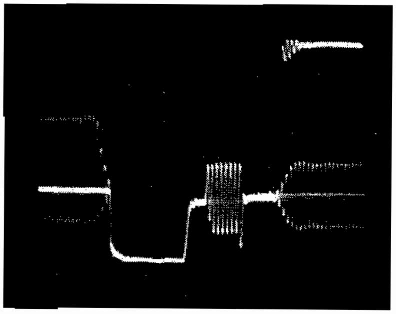


FIG. 5-39. Color-bar signal—expanded horizontal.

The broadcaster can observe the color-bar signal on a vector display oscilloscope (variously known as a vectorimeter, vectorscope, chromascope, etc.) to measure absolute amplitudes and phase angles for equipment adjustments. Differential phase and gain measurements of limited accuracy can also be made by this means.

### Staircase

The techniques most commonly used by the broadcasters at present for the measurement of differential phase and differential gain involve the transmission of a staircase signal, as in Fig. 5-40. A sine wave, usually at 3.6 Mc, is superimposed on 10 steps extending progressively from black to white level. At the receiving point, the high-frequency sine wave is separated from the low frequencies of the steps by a high-pass filter and displayed on the oscilloscope as in Fig. 5-41. Any difference between the amplitudes of the blocks represents differential gain. By means of a color-signal analyzer used in conjunction with the receiving oscilloscope, differential phase can be measured.

The staircase signal, without sine wave added, is also used in some cases as a linearity check, as shown in Fig. 5-42. In this case, the relative height between steps is used as an indication of compression or nonlinearity. Figure 5-43 illustrates for information the picture-monitor presentation of a staircase signal.

In some forms of the staircase signal, a single scanning line of stairsteps may be followed by several lines of adjustable amplitude. The amplitude is adjusted to permit changes in the over-all duty cycle, principally for tests on television broadcast transmitters. Figure 5-44 illustrates a signal with a duty cycle having 90 per cent window and 10 per cent staircase.

## SIGNAL-IMPAIRMENT ANALYSIS

Television-network facilities are designed to transmit picture signals so that they will be received at the distant connection in a condition to give a satisfactory reproduction of the signal furnished by the customer. The network transmission facility is only part of the transmission path from camera to receiver. The other elements contributing to the faithfulness of the reproduced scene are:

1. Performance of camera and other studio equipment
2. Performance of local loop facilities not included as part of the network facilities, i.e., studio-to-transmitter link
3. Performance of the broadcaster's transmitting facilities

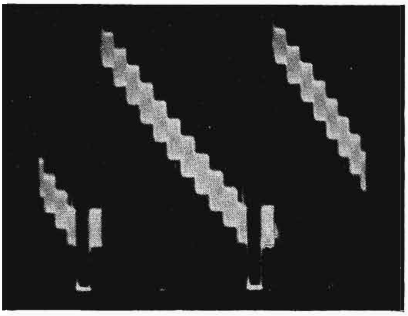


FIG. 5-40. Staircase signal—modulated—horizontal.

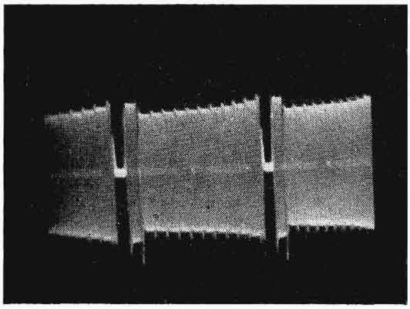


FIG. 5-41. Staircase signal—modulated—horizontal—through high-pass filter.

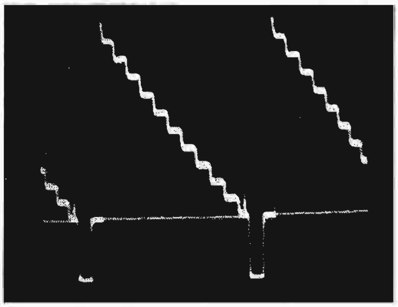


FIG. 5-42. Staircase signal—unmodulated—horizontal.

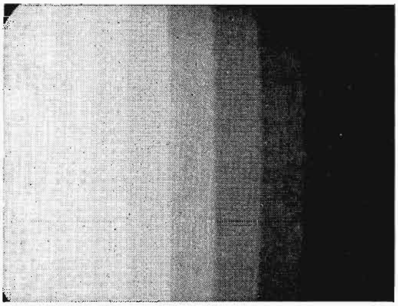


FIG. 5-43. Staircase signal—picture.

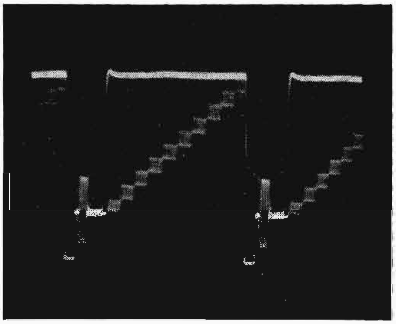


FIG. 5-44. Staircase signal—variable over-all duty cycle—horizontal.

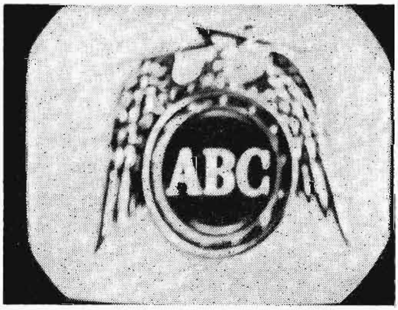



FIG. 5-45. Blooming.

4. Radio path between broadcast transmitter and the receiver, i.e., distance, obstructions, interference
5. Ability of the receiver to reproduce a picture from the signals received

Since all the above elements must work together, discrepancies occurring in any of the individual units will affect the received picture adversely. The broadcaster and the telephone company have no control over the last two links in the chain—the path from the transmitter to receiver and the home receiver. However, network transmission from camera to the broadcaster's transmitter generally involves close cooperation. Because of the necessity of using different pickup points and cameras or of rearranging the network facilities to meet customers' requirements, it is essential that each transmission element be engineered and maintained with this flexibility in mind.

The composition of a television signal, as discussed previously, determines the objectives for network facilities. Compared with telephone transmission, the bandwidth is of the order of 1,000 times as great, the amplitude distortion requirements are about 10 times as severe in spite of the wider band, and interference requirements are about 3 times as severe. In addition, delay distortion requirements are more severe. Since color-television signals are more complex than monochrome signals, they are correspondingly more difficult to transmit.

Distortion of video signals during transmission may be the result of trouble conditions or inherent limitations of the facilities in the transmission path. This distortion in general will be apparent in the oscilloscope presentation of the signal and will show in the picture monitor as an impairment. The A-scope signal distortions and picture-monitor impairments fall into several categories. The following pages illustrate a number of typical distortions as observed on picture monitors and A scopes, together with an explanation of the causes. In many instances it has been found necessary for photographic-reproduction reasons to introduce impairments beyond the degree to which it would be expected to find them under actual conditions. This is particularly true of the picture-monitor photographs where a given impairment generally has greater effect upon the eye under actual conditions than is evident in the photographs.

## Level Irregularities

### *General*

An essential factor in good television operation is the maintenance of correct video levels at both broadcasters' and telephone company locations. The observed effect of incorrect levels as seen on picture monitors and A scopes is dependent upon the magnitude of error, whether the level is constant or varying, and whether all or only part of the frequency range is affected. This discussion is concerned with level errors that affect the entire frequency range in a relatively uniform manner. Such level irregularities can be caused by improper amplifier gains or pad losses along the transmission path, defective electron tubes or other components, or change in camera level from broadcasters' studios or pickup points.

### *Long-duration Level Changes*

**High Levels.** Small increases in level cause an increase in the over-all picture brightness and a general loss of contrast. Larger changes may result in more serious defects. Blooming, bleeding whites, clipping, and sync compression are long-duration impairments generally caused by an increase in level sufficient to cause some degree of overloading.

*Blooming* (Fig. 5-45). This is an increase in the size of the scanning spot with resultant loss of detail in white areas due to overloading the picture tube. The A-scope presentation will appear normal when the difficulty is due to high-gain setting of the monitor itself.

*Bleeding Whites* (Figs. 5-46 to 5-48). As the level is increased on the network to an extent where overloading occurs, the A scope, in addition to indicating too high

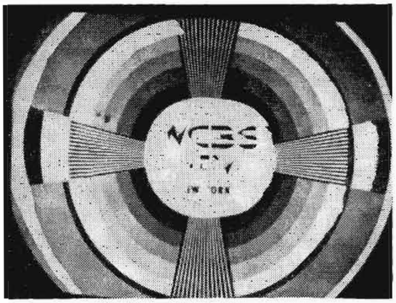


FIG. 5-46. Bleeding whites.

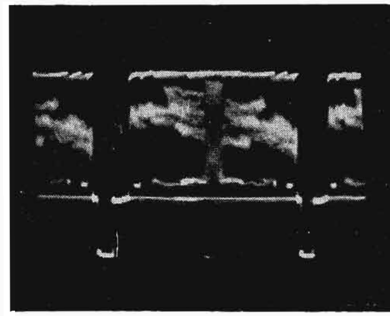


FIG. 5-47. Bleeding whites–horizontal.

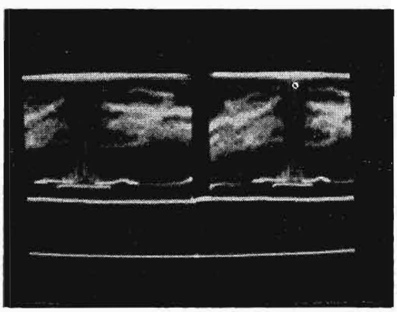


FIG. 5-48. Bleeding whites–vertical.

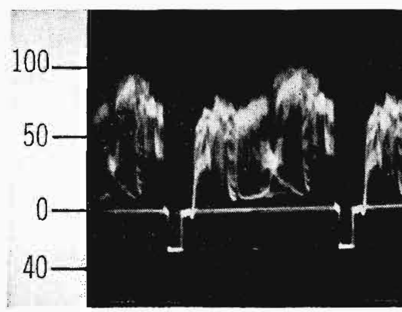



FIG. 5-49. Sync compression–horizontal.

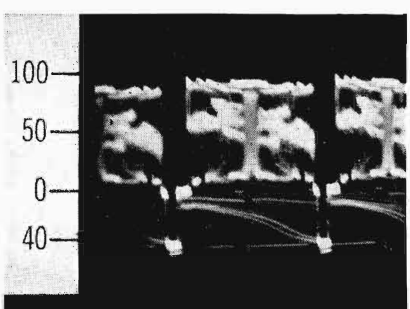



FIG. 5-50. Partial clamping failure–horizontal (A-scope presentation expanded to normal height).

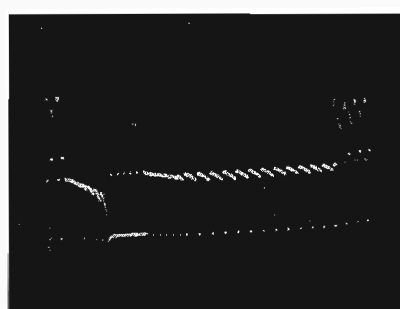


FIG. 5-51. Partial clamping failure–expanded vertical.

level, will also show evidence of clipping, or compression, as indicated by the square tops of the waveforms of Figs. 5-47 and 5-48. The picture (Fig. 5-46) as observed will have lost contrast and may appear to have white areas "bleeding" into black, although the defocusing found under blooming conditions may not exist. The effects shown in Figs. 5-46 to 5-48 were obtained by overloading an amplifier.

*Black or Sync Compression* (Fig. 5-49). High-level conditions sufficient to cause overloading may also result in black peak or sync compression. Here the sync-pulse amplitude is reduced and loss of contrast may be noticeable in the black region. If the sync signals are sufficiently compressed, difficulty will be experienced in keeping pictures in step. Figure 5-49 illustrates sync compression as seen on the oscilloscope at horizontal rate. The sync level in this case reads approximately 30 on the IRE scale, or about 10 divisions lower than normal. The picture monitor, in this case, showed no evidence of trouble.

Low Levels (Figs. 5-50 and 5-51). Lower than normal levels cause a decrease in average picture brightness and make the signal more susceptible to interference. When the television signal level is reduced by only a small amount, ill effects are not likely to be noticed. As the signal is transmitted through clamping or stabilizing circuits at still lower levels, clamping action will be partially or completely lost. Streaking, smearing, and loss of synchronism may occur. Figures 5-50 and 5-51 illustrate a signal transmitted through a clamper amplifier at about one-half normal level. Partial failure of clamping is seen on the A scope at horizontal and vertical rates. The picture was not affected appreciably. The impairments observed when clamper failure occurs will depend upon the amount of low-frequency distortion present in the signal. The results of complete clamping failure are discussed at a later point.

### *Short-duration Level Changes*

Intermittent level changes, at either regular or irregular intervals, may have several causes. Fluctuating a-c line voltage and hunting regulators in power supplies or on transmission facilities are some of the possible sources for this type of trouble. These usually give short changes in picture brightness, evident on A scopes as momentary voltage changes. If of sufficient magnitude, frame rolls, momentary tearing, etc., can be observed.

*Bounce and Breathing.* In operating parlance bounce is the condition where there are sudden irregular changes in level while breathing is the condition where the changes occur more slowly and at a regular rate.

## Transmission-frequency Irregularities

### *General*

Uniform amplitude response and linear phase shift throughout the passband of the transmission system of a television network are characteristics to be desired. In addition, the shape of these two characteristics beyond the passband, usually at the high-frequency end, should be such that the gain characteristic gradually rolls off without affecting the phase characteristic. A large family of impairments to picture transmission is caused by inability to attain these conditions or by adjustments or troubles affecting them. Some of these impairments differ from one another so greatly in manifestation that they do not appear related. In this discussion the impairments resulting from distortions in various parts of the video band are grouped together, that is, those affecting field rate and harmonic frequencies, those affecting line rate and its first 10 or so harmonics, and those affecting frequencies above about 200 kc.

Figures 5-52 to 5-59 show some of the relationships between low- and high-frequency distortion. A telephone company window signal was used for test signal for reference. In the remaining figures both attenuation and related phase distortion are present. Minimum phase-shift networks were used to vary the gain-frequency characteristic.

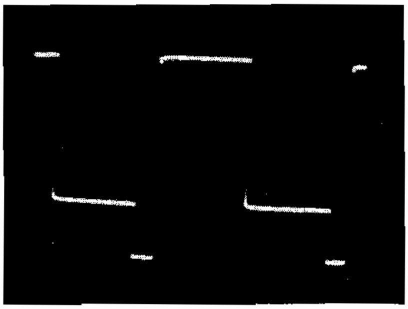


Fig. 5-52. Window signal—unimpaired—horizontal.

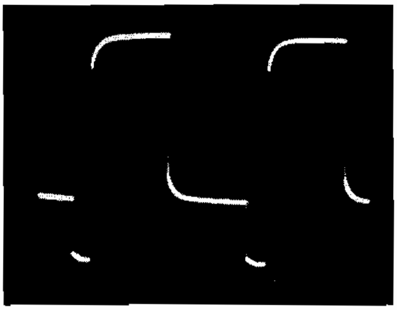


Fig. 5-53. Window signal—lows raised—horizontal.

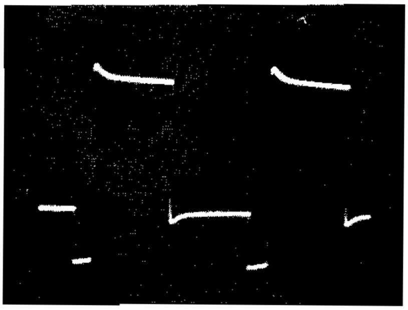


Fig. 5-54. Window signal—lows depressed—horizontal.

Fig. 5-55. Window signal—highs depressed—horizontal.

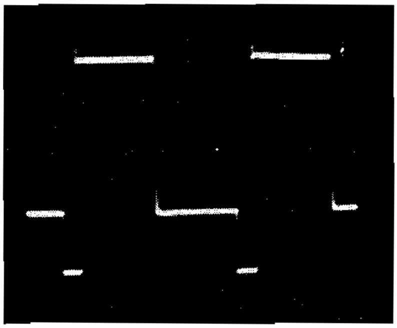


Fig. 5-56. Window signal—highs raised—horizontal.

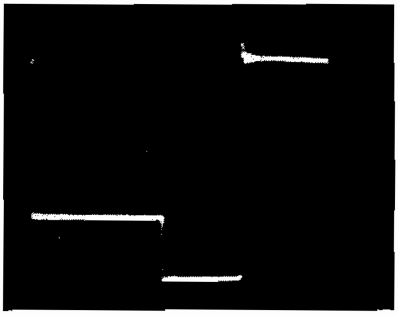


Fig. 5-57. Window signal—ringing—horizontal.

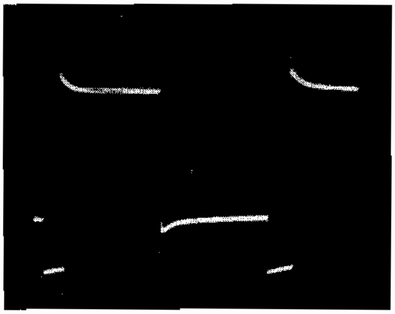


FIG. 5-58. Window signal—lows depressed, highs raised—horizontal.

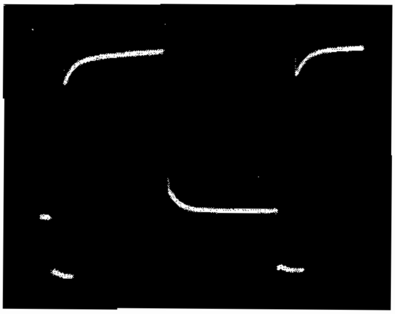


FIG. 5-59. Window signal—lows raised, highs raised—horizontal.

**Low-frequency Gain Changes** (Figs. 5-53 and 5-54). Figures 5-53 and 5-54 illustrate a relative 1.0-db increase or decrease, respectively, of frequencies below about 100 kc. With the low frequencies increased, there is illustrated the case of positive streaking in which the length of time for the streak to disappear is determined by the shape of the curve at the transition from white to black. The reverse case, with low frequencies decreased causing long-duration overshoots at transitions, illustrates negative streaking.

**High-frequency Gain Changes** (Figs. 5-55 to 5-57). Figures 5-55 and 5-56 show results when frequencies above about 100 kc are affected. The networks used give a gradual modification of characteristics with frequency, so that at 3.0 Mc the gain-frequency characteristic is changed by minus and plus 1.5 db, respectively. Figure 5-55, with the high frequencies depressed, shows some loss of sharpness or rounding-off of transitions, much less and of shorter duration than Fig. 5-53. The fine detail in a picture would thus be impaired in this transmission. The small overshoot, or spike, evident in Fig. 5-56 is the result of raising 3.0 Mc by only 1.5 db. This spiking is similar to that in Fig. 5-54 but of much shorter duration. Carried far enough, and possible at a somewhat lower frequency, this sort of thing will result in "edge effect"—a distinct outline following an object of a tone opposite to that of the object itself.

Figure 5-57 goes one step further by increasing the 3.0-Mc gain to +3.0 db and then cutting off rather abruptly. The result shows that an oscillatory transient, or ringing, has developed. With minimum phase shift, the ringing should be about equal on each side of the transitions. This was not the case here.

**Both Low- and High-frequency Gain Changes** (Figs. 5-58 and 5-59). Figures 5-58 and 5-59 illustrate cases where the gain-frequency characteristic is not flat at either end of the spectrum. In each case there is a 3.0-db rise at approximately 3.0 Mc. At the lower frequencies, Fig. 5-58 has a 1.0-db loss and Fig. 5-59 a 1.0-db gain. It can be seen that the individual characteristics previously illustrated are still recognizable and that adjustments at one end of the band do not compensate, in general, for maladjustments at the other end. The short duration spike, for example, is evident regardless of the lower frequency adjustment.

It should be noted that the sync pulse itself shows evidence of all these distortions. In the usual case, clamper action will tend to minimize these effects on tips of sync pulses. However, transitions between porches and sync and in the vertical interval are always available for observation and have been found to be sensitive indicators of the troubles described. Further detail on specific types of impairments is given below.

### *Streaking and Smearing*

Streaking is caused by transmission distortions in the frequency region up to about 200 kc. Smearing generally is caused by distortions at somewhat higher frequencies.

Streaking and smearing affect both color and black-and-white signal transmission almost equally.

Distortions that cause streaking and smearing can occur in any part of the transmission system, from the camera to the television receiver. Prevention of these de-

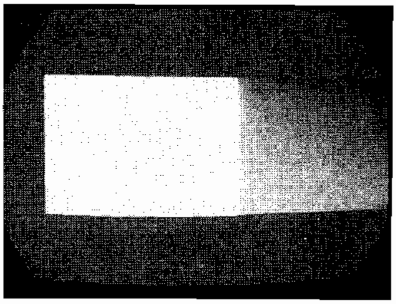


FIG. 5-60. Positive streaking—window signal.

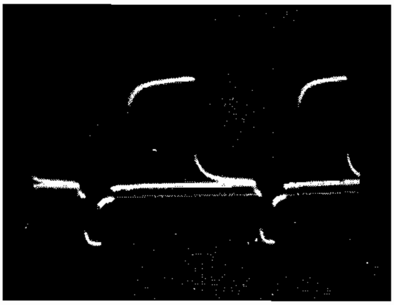


FIG. 5-61. Positive streaking—window signal—horizontal.

fects requires very close control of transmission characteristics in the lower frequency portion of the video band.

The amplitude and phase-characteristic tolerances at the very low end of the frequency band, say below half-line frequency, are probably not so critical but have not been evaluated accurately. When the signal is clamped, the amplitude characteristic at 60 cycles can be allowed to vary considerably. Furthermore, it can be deliberately adjusted to depart from a uniform response at 60 cycles or other points below half-line frequency in order to provide phase correction at line frequency and its harmonics.

**Streaking** (Figs. 5-60 to 5-71). Streaking is the appearance of an error luminance in the picture, extending horizontally toward the right edge of the picture from some point in the picture marked by a sharp transition in luminance. Streaking is most prominent for a change from a high luminance to a low luminance or vice versa. Since this type of impairment generally is caused by transmission irregularities in the region of the 15,750-cycle line scanning rate or its first few harmonics, the horizontal size of the object also affects the amount of streaking. Streaking is especially apparent when the objects move vertically in the scene and the streaking moves with them.

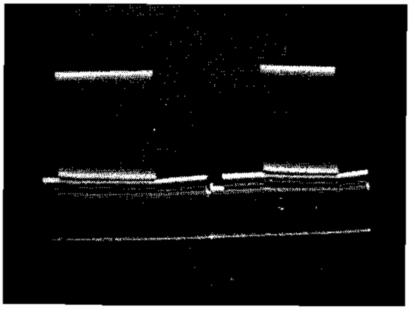


FIG. 5-62. Positive streaking—window signal—vertical.

If the streaking is the same shade as the original figure (white following white or black following black), it is called positive. If the streaking is the opposite shade, it is called negative. Figures 5-60 to 5-71 illustrate picture-monitor and A-scope presentations of positive and negative streaking.

In Fig. 5-61, the leading edge of the white window aprpoaching white level is heavily rounded while the trailing edge of the white window approaching black level rolls off gradually, indicating black following black and white following white, or positive streaking. The vertical presentation in Fig. 5-62 reveals in the signal region below the white level, a heavy trace above black level, the height of this trace being a measure of the streaking or

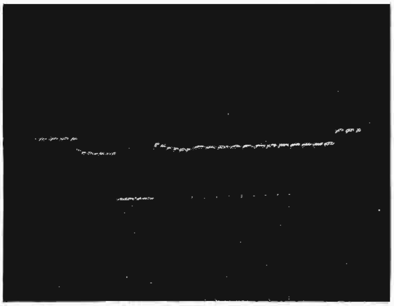


FIG. 5-63. Positive streaking–window signal–expanded vertical.

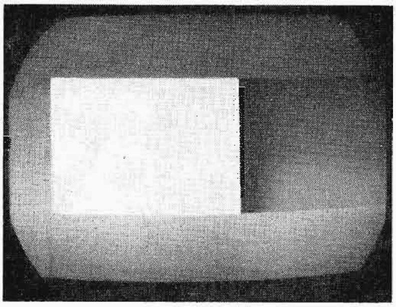


FIG. 5-64. Negative streaking–window signal.

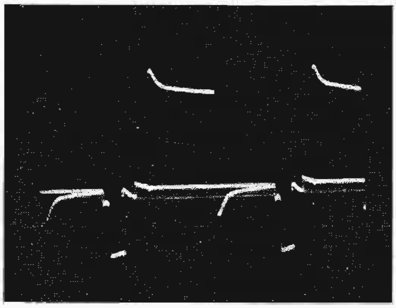


FIG. 5-65. Negative streaking–window signal–horizontal.

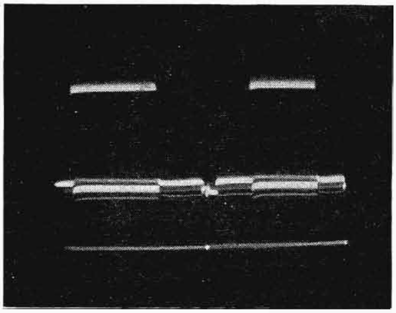


FIG. 5-66. Negative streaking–window signal–vertical.

FIG. 5-67. Negative streaking–window signal–expanded vertical.

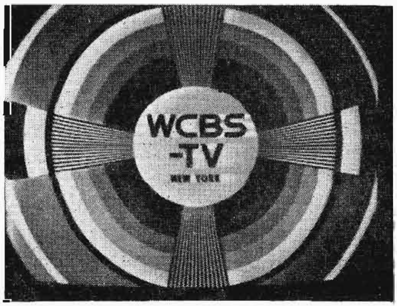



FIG. 5-68. Negative streaking–test pattern.

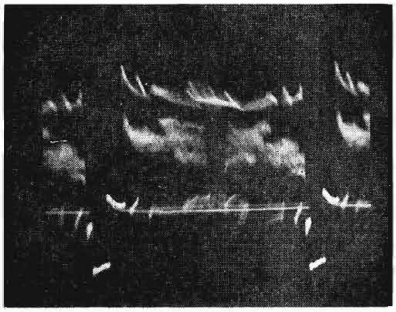


FIG. 5-69. Negative streaking—test pattern—horizontal.

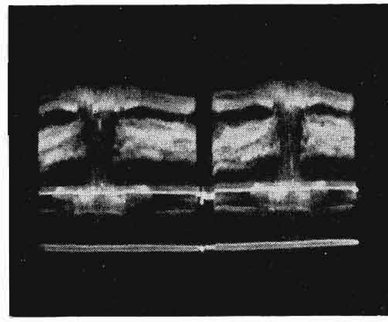


FIG. 5-70. Negative streaking—test pattern—vertical.

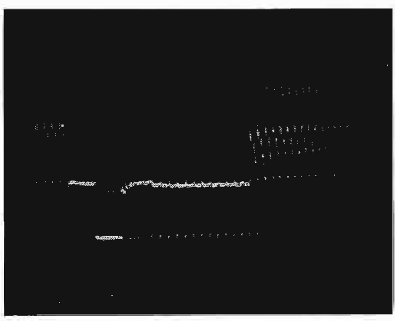


FIG. 5-71. Negative streaking—test pattern—expanded vertical.

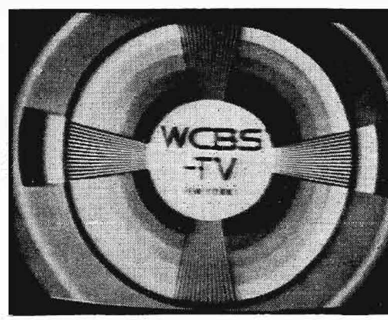



FIG. 5-72. Smearing—test pattern.

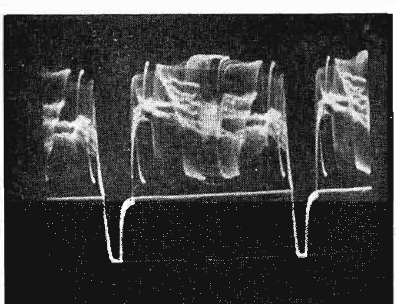


FIG. 5-73. Smearing—test pattern—horizontal.

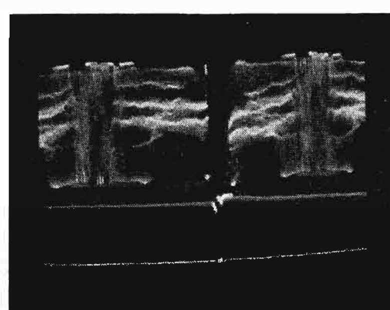


FIG. 5-74. Smearing—test pattern—vertical.

white following white. In like maner, Fig. 5-65 is the horizontal presentation for negative streaking, or black following white and white following black. Here the manifestations are just the opposite from Fig. 5-61; that is, there is a high peak, or white level, on the transition from black to white, while the trailing edge of the white window dips below blanking and gradually restores to reference-black level. The vertical presentation in Fig. 5-66 shows a heavy trace, or following black, in the window signal region, which is the opposite to Fig. 5-62. The picture-monitor presentations (Figs. 5-60, 5-64, and 5-68) show this streaking; however, in practice a comparison of A-scope presentations using suitable signals is preferred because of the possibility of streaking caused by the picture monitors.

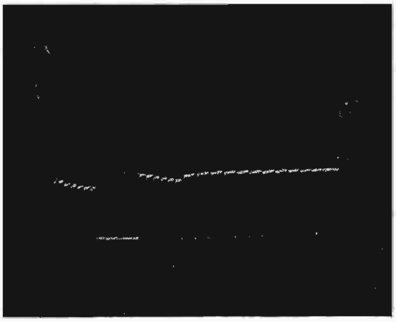


FIG. 5-75. Smearing–test pattern–expanded vertical.

In addition to the foregoing, comparison of the A-scope presentations for positive and negative streaking reveals opposite tilts of front and back porches and tip of sync for the horizontal presentations (Figs. 5-61, 5-65, and 5-69) and of the trace between the first and second sets of equalizing pulses for the vertical presentations (Figs. 5-63, 5-67, and 5-71).

**Smearing** (Figs. 5-72 to 5-75). Smearing is a distortion similar to streaking. The impairment is a blurring of the vertical edges of objects in the televised scene, and the whole picture looks as if it had been smeared along the horizontal axis. The smearing-error luminance may also be of the same or opposite sign as the luminance it follows.

## *Change of Setup (Figs. 5-76 to 5-81)*

The setup of the picture is the difference between the blanking and reference-black levels as viewed on the A scope using IRE roll-off. For normal operation this is 10 divisions on the IRE scale. Setup variation along network facilities is mainly affected by the lower portion of the frequency band, excessive transmission-frequency loss in this region causing too little setup and excessive transmission-frequency gain in this region causing too much setup.

**Loss of Setup** (Figs. 5-76 to 5-78). Low setup results in pictures having more contrast than normal. The whites in the scene will be unchanged, but some of the normal grays may become almost black. Some streaking may also occur owing to the deviations in the gain and phase characteristics at low frequencies. When loss

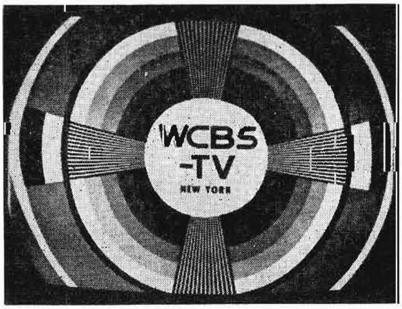



FIG. 5-76. Low setup–test pattern.

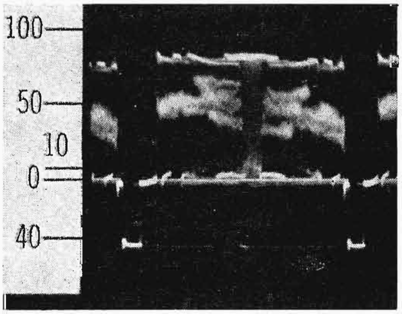



FIG. 5-77. Low setup–test pattern–horizontal.

of setup occurs to the point where the picture signal punches through the blanking level, normal clipping functioning of the customer's stabilizing amplifier will cause loss of this picture information. In severe cases, erratic operation of the customer's stabilizing amplifier may occur and the picture will be unusable.

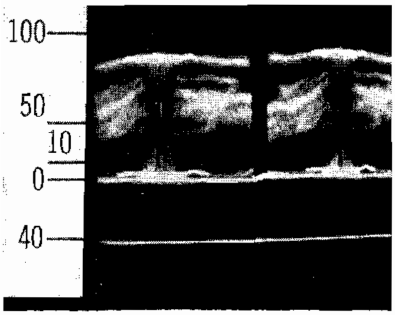



FIG. 5-78. Low setup—test pattern—vertical.

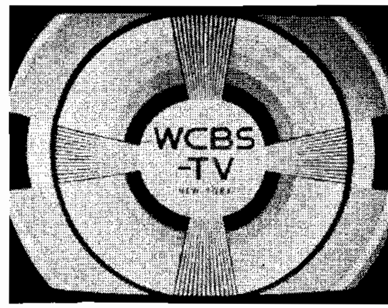



FIG. 5-79. High setup—test pattern.

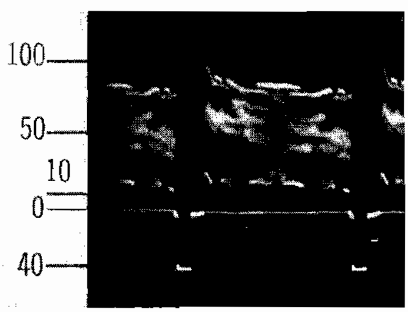



FIG. 5-80. High setup—test pattern—horizontal.

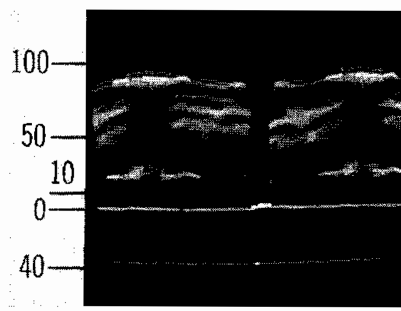



FIG. 5-81. High-setup—test pattern—vertical.

**Increase in Setup** (Figs. 5-79 to 5-81). High setup resnlts in reduced contrast range and reduced signal-to-noise ratio.

### *Ringing (Figs. 5-82 to 5-86)*

Ringing geuerally results from the transmission of sudden tonal transitions over a system that has a finite passband with a sharp cutoff at the upper end of the frequency range. It may also result from a marked transmission discontinuity at some frequency below cutoff. When a signal containing a sudden transition is applied to such a circuit, damped oscillations or ringing will occur at approximately the frequency of cutoff or other discontinuity, the duration of the ringing depending upon the sharpness of the discontinuity. Ringing will be accentuated by a rising gain characteristic preceding the discontinuity.

The RETMA test pattern and the typical broadcaster's test pattern shown in Figs. 5-33 and 5-34 are sensitive indicators of ringing. The phenomenon will be apparent as additional lines on either or both sides of the vertical wedges. These lines will be strongest at the vertical position correspondiug to the frequency of cutoff or other discontinuity of the circuit elements causing the ring.

Ringing can also be detected by using the A-scope horizontal presentation to uote the presence of damped oscillations following sharp transitions in the signal. It is possible to observe the transitions during the blanking interval, such as sync pulse to back porch. The window or other square-wave type of signal is also suitable for

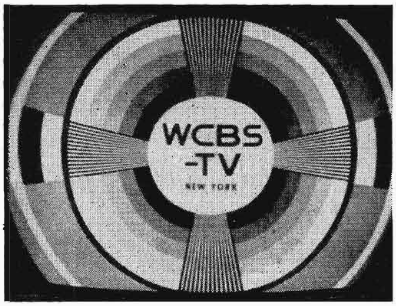



FIG. 5-82. Ringing (3 Mc)—test pattern.

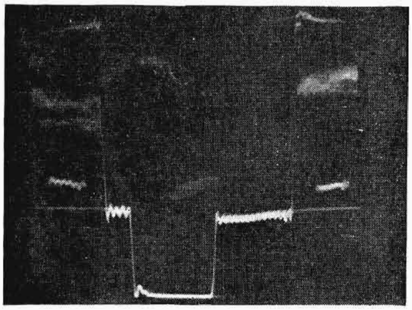


FIG. 5-83. Ringing (3 Mc)—test pattern—expanded horizontal.

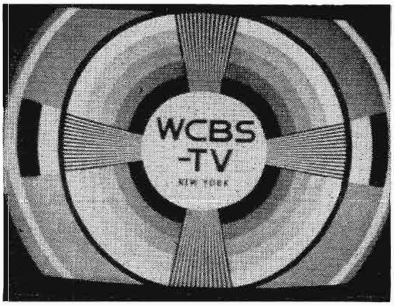



FIG. 5-84. Ringing (4 Mc)—test pattern.

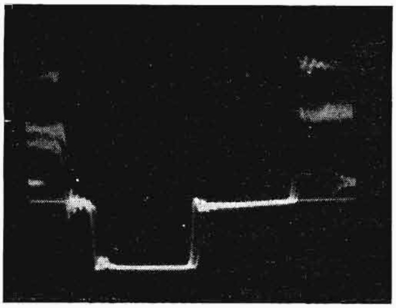


FIG. 5-85. Ringing (4 Mc)—test pattern—expanded horizontal.

noting this type of distortion. The ringing frequency can be determined by counting the number of complete oscillations appearing in a known time interval and converting to frequency by using the following formula:

Ringing frequency = number of oscillations $\times 10^6 \div$ time interval, $\mu$sec

$$f = n \frac{10^6}{t(\mu\text{sec})}$$

The accompanying illustrations were produced by introducing sharp cutoff at approximately 3 Mc (Figs. 5-82 and 5-83) and 4 Mc (Figs. 5-84 and 5-85). Close observation of Fig. 5-86 will reveal to the lower right of the necktie that there is in succession a trailing white, a trailing black, and a second lower level trailing white, indicating a damped transient or ringing. Had this following signal been damped to the extent that only one white edge trailed the necktie, the impairment might be described as "edge effect" as covered in Overshoots, following.

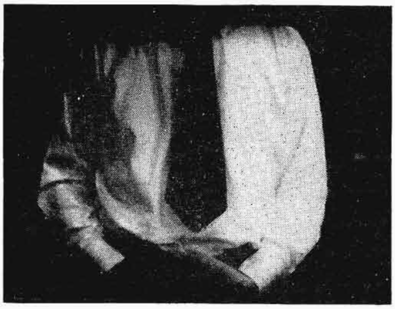


FIG. 5-86. Ringing.

### *Overshoots (Figs. 5-87 and 5-88)*

In a television signal, an overshoot is an excessive response to a sudden change in signal. A sharp overshoot is commonly referred to as a spike. An overshoot is generally caused by excess gain at high frequencies. In vestigial sideband systems, another possible cause is insufficient carrier-to-sideband ratio.

**Following Whites or Blacks** (Fig. 5-87). Overshoots within the picture area result in impairments to the picture called following white or black (edge effect).

FIG. 5-87. Edge effect.

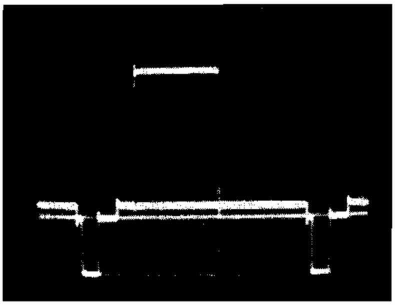


FIG. 5-88. Overshoots—window signal—horizontal.

These appear as a black outline to the right of white objects and a white outline to the right of black objects. In Fig. 5-87 this is most evident as a white edge following the man's head. A black edge follows the white of the handkerchief. Wide following whites or blacks are similar to negative smear.

**Overshoot on Back Porch.** An overshoot of the trailing edge of the sync pulse is called a "positive spike on the back porch." If this extends above black level, it may be visible in the picture as a gray vertical bar due to illuminating portions of the horizontal return traces. Figure 5-88 illustrates a slight overshoot on the back porch.

**Overshoot on Front Porch.** An overshoot of the transition from picture to blanking is called a "negative spike on the front porch." Since this is below black level, it will not be visible in the picture. However, if the overshoot is of sufficient magnitude, it may cause improper triggering of stabilizing amplifiers, monitors, or clampers, with serious tearing or complete loss of picture. Figure 5-88 also shows a slight overshoot on the front porch.

### *Resolution (Figs. 5-89 to 5-91)*

Resolution is the ability to reproduce detail in a transmitted picture. Resolution is measured in lines, as discussed under the descriptions of the RETMA and broadcasters' test patterns. The degree of resolution can be affected by the dimensions of camera and receiver scanning beams. Horizontal resolution is also a function of bandwidth. A rule of thumb is that 1.0 Mc of bandwidth corresponds to 80 lines of resolution. For maximum resolution with a given bandwidth, a flat amplitude and linear phase characteristic up to the point of cutoff would be favored. However, the resulting sharp cutoff would cause ringing. Assuming a transmission system having the same passband but rolled off gradually with frequency, the resolution will become poorer as lower and lower frequencies are selected as the start of the roll-off, but transient effects in the region of cutoff will be reduced. The actual shape of a passband, then, is a compromise between transient effects in the region of cutoff and the distortion introduced at lower frequencies (loss of resolution) by the extent and shape of the roll-off.

In addition to frequency response, excessive noise also can mask fine picture detail and result in apparent loss of resolution.

Figures 5-89 and 5-90 show test-pattern transmissions when the high frequencies are strongly rolled off starting at about 1 Mc. The A-scope expanded presentation shows loss of sharpness at transition points. Figure 5-91 illustrates loss of both horizontal and vertical resolution caused by too large a receiver scanning spot.

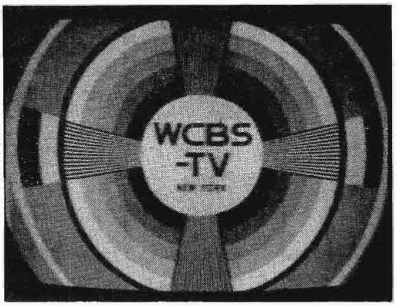



Fig. 5-89. Low resolution—roll-off from 1 Mc.

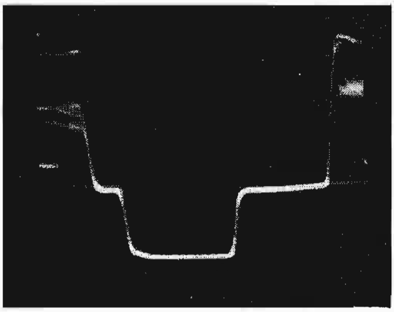


Fig. 5-90. Low resolution—roll-off from 1 Mc—expanded horizontal.

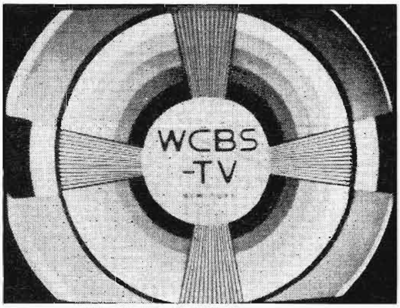



Fig. 5-91. Low resolution—receiver scanning spot too large.

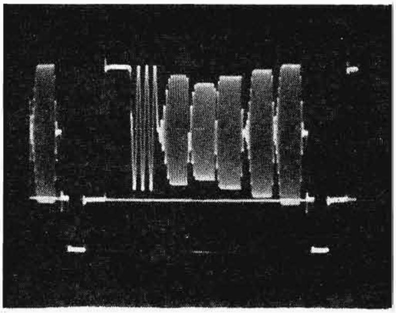


Fig. 5-92. Hourglass effect.

### *Hourglass (Fig. 5-92)*

When multiburst signals are transmitted over a video facility having a transmission-frequency-response characteristic such that the middle multiburst test frequencies are attenuated with respect to both the lower and higher test frequencies, the resulting A-scope presentation of the multiburst test signal has been referred to as the "hourglass" effect. The frequency characteristic usually results from partial equalization, such as would occur when compensating for a facility having a gradually increasing loss with frequency, using an equalizer effective only in the upper portion of the frequency band. As improvement is made in the facility having increased loss with frequency, less compensation is required from the high end equalizers eliminating the hourglass.

### *Echoes (Figs. 5-93 to 5-105)*

An echo signal or ghost can be defined as a duplicate of the original video signal displaced horizontally from the original signal. A complete reproduction of the original signal is called a ghost, while a partial reproduction is called an echo or reflection. Ghosts and echoes are due to impairment in the transmission path which causes the signal pulses to reach the viewer at two or more discrete times. Generally, the echo signal is weaker than the original signal, so the echo picture is also weaker than the main picture. When two or more echo patterns are present, one pattern usually predominates and the others are relatively weak.

The impairment effect of the echo picture varies not only with echo signal strength but also with the time offset and the nature of the original video signal. This is illustrated by Fig. 5-93.

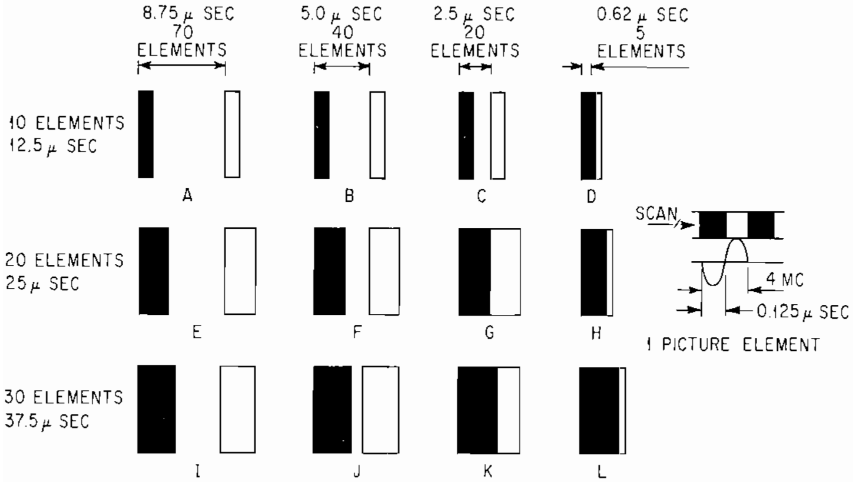



Fig. 5-93. Echo impairment effect vs. image size and echo displacement.

As a practical matter, echo signals are generally not true reproductions of the original signal, since the conditions that give rise to echo signals are usually not linear throughout the band. This adds still another variable factor, since distorted echo signals result in a lesser picture impairment than undistorted echo signals. Echoes may be either leading or lagging, and they may be either positive (same tonal range) or negative (reverse tonal range). Figures 5-94 to 5-101 show positive lagging echoes; Figs. 5-102 to 5-105 show negative lagging echoes.

The most usual cause of ghosts and echoes seen on home receivers is two transmission paths from the broadcast station to the receiving location—the direct path and a second path produced by a reflection from some tall building or high point of terrain. The ghost is offset to the right of the direct image by an amount of time equivalent to the difference in length of transmission time of the two paths. Transmission over the reflected path is generally attenuated as compared with the direct path, so the ghost appears weaker than the direct signal. When FM radio signals are used, as in radio relay systems, an impairment from a reflected path generally does not result in a television picture with a distinct echo, since its echo-producing signal would be smothered by the FM capture feature of the radio relay receivers.

Ghosts and echoes may also be produced in transmission facilities as a result of troubles or unsatisfactory adjustments. A trouble such as impedance irregularity in a cable section or an improperly terminated cable will produce electrical reflections which are delayed in transmission compared with the original signal and thus produce ghosts or echoes. Ghosts will be produced if the irregularity affects substantially the whole video frequency band, and echoes when only a part of the frequency band is affected.

The same effects can also be caused by nonuniformity of gain- and delay-frequency characteristics. In particular, a gain-frequency characteristic having periodic peaks

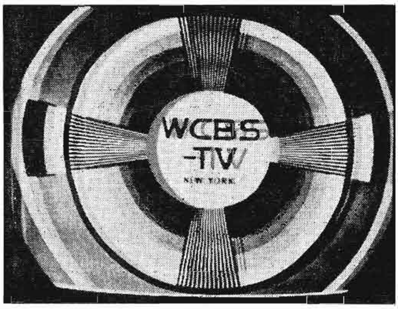



Fig. 5-94. Positive echo—test pattern.

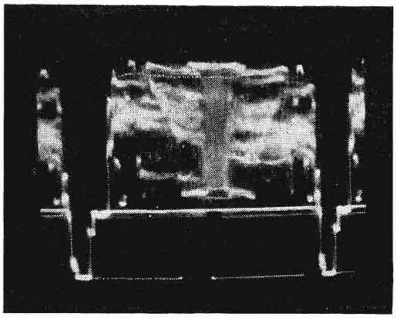


Fig. 5-95. Positive echo—test pattern—horizontal.

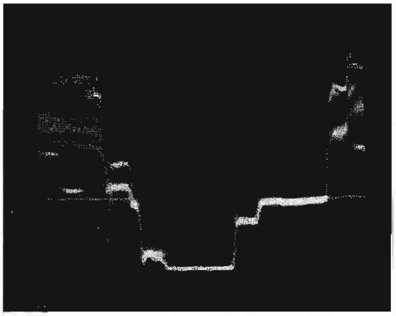


Fig. 5-96. Positive echo—test pattern—expanded horizontal.

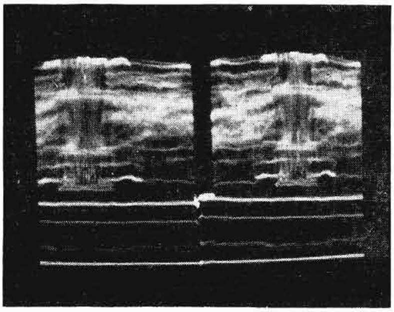


Fig. 5-97. Positive echo—test pattern—vertical.

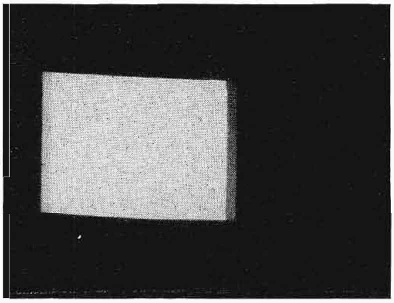


Fig. 5-98. Positive echo—window signal.

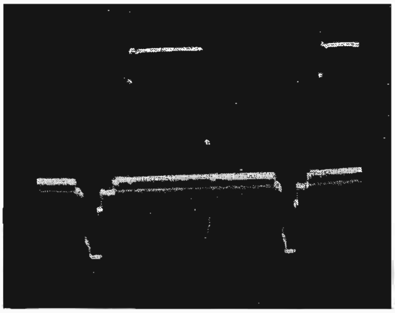


Fig. 5-99. Positive echo—window signal—horizontal.

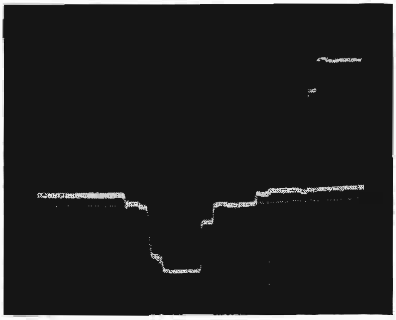


Fig. 5-100. Positive echo–window signal —expanded horizontal.

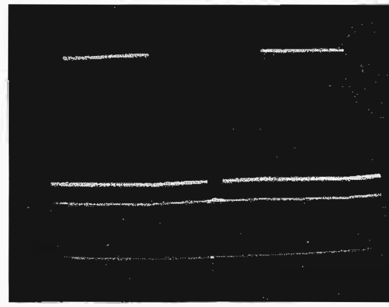


Fig. 5-101. Positive echo–window signal —vertical.

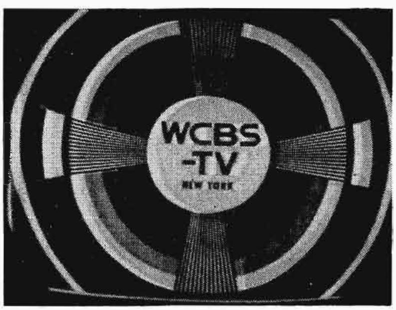



Fig. 5-102. Negative echo–test pattern.

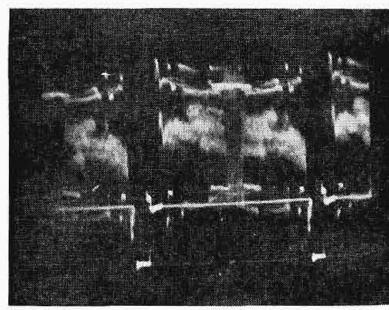


Fig. 5-103. Negative echo–test pattern—horizontal.

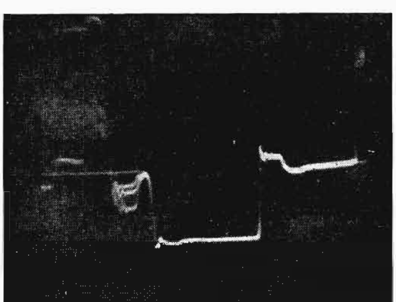


Fig. 5-104. Negative echo–test pattern—expanded horizontal.

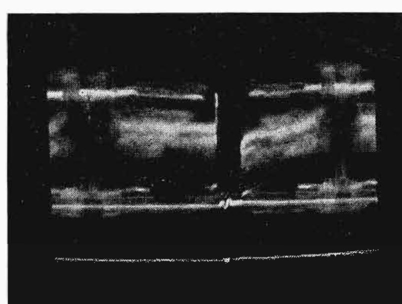


Fig. 5-105. Negative echo–test pattern—vertical.

and valleys across the frequency band will act the same as an impedance irregularity on cable affecting a broad band of frequencies.

The spacing of the reflected image or images from the original object and from each other is determined by the location of the irregularity in the frequency spectrum and usually can be calculated by the relationship that the reflection displacement in seconds is equal to the reciprocal of the frequency in cycles at which the irregularity occurs. For example, an irregularity occurring at 500 kc will produce reflections displaced from the original and from each other by 2 μsec. Remembering that one line in a television picture (exclusive of blanking) is equal to about 53 μsec, we can then see that in this case the reflections will be displaced by a fraction of the total picture width equal to $\frac{2}{53}$, or about $\frac{3}{8}$ in. in the case of a 10-in. picture tube. Where carrier-type facilities are involved, it should be remembered that this is a video-frequency calculation and that further conversion to carrier frequencies may be required. The number of reflections is dependent upon the sharpness of the irregularity, being only one for a broad irregularity and increasing in number with irregularity sharpness.

## Interference

### *General*

Interference is the introduction of extraneous signals into the desired signal. In the case of television transmission, the resulting picture impairments may be in the form of bars, moving spots, salt-and-pepper effect, or erratic synchronizing. One form of interference is called noise, this term being used generally to describe natural phenomena such as thermal noise in electronic components, whereas "interference" generally refers to man-made signals, such as extraneous single-freqnency voltages, cross talk from another video channel, and the like. The term *noise* is a carry-over from audio work. In television the effects are visual rather than aural.

Interference can be simply added into the path of the desired signal, or it can modulate the signal itself. Signal modulation by interference may occur in nonlinear circuit elements such as vacuum tubes and results in the whole picture-signal amplitude changing at the interfering rate. The two types of interference are difficult to distinguish in a television picture. Treatments that will minimize additive interference, such as filtering, use of clamper amplifiers for low-frequency interference, etc., will not affect modulation products. Additive interference is the case discussed and illustrated in this section.

### *Single-frequency Interference*

The appearance on a television picture of extraneous regularly spaced bars or lines indicates the presence of an interfering frequency. At low levels of interference the amount of single-frequency interference that can be tolerated varies quite widely, depending on the part of the spectrum in which it is operative.

**Low-frequency Interference** (Figs. 5-106 to 5-113). A particularly sensitive portion of the spectrum is the immediate region of the field rate, 60 cycles. It has been found that as the level of such an extraneous frequency is increased from a very low value, flicker is much more objectionable than the brightness distortion corresponding to a broad bar pattern. The flicker effect is accordingly controlling in this level region. The tolerable level of interference varies with the flicker frequency (difference between the extraneous and field frequencies), a flicker rate of about 5 cycles being the most objectionable. This holds for frequencies either side of the field rate; that is, the most critical frequencies are 55 and 65 cycles. To be tolerated, the peak-to-peak amplitude of these interfering frequencies has to be about 54 db less than the peak-to-peak amplitude of the television signal.

Figures 5-106 and 5-109 are cases of 120- and approximately 1,000-cycle interference. For low-frequency interference which is an exact multiple of the field rate (60 cycles) the extraneous bars will be horizontal and will remain stationary. The interfering freqnency can be determined by multiplying 60 cycles by the number of white or the number of dark bars observed. Two horizontal white bars can be distinguished in the first instance, and 16 or 17 for the 1,000-cycle picture. When the extraneous frequency differs slightly from the 60-cycle field rate or its multiples, the bars will remain horizontal but will move vertically through the picture, the rate of motion increasing with the difference in frequency. Interference at 60 cycles and its first few harmonics is frequently called "hum," as it is often caused by defects in power supplies—similar to the audio case.

Low-frequency interference shows on the A-scope horizontal presentation as thickened horizontal lines, the thickness indicating the relative amplitude of the interference, as in Figs. 5-107 and 5-110 for the 120- and 1,000-cycle cases, respectively. The vertical presentation shows no thickening of the trace. The interference may appear as a waveform on the blanking line, horizontal sync tips, and sometimes the picture signal, as in Figs. 5-108 and 5-111 for the same two examples.

Clamper amplifiers effectively reduce interference at 60 cycles by about 33 db. This figure reduces progressively as the interfering frequency is increased, and the clamper is not effective on interference above about 2 kc. (This varies somewhat with the clamper time constant.) Figures 5-112 and 5-113 show the 120-cycle interference of Figs. 5-107 and 5-108 after passing through a clamper amplifier. No impairment is visible in the pictures.

**Glitch** (Figs. 5-114 and 5-115). A type of low-frequency interference, which has been commonly referred to by the broadcasters as a "glitch," is observed as a narrow horizontal bar moving through the picture (Fig. 5-114). Simultaneous observation of the A scope at field or frame rate will indicate one or more extraneous voltage pips moving along the signal at approximately reference-black level. The pip in Fig. 5-115 was moving rapidly from right to left.

This may be present in the signal from the customer's pickups as a result of a difference in frequency between a remote camera power supply and the customer's local 60-cycle power supply. When some types of radio relay equipment are used, the impairment also may result from spiking on the positive and negative sine-wave peaks of commercial power supplies. The speed of movement of the dark bar depends on the difference between the frequency of the picture field rate and the frequency of the commercial power supply. Such spiking is sometimes introduced from mercury-vapor rectifiers or similar systems feeding back voltage pips at a 60-cycle rate into the commercial power supply. Thus, this is not pure single-frequency interference but has many similar characteristics. It is possible to observe this spiking from such power supplies through use of an oscilloscope bridged on the power line. Effects are eliminated through filtering, either at the source of interference or at the point of connection of the radio relay equipment.

**High-frequency Interference** (Figs. 5-116 to 5-127). In the region above the line rate, 15,750 cycles, the most critical frequency is found to be in the ½- to ⅓-Mc range. The maximum tolerable interference level at this point in the spectrum is about 65 db below the signal. High-frequency interference will appear as regularly spaced diagonal or vertical bars which become finer as the frequency increases. If this frequency is an exact multiple of the line rate, the pattern will be stationary and vertical. The interfering frequency can be determined by multiplying the line rate by the number of white or the number of dark bars observed cutting a horizontal cross section of the picture. Figures 5-116 to 5-119 are samples, respectively, of 31.5-kc, 311-kc, 1.0-Mc, and 3.6-Mc interference. The first picture contains light vertical areas just to the left of center and on the right side of the pattern which are difficult to distinguish. The bar patterns on the other three pictures are quite evident, and a count of the bars will give the interfering frequency accurately.

The A-scope presentations are shown by Figs. 5-120 to 5-123 at horizontal rate and Figs. 5-124 to 5-127 at vertical rate, respectively. It will be noted that, on the horizontal display, the interference shows as a wave whose frequency can be determined by counting the cycles appearing in the scanning interval. If the frequency is very high, expanding the scope presentation may be necessary to resolve the individual wave shapes. The vertical trace shows thickening as illustrated.

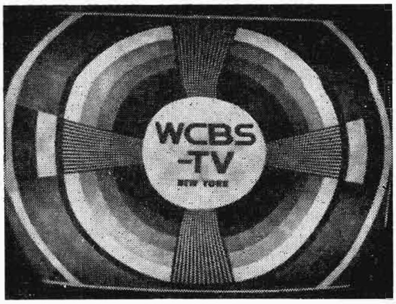



Fig. 5-106. Interference—120 cycles.

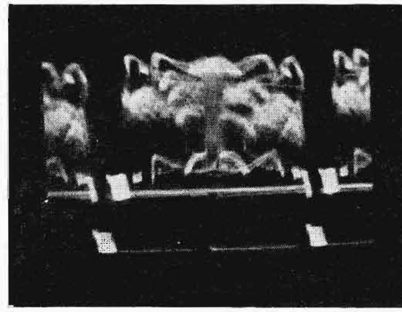


Fig. 5-107. Interference—120 cycles—horizontal.

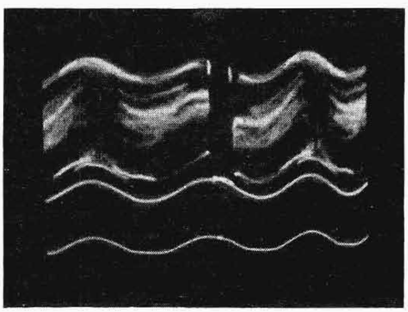


Fig. 5-108. Interference—120 cycles—vertical.

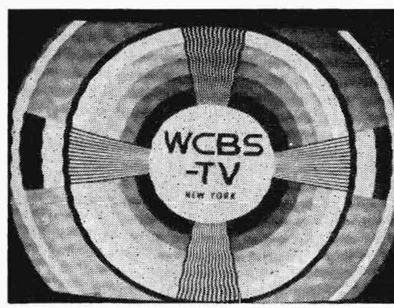



Fig. 5-109. Interference—1,000 cycles.

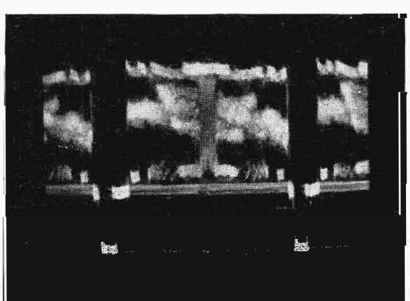


Fig. 5-110. Interference—1,000 cycles—horizontal.

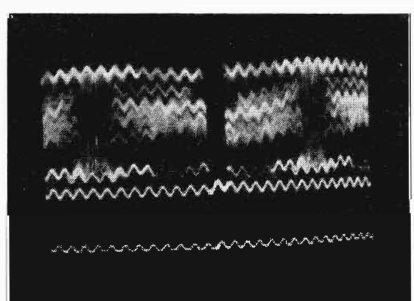


Fig. 5-111. Interference—1,000 cycles—vertical.

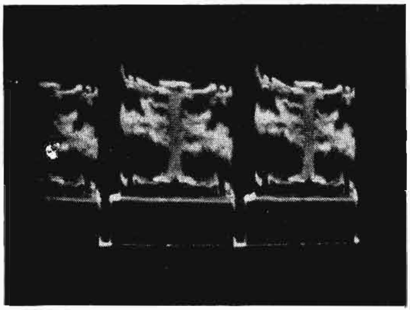


FIG. 5-112. Interference–clamped–120 cycles–horizontal.

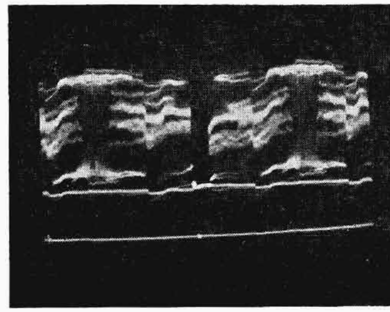


FIG. 5-113. Interference–clamped–120 cycles–vertical.

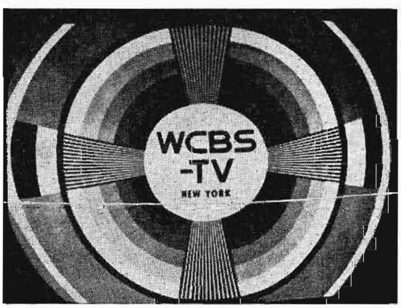



FIG. 5-114. Glitch.

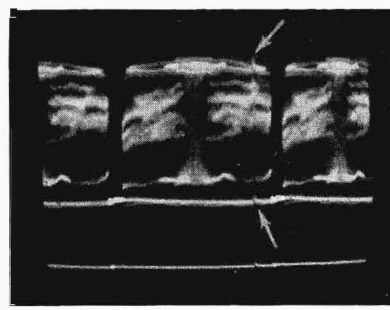


FIG. 5-115. Glitch–vertical.


FIG. 5-116. Interference–31.5 kc.

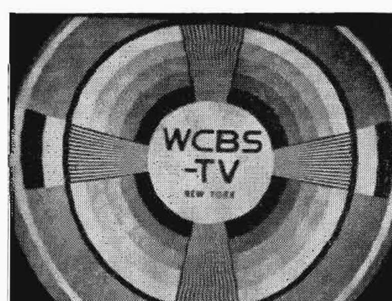



FIG. 5-117. Interference–311 kc.

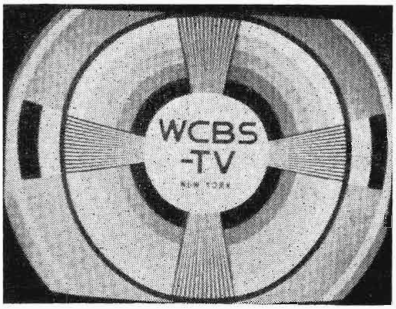



FIG. 5-118. Interference—1 Mc.

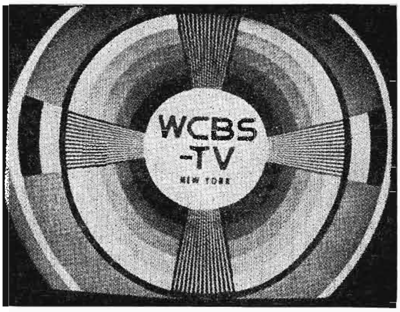



FIG. 5-119. Interference—3.6 Mc.

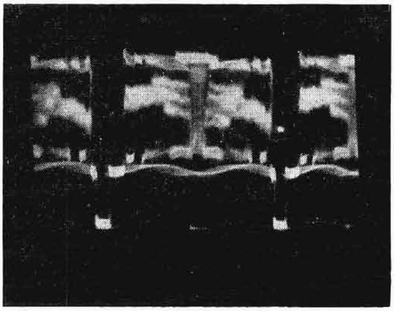


FIG. 5-120. Interference—31.5 kc—horizontal.

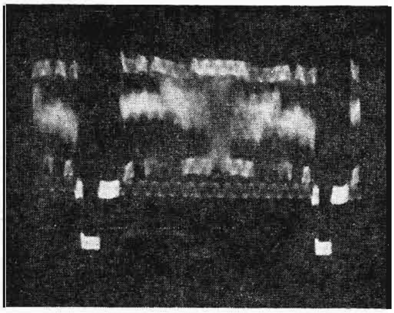


FIG. 5-121. Interference—311 kc—horizontal.

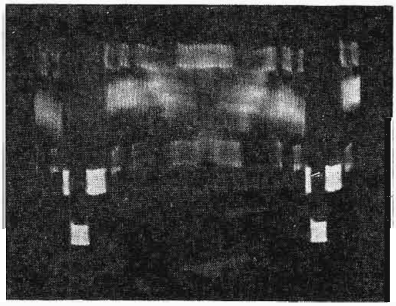


FIG. 5-122. Interference—1 Mc—horizontal.

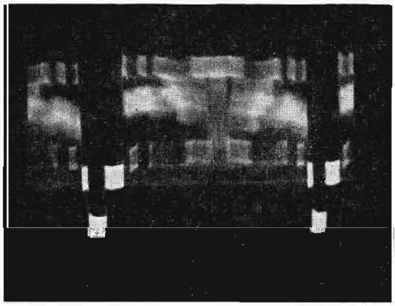


FIG. 5-123. Interference—3.6 Mc—horizontal.

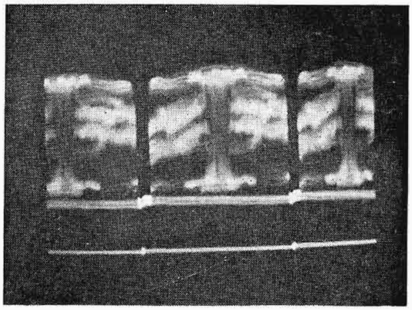


Fig. 5-124. Interference–31.5 kc–vertical.

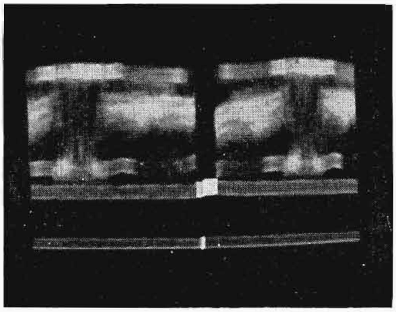


Fig. 5-125. Interference–311 kc–vertical.

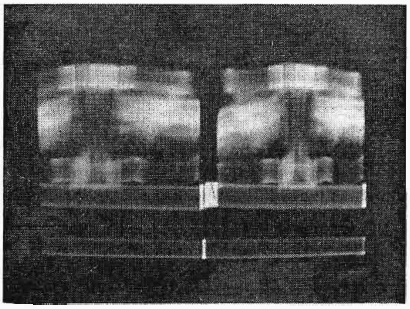


Fig. 5-126. Interference–1 Mc–vertical.

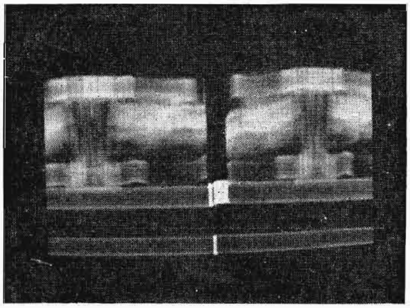


Fig. 5-127. Interference–3.6 Mc–vertical.

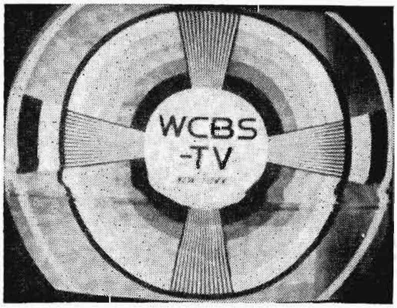



Fig. 5-128. Interference–cross talk.

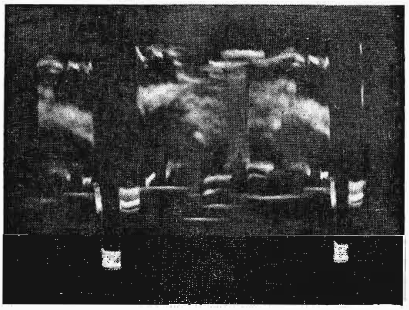


Fig. 5-129. Interference–cross talk–horizontal.

### *Cross Talk* (*Figs. 5-128 to 5-130*)

Cross talk, as considered herein, is the effect of coupling between two television channels. If the coupling is strong enough, the result is a weak extraneous image, usually somewhat distorted, superimposed on the main image similar to Fig. 5-128. Since different video systems normally are not exactly synchronized, rather violent horizontal motion of the cross-talking image usually occurs. Vertical motion is not likely to be so violent, since the field rates usually will be closer together than the line rates.

FIG. 5-130. Interference—cross talk—vertical.

The most prominent feature of the cross-talking image will be the line and field synchronizing interval. These are, of course, blacker than black, and they effectively frame the cross-talking image. As cross-talk coupling is reduced, the cross-talking image is no longer visible, but the horizontal interval which appears as a wide black vertical bar and the vertical interval which appears as a wide black horizontal bar will be visible moving through the picture. The rate of horizontal and vertical motion will vary with the differences between the sync rates of the two signals. The horizontal interval is usually the most disturbing, since it extends the whole height of the raster as a wide black bar, with appreciable motion. The vertical interval is not usually so noticeable.

It would appear that the limiting loss in the coupling path should be 58 db or higher for equal-level circuits.

Depending upon the strength of the unwanted signal, the interference may or may not be seen on the A scope. In the example used, it was necessary for photographic reasons to introduce the cross-talking signal only about 10 db below the desired signal. Therefore, the interfering signal is evident as modulation on both the horizontal and vertical presentations (Figs. 5-129 and 5-130).

### *Random Noise* (*Figs. 5-131 to 5-136*)

This type of noise is of the general type obtained by vacuum-tube amplification of thermal noise but is not necessarily confined to that source. It covers a wide band of frequencies without too much energy variation. The over-all rms amplitude is reasonably stable over time intervals corresponding to one line scan. Experience to date indicates that, assuming noise peaks to run around three times the rms value, peak random noise should be limited to approximately 30 db below the picture signal for a 4-Mc bandwidth system. It appears that "noise per megacycle of bandwidth" rather than total noise in the band determines the impairment. An 8-Mc system, for example, would be 3 db more tolerant to noise than a 4-Mc system.

The visual effect of random noise is that the picture acquires a pronounced graininess. When noise is strong enough, this may be called "snow" as shown in Fig. 5-131. Thickening of the blanking lines and tips of sync pulses is usually evident, as in Figs. 5-132 and 5-133, which show the horizontal and vertical scanning intervals of the picture of Fig. 5-131. These three illustrations are of noise caused by transmitting low level into a microwave repeater and restoring the signal to normal amplitude at the receiving terminal, thus amplifying the thermal noise in the equipment.

Figure 5-134 illustrates another type of random noise. This is the result of a microwave message channel, with a large number of busy circuits, interfering with the picture channel.

Light random noise (Figs. 5-135 and 5-136), visible only in the background of the picture has been referred to sometimes as "busy background," since variations in

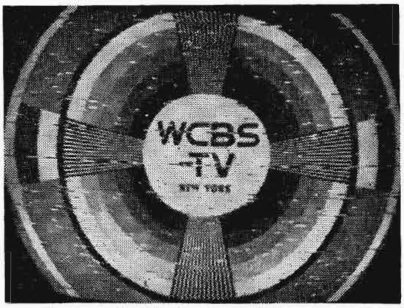



FIG. 5-131. Random noise.

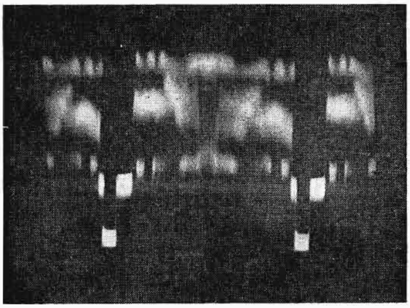


FIG. 5-132. Random noise—horizontal.

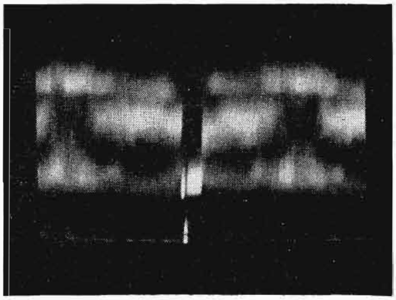


FIG. 5-133. Random noise—vertical.

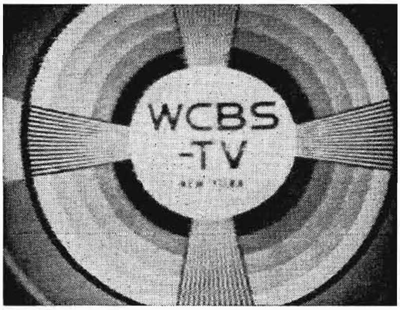



FIG. 5-134. Message-channel interference.

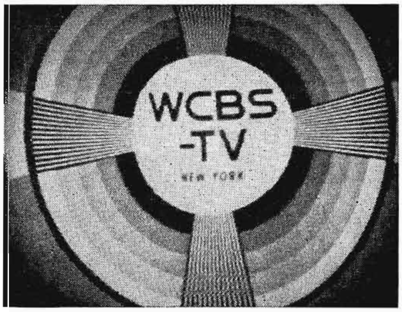



FIG. 5-135. Light random noise.

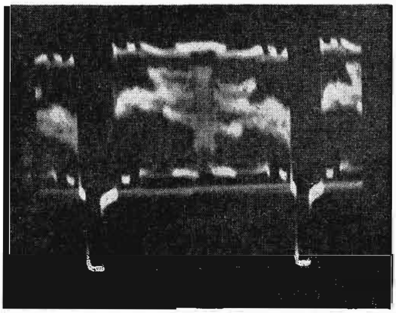


FIG. 5-136. Light random noise—horizontal.

intensity of the noise peaks usually cause the appearance of movement of the gray background, with minor thickening of the A-scope traces. This term is used with a different meaning by other groups connected with television and theatrical work, and its use is not recommended for description of television-signal impairments. "Light noise" or "light high-frequency noise" are preferred terms.

### *Impulse Noise (Fig. 5-137)*

The effect of impulse noise, which is composed usually of intermittent bursts or pulses, is difficult to evaluate. Assuming noise peaks at one per minnte, one objective thought to be reasonable is to limit the peak noise to 20 db below the signal level. The division between impulse noise and random noise is not sharp; as the rate of occurrence of noise pulses increases, the more nearly it approaches random noise. Picture impairments resulting from impulse noise, as shown in Fig. 5-137, are sometimes called "pigeons," since the spots seem to fly across the picture. The picture was obtained by reducing levels on a microwave system just enough to allow a few noise peaks to act on the picture, infrequently and unpredictably enough to be called impulse noise. Unless observation is made of the A scope at the time of occurrence of the noise pulse, or unless the pulses occur frequently, thickening of blanking lines or other signal indications will not be observed.

### *Microphonics (Fig. 5-138)*

When some vacuum tubes are physically disturbed by vibrations due to nearby machinery, shocks from installation operations, or even loud noises, their elements may vibrate, usually at a rate below 15,750 cps. The varying tube characteristics


Fig. 5-137. Impulse noise.

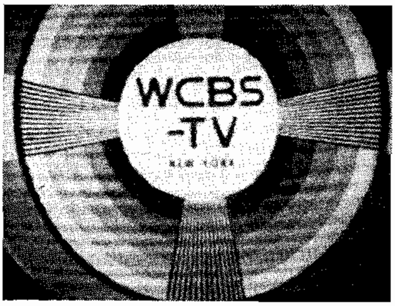



Fig. 5-138. Microphonics.

will cause any signal being handled to be modulated at the vibration rate. Since this can be considered as low-frequency interference, the effect on pictures is to add a series of horizontal bars, usually moving and changing in size in accordance with the amplitude and frequency of the vibration. Figure 5-138 was obtained by lightly tapping a tube in microwave terminal equipment.

## Miscellaneous

### *Clamping*

The effect on a composite video signal of low-frequency distortion is the same as though a low-frequency signal were added to the video signal. Thus low-frequency interference and low-frequency transmission deviations produce similar distortions of the video waveform. Clamping is a process whereby the effects of low-frequency interference and low-frequency transmission deviations are removed from the video

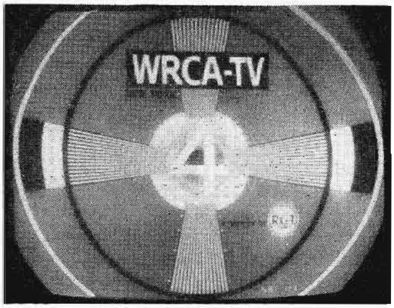



FIG. 5-139. Clamping failure.

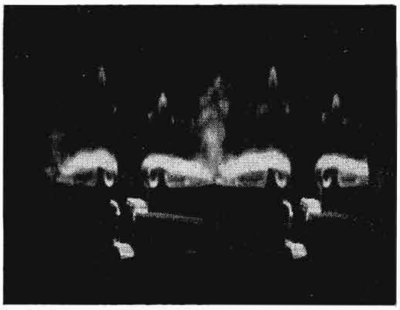


FIG. 5-140. Clamping failure—horizontal.

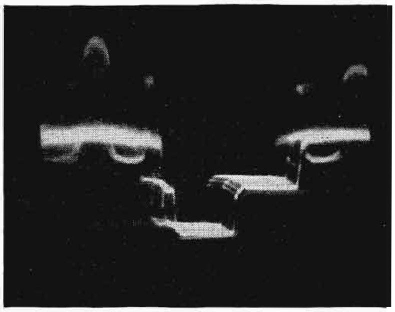


FIG. 5-141. Clamping failure—expanded horizontal.

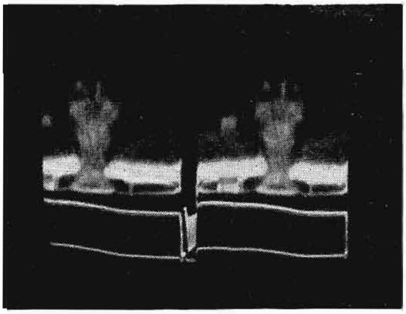


FIG. 5-142. Clamping failure—vertical.

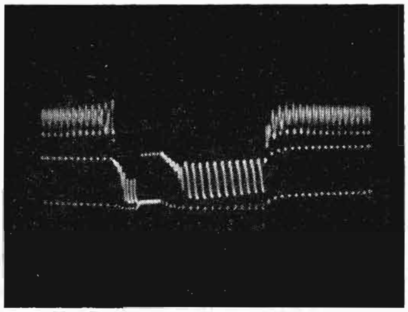


FIG. 5-143. Clamping failure—expanded vertical.

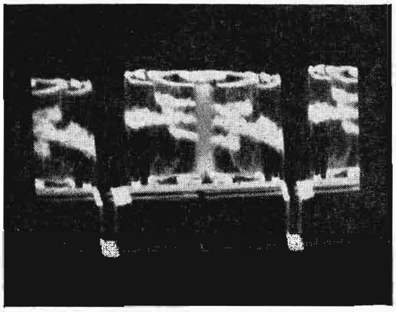


FIG. 5-144. Lack of clamping—horizontal.

signal. Telephone company clamper amplifiers are designed so that a correcting bias voltage is added to the signal at the start of each horizontal synchronizing pulse, the magnitude and polarity of this correcting voltage being sufficient to keep the tips of the horizontal sync pulses at a fixed reference level.

Since the back porch immediately follows the tip of the synchronizing pulse which has been adjusted to a fixed reference voltage, it is subjected to approximately the full clamper correction. The front porch, however, occurs at the end of a line signal, and its level is displaced by the over-all frequency distortion change during the preceding line interval. Since the clamper is triggered by the leading edge of the sync pulse, the front porch is unaffected by any subsequent correction that is applied by the clamper. Therefore, if the levels of the front and back porches were equal except for the low-frequency impairment experienced, the correcting voltage supplied by the clamper would be equal to the difference in the level of the two porches. However, porches are frequently displaced owing to other causes, such as transmission over a vestigial sideband carrier system where front-porch level may vary depending upon the signal level at the end of each scanning line. In general, therefore, porch displacement should not be depended upon as a measure of clamper correction voltage except under known conditions.

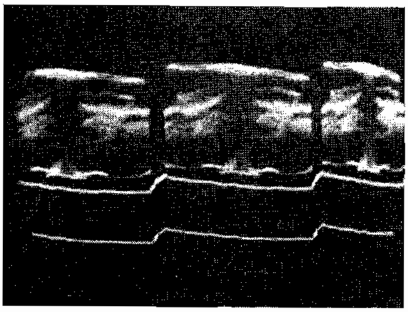


FIG. 5-145. Lack of clamping—vertical.

**Loss of Clamping** (Figs. 5-139 to 5-145). Loss of clamping results when the output level of the clamper amplifier drops to such a low level as to exceed the range of the clamping amplifier and thus make the clamping action ineffective. Figures 5-139 to 5-145 show the result of loss of clamping due to low level. Loss of clamping also may be caused by defective tubes or other defective components within the amplifier. Erratic or no clamping action may also result from an overshoot on the leading edge of the front porch sufficiently large to cause the clamper to be falsely triggered, resulting in complete tearing of the picture. In the examples, only a few lines of tearing are visible at the top of the pictures; however, the A scope reveals an erratic horizontal interval and serious distortion of the vertical blanking interval.

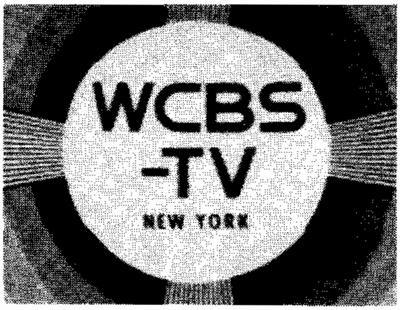



FIG. 5-146. Serrations.

Loss of clamper action on a signal transmitted through a coil is illustrated in Figs. 5-144 and 5-145. As previously discussed, the impairments observed as a result of low-frequency distortion are the same as though a low-frequency interfering signal were introduced and, therefore, will vary depending upon the nature and amount of low-frequency impairment present in the signal being observed. This is shown on the horizontal presentation (Fig. 5-144) by the thickening of the traces and in the vertical presentation (Fig. 5-145) by the varying tilts during vertical blanking and picture intervals.

## *Serrations (Fig. 5-146)*

Serrations are jaggedness in the vertical and diagonal structure of images as seen in a picture monitor. They result from horizontal displacement of some of the scanning lines due to nonuniformity in the triggering time of the horizontal-sweep oscillator. This condition may be caused by a distortion of the leading edge of the sync pulse as a result of interference, streaking, etc. Figure 5-146 sbows serrations of vertical and diagonal lines in the center of the test pattern.

### *Tearing (Figs. 5-147 and 5-148)*

Tearing is a horizontal displacement of the scanning lines to the extent that the picture appears torn. Tearing of the picture on the receiver or monitor may be caused by distortion or lack of horizontal sync pulses. It also may be caused by video black peaks or spikes which drop below blanking level near the horizontal sync pulse. Any other form of interference whose amplitude is such as to cause false triggering of the horizontal scanning circuit of a receiver or monitor will give similar effects. One illustration of such tearing is shown in Fig. 5-147.

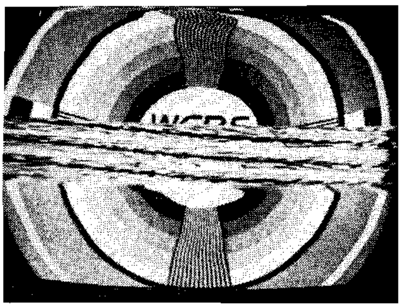


FIG. 5-147. Tearing.

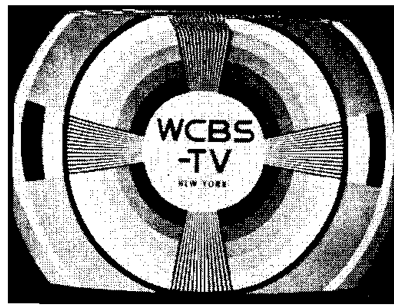



FIG. 5-148. Tearing.

Tearing at only the top of a picture, as in Fig. 5-148, is usually caused by impairment or loss of some equalizing pulses. This may be due to syuc generator trouble or improper clamping action due to defective clampers or improper levels.

### *Nonlinearity (Figs. 5-149 and 5-151)*

The requirement in most transmission circuits and amplifiers that the output be directly proportional to the input over the working range of voltages or power means that these circuits must be "linear." Operation outside the range of linearity may occur when exceeding ratings of equipment, when maladjustments occur, when components such as vacuum tubes age, or owing to improper design. The departure from linearity that can be tolerated varies over wide ranges. For example, sync expansion circuits have been built into some telephone company clamper amplifiers deliberately to "expand" the sync part of the video signal relative to the picture signal to compensate for unwanted compression which may accumulate in transmission. This illustrates that the results of nonlinearity may be either "compression," which is the more usual, or "expansion."

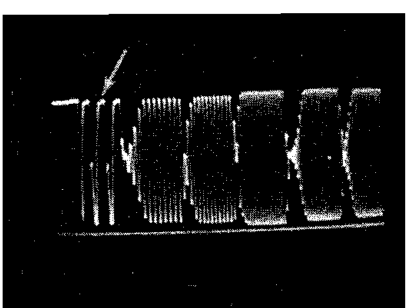


FIG. 5-149. Harmonic distortion—500 kc.

As discussed in the section on Level Irregularities, is it possible to compress either the negative or the positive peaks of a signal passing through an amplifier. The resulting video signal will contain either "black compression" or "white compression." In analyzing the effects of compression on a sine wave, it can be shown that the compressed signal, in addition to containing the fundamental sine wave, may include a d-c component and other components made up of harmonics of the original sine-wave frequency. When all these components can be transmitted, the received wave is distorted and limited, as in Fig. 5-149, showing harmonic distortion on the 500-kc burst of a multiburst test signal. Other examples of compression effects are shown in the portion of this part dealing with level variations such as blooming, bleeding whites, etc. When compression becomes severe, it sometimes is called clipping and is observed as a sharp line of demarcation in level beyond which no signal is found.

If the nonlinearity is not equal for different impressed frequencies, combinations of effects may result which may be difficult to analyze. Such unequal distortions may occur in feedback amplifiers, where the feedback is a function of frequency in order to maintain over-all flatness, or in circuits such as those of video cable amplifiers, where the high frequencies are transmitted at somewhat greater levels than the

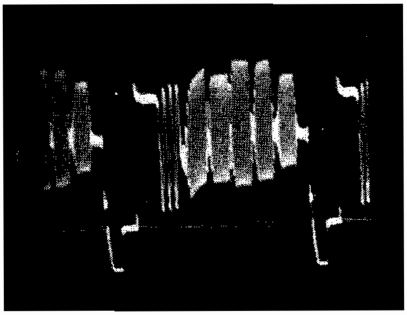


FIG. 5-150. Axis shift.

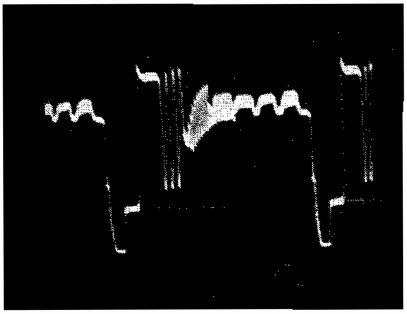


FIG. 5-151. Axis shift—through low-pass filter.

lows in order to compensate partially for succeeding cable loss. Compression of higher frequency compouents of a signal compared with the lows has been noted fairly frequently.

The multiburst test signal has proved to be a good indicator for this selective type of compression and may sometimes detect this condition when differential-gain measurements indicate no trouble. When this distortion is present, close observation of the higher frequency burst will reveal that the axes of some or all of these bursts are shifted vertically by varying amounts, as in Fig. 5-150. As mentioned above, the distorted wave contains a d-c or, in the case of a video-type signal because of the horizontal scanning frequency, a 15,750-cycle component and harmonics of the distorted burst. For frequencies above about 2.5 to 3.0 Mc, most transmission facilities cut out the burst harmonics, leaving only the 15,750-cycle component and the fundamental frequency. This 15,750-cycle component will shift the axis of the multiburst through the burst in question. For frequencies whose second or higher harmonics are passed by the system, the axis shift is not so pronounced, but an expansion of the wave will show distortion, as on the 500-kc burst illustrated in Fig. 5-149. This shiftiug of the axis of the bursts has sometimes been called "rectification" because of the production of the effective d-c component. Figure 5-151 is the same signal as Fig. 5-150, but in this case the signal has been put through a low-pass filter which effectively eliminates the higher frequency bursts and makes the axis shift more evident.

### *Halo (Fig. 5-152)*

Halo usually is the appearance of a black border around unusually bright objects in a televised scene. As shown in Fig. 5-152, the border may be irregular in size and shape but is easily distinguished from streaking and smearing. It is caused by overloading of the pickup tube in scanning bright objects. While the accompanying figure indicates halo around an object occupying a large part of the viewing screen, it also is commonly noticed when stage lights are reflected from jewelry, eyeglasses, and other small objects. With certain camera tube operating adjustments, a white area may surround dark objects.

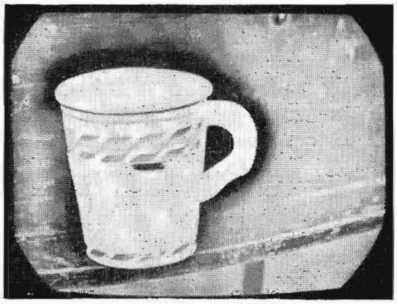


Fig. 5-152. Halo.

### *Moiré (Figs. 5-153 and 5-154)*

Mesh beat, or moiré effect, is the appearance of vertical or diagonal lines on a picture which resemble high-frequency interference. In Fig. 5-153, these lines are most noticeable across the top and bottom of the kitchen cabinet close-up. This difficulty may be caused by image-orthicon cameras where a beat is obtained between the scanning signal and the screen, or mesh, associated with the target plate.

Moiré pattern is also a natural optical effect when scanning closely spaced picture lines which are almost horizontal. It is evident on the horizontal wedges of the test pattern shown in Fig. 5-154 (which is a reprint of Fig. 5-137, Impulse Noise).

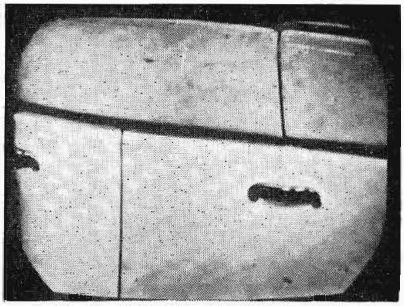


Fig. 5-153. Moiré.

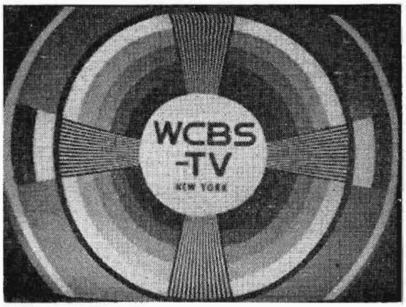



Fig. 5-154. Moiré.

### *Burned-in Image (Figs. 5-155 and 5-156)*

A burned-in image is one which persists in the camera output signal when the camera has been focused on another scene. Figure 5-155 illustrates the case of a camera having been shifted to one side of a prompting chart, with the original image still visible to the right of the new one. Figure 5-156 shows a burned-in image of the RETMA test pattern, originally being viewed, superimposed on a close-up of a stove top and grillwork. This phenomenon is associated with orthicon camera tubes where the persistence of the burned-in image depends upon the length of time that the camera is focused on the original scene and the brightness of the scene. It may last as long as several minutes in extreme cases.

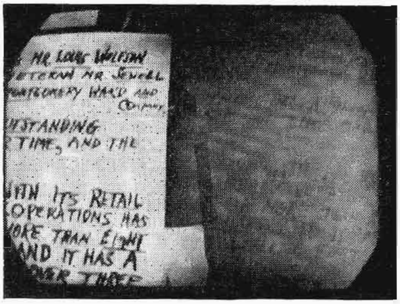


FIG. 5-155. Burned-in image.

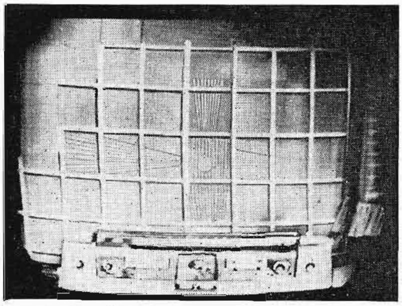


FIG. 5-156. Burned-in image.

## Color-signal Impairments

In general, color-television signals are subject to the same impairments as monochrome transmissions. However, color-television signals may be impaired seriously by additional conditions that might not affect a monochrome picture.

### *High or Low Chrominance-signal Level*

When the chrominance-signal component of a color-television signal is received at too high a level, colors will increase in saturation; when this component is received at too low a level, colors will tend to wash out. So long as overloading or differential gain is not controlling, the proper relationship in saturation between various hues will be maintained.

A high or low chrominance-signal level occurring when luminance-signal levels are normal would result from excess gain or loss at the upper portion of the video-signal frequency spectrum.

Since the color burst has the same frequency as the color subcarrier, any transmission characteristic affecting the amplitude of the chrominance signal will usually also affect the amplitude of the color burst (Figs. 5-157 and 5-158). For rapid location of large deviations it is possible, using an A scope with a wideband characteristic, to observe the color-signal waveform for comparison of color burst and sync pulse amplitudes, which should be the same. However, a comparative measurement of color-burst amplitudes is necessary for more precise locations.

Because results can be expressed quantitatively, A-scope location of impairments can usually be made more accurately and rapidly than would be possible using color monitors, although color monitors can be used also for verification.

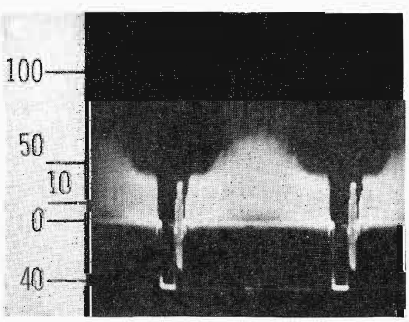



FIG. 5-157. High-level chrominance signal—horizontal.

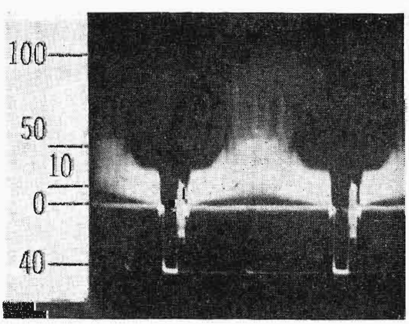



FIG. 5-158. Low-level chrominance signal—horizontal.

### *Loss of Color*

In the general case this is caused by very low chrominance-signal level. However, such a condition has occurred with an apparently normal color burst, as viewed on an A scope. In this case, the frequency of the apparent color burst has been shifted from the normal 3.6-Mc value during transmission. Color monitors are required for quick location in such cases.

### *Differential Phase Distortion (Figs. 5-159 and 5-161)*

Differential phase is the change in phase of the 3.6-Mc color subcarrier as the level of the luminance signal on which it rides is varied from blanking to white. It causes error in portrayal of hues. Figures 5-159 and 5-161 illustrate large amounts of differential phase of opposite signs, as compared to Fig. 5-160 which is a "normal" picture.

In FM radio relay systems, this distortion is usually caused by a nonuniform delay-frequency characteristic in the IF equipment, where varying amplitudes of input signal are represented by varying frequencies. The color burst is always at blanking level and, therefore, will always swing about the same frequency on the radio relay system. Color components of the signal generally are not at blanking level; therefore, the FM swing will be about a different frequency and any difference in delay between the two results in differential phase. In telephone company systems, delay equalizers in IF paths are used to correct for differential phase.

In addition to FM radio systems, differential phase distortion may be experienced in any equipment having transmission paths that vary in phase with level. Hue impairments are observable in color picture monitors, but are not apparent in either monochrome picture monitors or in A scopes. Color monitors are neither sufficiently precise nor stable to use as a basis for correction of differential phase, and it is therefore necessary to release facilities from service in order to make differential phase measurements. The 47A transmission-measuring system is used for proper adjustment of differential phase equalizers.

### *Differential Gain Distortion*

In color-television transmission, differential gain is the change in gain of the 3.6-Mc color subcarrier as the level of the luminance signal on which it rides is varied from blanking to white. It causes error in color saturation of the received picture.

Differential gain is generally observed as signal compression as luminance levels are increased, although expansion can be experienced. The effects of differential gain may be observable in color monitors, depending upon degree. Severe cases of such signal impairment should be evidenced in the A-scope presentation of a color-bar test signal as an overloading or expansion condition of the chrominance components. Other than for severe conditions of this type, the facility or equipment to be tested must be released from service for differential-gain tests to enable location of causative facility sections.

When excess differential gain is experienced, the first step is to assure that proper amplitude levels have been maintained. Further investigation would include location of the portions of the layout or piece of equipment contributing appreciably to this condition. Clearance is then generally accomplished by replacement of tubes or other defective components.

### *Leading or Lagging Chrominance*

When the chrominance signal is not received at the same time as the luminance signal, colors will appear in the color-picture monitor to either one side or the other of the image. For example, a blob of red may occur at lip level to one side or the other of a face. Since the synchronizing of the color signal is governed by the color

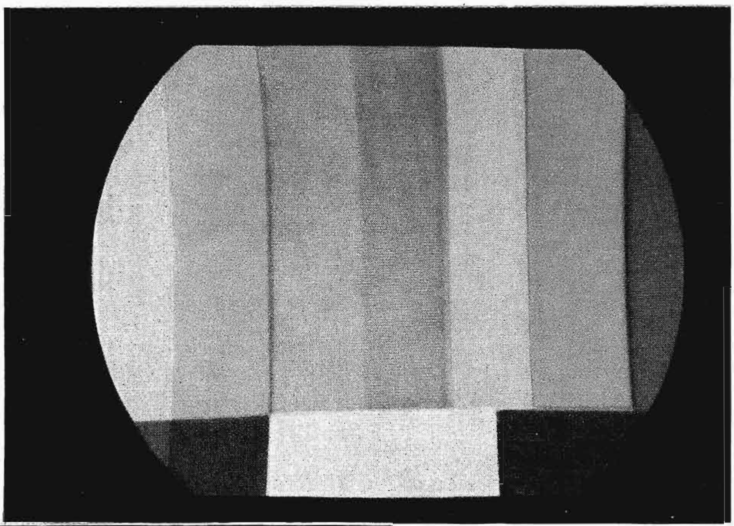


FIG. 5-159. Color-bar signal—yellow shifted toward red.

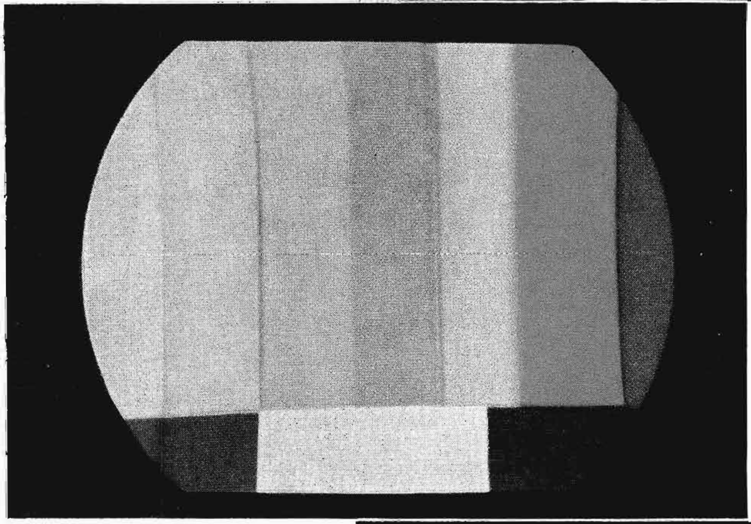


FIG. 5-160. Color-bar signal—normal phase.

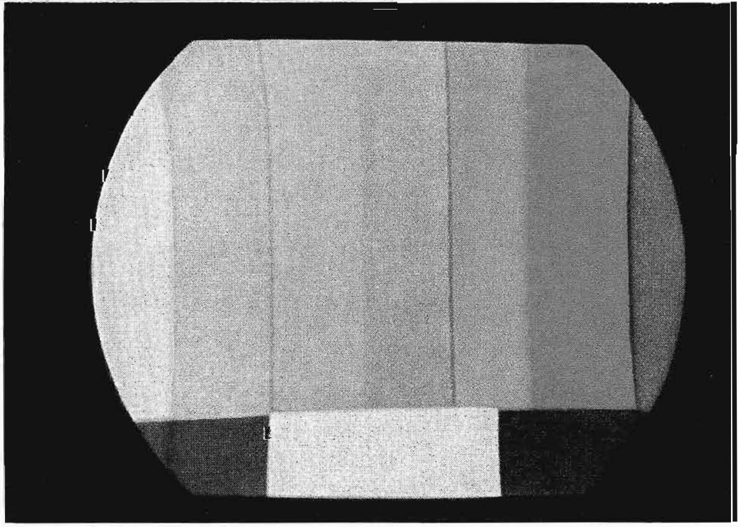


FIG. 5-161. Color-bar signal—yellow shifted toward green.

burst, observation of an A scope having wideband characteristic will reveal whether the color burst has been shifted from normal position in the back-porch interval. A shift to the left results in leading chrominance information. When severe, this impairment might be observed as edge effect on monochrome pictures transmitted over the same facility.

This condition can result from improper delay relationship between the lower and the upper portions of the frequency spectrum over transmission facilities or through equipment. Therefore, envelope-delay characteristics of television layouts in color condition should be checked if leading or lagging chrominance is experienced.

## GLOSSARY OF TELEVISION TERMS

### General

This glossary defines various terms presently used in the line-up, operation, and maintenance of video transmission systems. Experience in providing video service has indicated that a common understanding and use of the terms outlined in this section by the telephone companies and the broadcasting companies is desirable. Because these terms are intended for practical use by operating personnel, they may differ somewhat in wording from published standards, which are not so well suited for the intended purpose.

### Terms and Definitions

Aspect Ratio: The numerical ratio of picture width to height.

Back Porch: That portion of the composite picture signal which lies between the trailing edge of the horizontal sync pulse and the trailing edge of the corresponding blanking pulse.

Back-porch Tilt: The slope of the back porch from its normal horizontal position. Positive or negative refer, respectively, to upward or downward tilt to the right.

Bandwidth: The number of cycles per second expressing the difference between the limiting frequencies of a frequency band. For example, the 2.5- to 3.5-Mc band has a width of 1 Mc.

Black Compression: Amplitude compression of the signals corresponding to the black regions of the picture, thus modifying the tonal gradient.

Black Peak: The maximum excursion of the picture signal in the black direction at the time of observation.

Blacker-than-black: The amplitude region of the composite video signal below reference-black level in the direction of the synchronizing pulses.

Blanking (Picture): The portion of the composite video signal whose instantaneous amplitude makes the vertical and horizontal retrace invisible.

Blanking Level: The level of the front and back porches of the composite video signal.

Bleeding Whites: An overloading condition in which white areas appear to flow irregularly into black areas.

Blooming: The defocusing of regions of the picture where the brightness is at an excessive level owing to enlargement of spot size and halation of the fluorescent screen of the cathode-ray picture tube.

Bounce: An unnatural sudden variation in the brightness of the picture.

Breathing: Amplitude variations similar to "bounce" but at a slow regular rate.

Breezeway: In NTSC color, that portion of the back porch between the trailing edge of the sync pulse and the start of the color burst.

Burned-in Image: An image which persists in a fixed position in the output signal of a camera tube after the camera has been turned to a different scene.

Camera Tube: See Pickup Tube.

Cathode-ray Tube: An electron-tube assembly containing an electron gun arranged to direct a beam upon a fluorescent screen. Scanning by the beam can produce light at all points in the scanned raster.

Chrominance Signal: That portion of the NTSC color-television signal which contains the color information.

Clamper: A device which functions during the horizontal blanking or sync interval to fix the level of the picture signal at some predetermined reference level at the beginning of each scanning line.

CLAMPING: The process that establishes a fixed level for the picture signal at the beginning of each scanning line.

CLIPPING: The shearing off of the peaks of a signal. For a picture signal this may affect either the positive (white), or negative (black) peaks. For a composite video signal, the sync signal may be affected.

COLOR BURST: In NTSC color, normally refers to a burst of approximately 9 cycles of 3.6-Mc subcarrier on the back porch of the composite video signal. This serves as a color-synchronizing signal to establish a frequency and phase reference for the chrominance signal.

COLOR SUBCARRIER: In NTSC color, the carrier whose modulation sidebands are added to the monochrome signal to convey color information, i.e., 3.6 Mc (3.579545 Mc).

COLOR TRANSMISSION: The transmission of a signal which represents both the brightness values and the color (chrominance) values in a picture.

COMPOSITE VIDEO SIGNAL: The complete video signal. For monochrome, it consists of the picture signal and the blanking and synchronizing signals. For color, additional color-synchronizing signals and color-picture information are added.

COMPRESSION: An undesired decrease in amplitude of a portion of the composite video signal relative to that of another portion. Also, a less than proportional change in output of a circuit for a change in input level. For example, compression of the sync pulse means a decrease in the percentage of sync during transmission.

CONTRAST: The range of light and dark values in a picture or the ratio between the maximum and minimum brightness values. For example, in a high-contrast picture there would be intense blacks and whites whereas a low-contrast picture would contain only various shades of gray.

CROSS TALK: An undesired signal interfering with the desired signal.

CUTOFF FREQUENCY: That frequency beyond which no appreciable energy is transmitted. It may refer to either an upper or lower limit of a frequency band.

DAMPED OSCILLATION: Oscillation which, because the driving force has been removed, gradually dies out, each swing being smaller than the preceding in smooth, regular decay.

DEFINITION: See Resolution (Horizontal) and Resolution (Vertical).

DELAY DISTORTION: Distortion resulting from nonuniform speed of transmission of the various frequency components of a signal; i.e., the various frequency components of the signal have different times of travel (delay) between the input and the output of a circuit.

DETAIL: Refers to the most minute elements in a picture which are distinct and recognizable. Similar to definition or resolution.

DIFFERENTIAL GAIN: The amplitude change, usually of the 3.6-Mc color subcarrier, introduced by the over-all circuit, measured in decibels or per cent, as the subcarrier is varied from blanking to white level.

DIFFERENTIAL PHASE: The phase change of the 3.6-Mc color subcarrier introduced by the over-all circuit, measured in degrees, as the subcarrier is varied from blanking to white level.

DISPLACEMENT OF PORCHES: Refers to any difference between the level of the front porch and the level of the back porch.

DISTORTION: The departure, during transmission or amplification, of the received-signal waveform from that of the original transmitted waveform.

DRIVING SIGNALS: Signals that time the scanning at the pickup device.

ECHO (OR REFLECTION): A wave which has been reflected at one or more points in the transmission medium with sufficient magnitude and time difference to be perceived in some manner as a wave distinct from that of the main or primary transmission. Echoes may be either leading or lagging the primary wave and appear in the picture monitor as reflections, or "ghosts."

EDGE EFFECT: See Following or Leading White and Following or Leading Black.

EQUALIZING PULSES: Pulses of one-half the width of the horizontal sync pulses which are transmitted at twice the rate of the horizontal sync pulses during the blanking intervals immediately preceding and following the vertical sync pulses. The action of these pulses causes the vertical deflection to start at the same time in each interval and also serves to keep the horizontal-sweep circuits in step during the vertical blanking intervals immediately preceding and following the vertical sync pulse.

EXPANSION: An undesired increase in amplitude of a portion of the composite video signal relative to that of another portion. Also, a greater than proportional change in the output of a circuit for a change in input level. For example, expansion of the sync pulse means an increase in the percentage of sync during transmission.

FIELD: One-half of a complete picture (or frame) interval, containing all the odd or even scanning lines of the picture.

FIELD FREQUENCY: The rate at which a complete field is scanned, nominally 60 times a second.

FLASH: Momentary interference to the picture of a duration of approximately one field or less and of sufficient magnitude totally to distort the picture information. In general, this term is used alone when the impairment is of such short duration that the basic impairment cannot be recognized. Sometimes called "hit."

FLYBACK: See Horizontal Retrace.

FOLLOWING (OR TRAILING) BLACKS: A term used to describe a picture condition in which the edge following a white object is overshaded toward black. The object appears to have a trailing black border. Also called "trailing reversal."

FOLLOWING (OR TRAILING) WHITES: A term used to describe a picture condition in which the edge following a black or dark gray object is shaded toward white. The object appears to have a trailing white border. Also called "trailing reversal."

FRAME: One complete picture consisting of two fields of interlaced scanning lines.

FRAME FREQUENCY: The rate at which a complete frame is scanned, nominally 30 frames per second.

FRONT PORCH: That portion of the composite picture signal which lies between the leading edge of the horizontal blanking pulse and the leading edge of the corresponding sync pulse.

FRAME ROLL: A momentary roll.

GAIN-FREQUENCY DISTORTION: Distortion which results when all the frequency components of a signal are not transmitted with the same gain or loss. A departure from "flatness" in the gain-frequency characteristic of a circuit.

GHOST: A shadowy or weak image in the received picture, offset to either the left or right of the primary image, the result of transmission conditions which create secondary signals that are received earlier or later than the main or primary signal. A ghost displaced to the left of the primary image is designated as "leading," and one displaced to the right is designated as "followiug" (lagging). When the tonal variations of the ghost are the same as the primary image, it is designated as "positive," and when it is the reverse, it is designated as "negative."

GLITCH: A form of low-frequency interference appearing as a narrow horizontal bar moving vertically through the picture. This is also observed on an oscilloscope at field or frame rate as an extraneous voltage pip moving along the signal at approximately reference-black level.

HALO: Most commonly, a dark area surrounding an unusually bright object, caused by overloading of the camera tube. Reflection of studio lights from a piece of jewelry, for example, might cause this effect. With certain camera tube operating adjustments, a white area may surround dark objects.

HEIGHT: The size of the picture in a vertical direction.

HIGH-FREQUENCY DISTORTION: Distortion effects which occur at high frequency. Generally considered as any frequency above the 15.75-kc line frequency.

HIGH-FREQUENCY INTERFERENCE: Interference effects which occur at high frequency. Generally considered as any frequency above the 15.75-kc line frequency.

HIGHLIGHTS: The maximum brightness of the picture, which occurs in regions of highest illumination.

HIT: See Flash.

HORIZONTAL BLANKING: The blanking signal at the end of each scanning line.

HORIZONTAL DISPLACEMENTS: Describes a picture condition in which the scanning lines start at relatively different points during the horizontal scan. See Serrations and Jitter.

HORIZONTAL RETRACE: The return of the electron beam from the right to the left side of the raster after the scanning of one line.

HORIZONTAL (HUM) BARS: Relatively broad horizontal bars, alternately black and white, which extend over the entire picture. They may be stationary or may move up or down. Sometimes referred to as a "venetian-blind" effect. Caused by approximate 60-cycle interfering frequency or one of its harmonic frequencies.

HUE: Corresponds to "color" in everyday use, i.e., red, blue, etc. Black, white, and gray do not have hue.

ICONOSCOPE: A camera tube in which a high-velocity electron beam scans a photoemissive mosaic which has electrical-storage capability.

INTERFERENCE: In a signal-transmission path, extraneous energy which tends to interfere with the reception of the desired signals.

INTERLACED SCANNING (INTERLACE): A scanning process in which each adjacent line belongs to the alternate field.

ION: A charged atom, usually an atom of residual gas in an electron tube.

ION SPOT: A spot on the fluorescent surface of a cathode-ray tube which is somewhat darker than the surrounding area because of bombardment by negative ions which reduce the sensitivity.

ION TRAP: An arrangement of magnetic fields and apertures which will allow an electron beam to pass through but will obstruct the passage of ions.

IRE: The Institute of Radio Engineers.

IRE ROLL-OFF: The IRE standard oscilloscope frequency-response characteristic for measurement of level. This characteristic is such that at 2 Mc the response is approximately 3.5 db below that in the flat (low-frequency) portion of the spectrum and cuts off slowly.

IRE SCALE: An oscilloscope scale in keeping with IRE Standard 50, IRE 23.S., and the recommendations of the Joint Committee of TV Broadcasters and Manufacturers for Coordination of Video Levels.

JITTER: A tendency toward lack of synchronization of the picture. It may refer to individual lines in the picture or to the entire field of view.

KINESCOPE: Frequently used to mean picture tubes in general. However, this name has been copyrighted.

KINESCOPE RECORDING: A motion-picture-film recording of the presentation shown by a picture monitor. Also known as television recording (TVR), Vitapix, etc.

LEADING BLACKS: A term used to describe a picture condition in which the edge preceding a white object is overshaded toward black. The object appears to have a preceding or leading black border.

LEADING WHITES: A term used to describe a picture condition in which the edge preceding a black object is shaded toward white. The object appears to have a preceding or leading white border.

LINE FREQUENCY: The number of horizontal scans per second, nominally 15,750 times per second.

LOW-FREQUENCY DISTORTION: Distortion effects which occur at low frequency. Generally considered as any frequency below the 15.75-kc line frequency.

LOW-FREQUENCY INTERFERENCE: Interference effects which occur at low frequency. Generally considered as any frequency below the 15.75-kc line frequency.

LUMINANCE SIGNAL: That portion of the NTSC color-television signal which contains the luminance or brightness information.

MESH BEAT: See Moiré.

MICROPHONICS: In video transmission, refers to the mechanical vibration of the elements of an electron tube resulting in a spurious modulation of the normal signal. This usually results in erratically spaced horizontal bars in the picture.

MICROSECOND: One-millionth of a second.

MOIRÉ: A wavy or satiny effect produced by convergence of lines. Usually appears as a curving of the lines in the horizontal wedges of the test pattern and is most pronounced near the center where the lines forming the wedges converge. A moiré pattern is a natural optical effect when converging lines in the picture are nearly parallel to the scanning lines. This effect to a degree is sometimes due to the characteristics of color picture tubes and of image-orthicon pickup tubes (in the latter termed "mesh beat").

MONOCHROME TRANSMISSION (BLACK AND WHITE): The transmission of a signal wave which represents the brightness values in the picture but not the color (chrominance) values in the picture.

MULTIPLE BLANKING LINES: Evidenced by a thickening of the blanking-line trace or by several distinct blanking lines as viewed on an oscilloscope. May be caused by hum.

NEGATIVE IMAGE: Refers to a picture signal having a polarity which is opposite to normal polarity and which results in a picture in which the white areas appear as black and vice versa.

NTSC: National Television System Committee.

NOISE: The word "noise" is a carry-over from audio practice. Refers to random spurts of electrical energy or interference. May produce a "salt-and-pepper" pattern over the picture. Heavy noise sometimes is called "snow."

ORTHICON (CONVENTIONAL): A camera tube in which a low-velocity electron beam scans a photoemissive mosaic on which the image is focused optically and which has electrical-storage capability.

ORTHICON (IMAGE): A camera tube in which the optical image falls on a photoemissive cathode which emits electrons that are focused on a target at high velocity. The target is scanned from the rear by a low-velocity electron beam. Return beam modulation is amplified by an electron multiplier to form an over-all light-sensitive device.

ORTHICON EFFECT: One or more of several image-orthicon impairments that have been referred to as "orthicon effect" as follows:

1. Edge effect
2. Mesh beat or moiré
3. Ghost

4. Halo
5. Burned-in image

It is obviously necessary to indicate specifically the effect or effects experienced, and therefore, it is recommended that use of this term be discontinued.

OVERSHOOT: An excessive response to an unidirectional signal change. Sharp overshoots are sometimes referred to as "spikes."

PAIRING: A partial or complete failure of interlace in which the scanning lines of alternate fields do not fall exactly between one another but tend to fall (in pairs) one on top of the other.

PEAK TO PEAK: The amplitude (voltage) difference between the most positive and the most negative excursions (peaks) of an electrical signal.

PEDESTAL: This term is obsolete.

PEDESTAL LEVEL: This term is obsolete; "blanking level" is preferred.

PERCENTAGE SYNC: The ratio, expressed as a percentage, of the amplitude of the synchronizing signal to the peak-to-peak amplitude of tbe picture signal between blanking and reference-white level.

PHOTOEMISSIVE: Emitting or capable of emitting electrons upon exposure to radiation in and near the visible region of the spectrum.

PICKUP TUBE: An electron-beam tube used in a television camera where an electron current or a charge-density image is formed from an optical image and scanned in a predetermined sequence to provide an electrical signal.

PICTURE MONITOR: This refers to a cathode-ray tube and its associated circuits arranged to view a television picture.

PICTURE SIGNAL: That portion of the composite video signal which lies above the blanking level and contains the picture information.

PICTURE TUBE: A cathode-ray tube used to produce an image by variation of the intensity of a scanning beam.

PIGEONS: Noise observed on picture monitors as pulses or bursts of short duration at a slow rate of occurrence—a type of impulse noise.

POLARITY OF PICTURE SIGNAL: Refers to the polarity of the black portion of the picture signal with respect to the white portion of the picture signal. For example, in a "black negative" picture, the potential corresponding to the black areas of the picture is negative with respect to the potential corresponding to the white areas of the picture, while in a "black positive" picture the potential corresponding to the black areas of the picture is positive. The signal as observed at broadcasters' master control rooms and telephone company television operating centers is "black negative."

PREEMPHASIS (PREDISTORTION). A change in level of some frequency components of the signal with respect to the other frequency components at the input to a transmission system. The high-frequency portion of the band is usually transmitted at higher level than the low-frequency portion of the band.

RASTER: The scanned (illuminated) area of the cathode-ray picture tube.

REFERENCE BLACK LEVEL: The level corresponding to the specified maximum excursion of the luminance signal in the black direction.

REFERENCE WHITE LEVEL: The level corresponding to the specified maximum excursion of the luminance signal in the white direction.

REFLECTIONS OR ECHOES: In video transmission this may refer either to a signal or to the picture produced.

1. Signal:
   *a.* Waves reflected from structures or other objects
   *b.* Waves which are the result of impedance or other irregularities in the transmission medium
2. Pictures: "Echoes" observed in the picture produced by the reflected waves.

RESOLUTION (HORIZONTAL): The amount of resolvable detail in the horizontal direction in a picture. It is usually expressed as the number of distinct vertical lines, alternately black and white, which can be seen in three-quarters of the width of the picture. This information usually is derived by observation of the vertical wedge of a test patteru. A picture which is sharp and clear and shows small details has good, or high, resolution. If the picture is soft and blurred and small details are indistinct, it has poor, or low, resolution. Horizontal resolution depends upon the high-frequency amplitude and phase response of the pickup equipment, the transmission medium, and the picture monitor as well as the size of the scanning spots.

RESOLUTION (VERTICAL): The amount of resolvable detail in the vertical direction in a picture. It is usually expressed as the number of distinct horizontal lines, alternately black and white, which can be seen in a test pattern. Vertical resolution is primarily fixed by the number of horizontal scanning lines per frame. Beyond this, vertical resolution depends on the size and shape of the scanning spots of the pickup equipment and picture monitor and does not depend upon the high-frequency response or bandwidth of the transmission medium or picture monitor.

RESTORER: As used by the telephone company, a network designed to remove the effects of predistortion or preemphasis, thereby resulting in an over-all normal characteristic.

RETMA: Abbreviation for Radio Electronic Television Manufacturers Association.

RETRACE (RETURN TRACE): See Horizontal and Vertical Retrace.

RF PATTERN: A term sometimes applied to describe a fine herringbone pattern in a picture. May also cause a slight horizontal displacement of scanning lines resulting in a rough or ragged vertical edge of the picture. Caused by high-frequency interference.

RINGING: An oscillatory transient occurring in the output of a system as a result of a sudden change in input. Results in close-spaced multiple reflections, particularly noticeable when observing test patterns, equivalent square waves, or any fixed objects whose reproduction requires frequency components approximating the cutoff of the system.

ROLL: A lack of vertical synchronization which causes the picture as observed on the picture monitor to move upward or downward.

ROLL-OFF: A gradual attenuation of gain-frequency response at either or both ends of the transmission passband.

SATURATION (COLOR): The "vividness" of a color described by such terms as pale, deep, pastel, etc. The greater the amplitude of the chrominance signal, the greater the saturation.

SCANNING: The process of breaking down an image into a series of elements or groups of elements representing light values and transmitting this information in time sequence.

SCANNING LINE: A single continuous narrow strip of the picture area containing highlights, shadows, and half tones, determined by the process of scanning.

SCANNING SPOT: Refers to the cross section of an electron beam at the point of incidence in a camera tube or picture tube.

SERRATED PULSES: A series of equally spaced pulses within a pulse signal. For example, the vertical sync pulse is serrated in order to keep the horizontal-sweep circuits in step during the vertical sync-pulse interval.

SERRATIONS: This is a term used to describe a picture condition in which vertical or nearly vertical lines have a sawtooth appearance. The result of scanning lines starting at relatively different points during the horizontal scan.

SETUP: The separation in level between blanking and reference-black levels.

SMEAR: A term used to describe a picture condition in which objects appear to be extended horizontally beyond their normal bonndaries in a blurred, or "smeared," manner.

SNOW: Heavy random noise.

SPIKE: See Overshoot.

STREAKING: A term used to describe a picture condition in which objects appear to be extended horizontally beyond their normal boundaries. This will be more apparent at vertical edges of objects when there is a large transition from black to white or white to black. The change in luminance is carried beyond the transition and may be either negative or positive. For example, if the tonal degradation is an opposite shade to the original figure (white following black), the streaking is called negative; however, if the shade is the same as the original figure (white following white), the streaking is called positive. Streaking is usually expressed as short, medium, or long streaking. Long streaking may extend to the right edge of the picture and, in extreme cases of low-frequency distortion, can extend over a whole line interval.

SYNCHRONIZATION: The maintenance of one operation step with another.

SYNC: An abbreviation for the words "synchronization," "synchronizing," etc. Applies to the synchronization signals, or timing pulses, which lock the electron beam of the picture monitors in step, both horizontally and vertically, with the electron beam of the pickup tube. The color sync signal (NTSC) is known as the color burst.

SYNC COMPRESSION: The reduction in the amplitude of the syuc signal, with respect to the picture signal, occurring between two points of a circuit.

SYNC LEVEL: The level of the tips of the synchronizing pulses.

TEARING: A term used to describe a picture condition in which groups of horizontal lines are displaced in an irregular manner. Caused by lack of horizontal synchronization.

TELEVISION RECORDING (TVR): See Kinescope Recording.

TRANSIENTS: Signals which endure for a brief time prior to the attainment of a steady-state condition. These may include overshoots, damped sinusoidal waves, etc., and therefore, additional qualifying information is necessary.

VERTICAL BLANKING: Refers to the blanking signals which occur at the end of each field.

VERTICAL RETRACE: The return of the electron beam from the bottom to the top of the raster after completion of each field.

VESTIGIAL-SIDEBAND TRANSMISSION: A system of transmission wherein the sideband on one side of the carrier is transmitted only in part.

VIDEO: A term pertaining to the bandwidth and spectrum position of the signal which results from television scanning and which is used to reproduce a picture.

VIDEO BAND: The frequency band utilized to transmit a composite video signal.

VIDEO-IN-BLACK: A term used to describe a condition as seen on the waveform monitor when the black peaks extend through reference-black level.

WAVEFORM MONITOR: This refers to a cathode-ray oscilloscope used to view the form of the composite video signal for waveform analysis. Sometimes called "A scope."

WHITE COMPRESSION: Amplitude compression of the signals corresponding to the white regions of the picture, thus modifying the tonal gradient.

WHITE PEAK: The maximum excursion of the picture signal in the white direction at the time of observation.

WIDTH: The size of the picture in a horizontal direction.

## Degrees of Impairments

Television picture impairments may be present in varying degrees. In the case of oscilloscope presentations, most impairments can best be described to remote points by indicating the IRE scale readings of the various signal components. In the case of picture-monitor presentations, however, impairments generally must be described in qualitative terms rather than quantitative terms, and the exchange of intelligence between remote observers is more complicated. The following descriptive terms, without a sharp line of demarcation being possible, are in common usage for indicating the magnitude of impairments:

DETECTABLE: Impairment is not readily noticeable in a normal picture or oscilloscope display but can be discerned by a minute inspection of the signal, it sometimes being necessary to vary picture-monitor brightness or expand oscilloscope presentations.

NOTICEABLE: Impairment is readily observed.

OBJECTIONABLE: Impairment interferes with the viewing of the picture.

UNCOMMERCIAL: Impairment is present to such degree that the program or portion of the program is not broadcast.