RADIO ENGINEERING
MICROWAVE RADIO
VIDEO TRANSMISSION
LOCAL LINKS

CONTENTS PAGE

1. GENERAL

1.01 This section reviews some of the factors to be considered when engineering local links for video transmission. Part 1 covers general circuit configurations and types of equipment. Transmission parameters are detailed in Part 2. Parts 3 and 4 review installation and performance requirements for radio equipment; performance tests are summarized in Part 5. Pertinent references are listed in Part 6.

> ***Note:*** While the greater part of local links use radio as the transmission medium, interconnecting cable spans must not be overlooked since cable transmission characteristics affect the amplitude and delay response of the overall link.

1.02 This section is reissued to update the information and consolidate material from Appendix 1 which is canceled.

TYPES OF LOCAL LINKS

1.03 Local television links are classified as local video channels and provide for the one-way transmission of standard 525-line video signals (NTSC color or monochrome). The types of local links which may be used are:

(a) Pick-up point to studio

(b) Studio to studio

(c) Studio to transmitter

(d) Studio to network connection

(e) Special (theater, industrial applications, etc.)

1.04 A local link may consist of radio in tandem with cable in various combinations, as shown in Fig. 1. These links may include a radio hop, A4 or A2AT cable systems, or combinations thereof.

GENERAL REQUIREMENTS

1.05 A decision to use radio, or cable, for video transmission will be influenced by a number of factors such as the availability of suitable radio sites, length of circuit, and whether the service is permanent or temporary. For permanent service on a long circuit, radio should be considered where it will save equipping cable with repeater amplifiers and equalizers. Where the route length is less than a half mile, the A4 cable system may be considered (Fig. 1B). Where service is required on very short notice, radio may be more applicable than cable since the equipping and equalization of cable facilities in a short time may not be practical. In either case, careful judgments must be made weighing cost against those factors necessary to engineer the system.

1.06 Table A lists typical circuit characteristics for various combinations of radio and cable television links as measured on actual systems in the field. Since these measurements are typical, measurements on other systems will vary somewhat; therefore, Table A should only be used as a guide as to what can be expected of various types of local links.

A. Cable Systems

1.07 The A4 video transmission system (Fig. 1B) is a baseband cable system which may be used on spans of up to 0.5 mile of 16-PEV-L cable or equivalent. Short lengths of 75-ohm coaxial cable may also be used as a cable facility. Specific application of the A4 system may be found in Sections 318-220-100, 318-220-501 and 857-413-101. Briefly, the system consists of a transmitter whose function is to convert a 75-ohm unbalanced line input into a balanced line output and a receiver with inputs for balanced or unbalanced lines. The output of the receiver may be balanced or unbalanced. Gain, equalization, and clamping are provided in the receiver. The receiver may be connected to the transmission line as a pre-equalizer or at the end for post-equalization. Possible uses for the A4 system are:

(a) An entrance link for radio

(b) Short term video connection between TELCO equipment and mobile units of broadcasters

(c) A clamper-amplifier

(d) TOC test and monitor-trunks

(e) TELCO/TOC video link to TELCO/customer video connections

1.08 The A2AT (Fig. 1c) is a cable video baseband transmission system. It is designed to be complete in itself and may be used where microwave

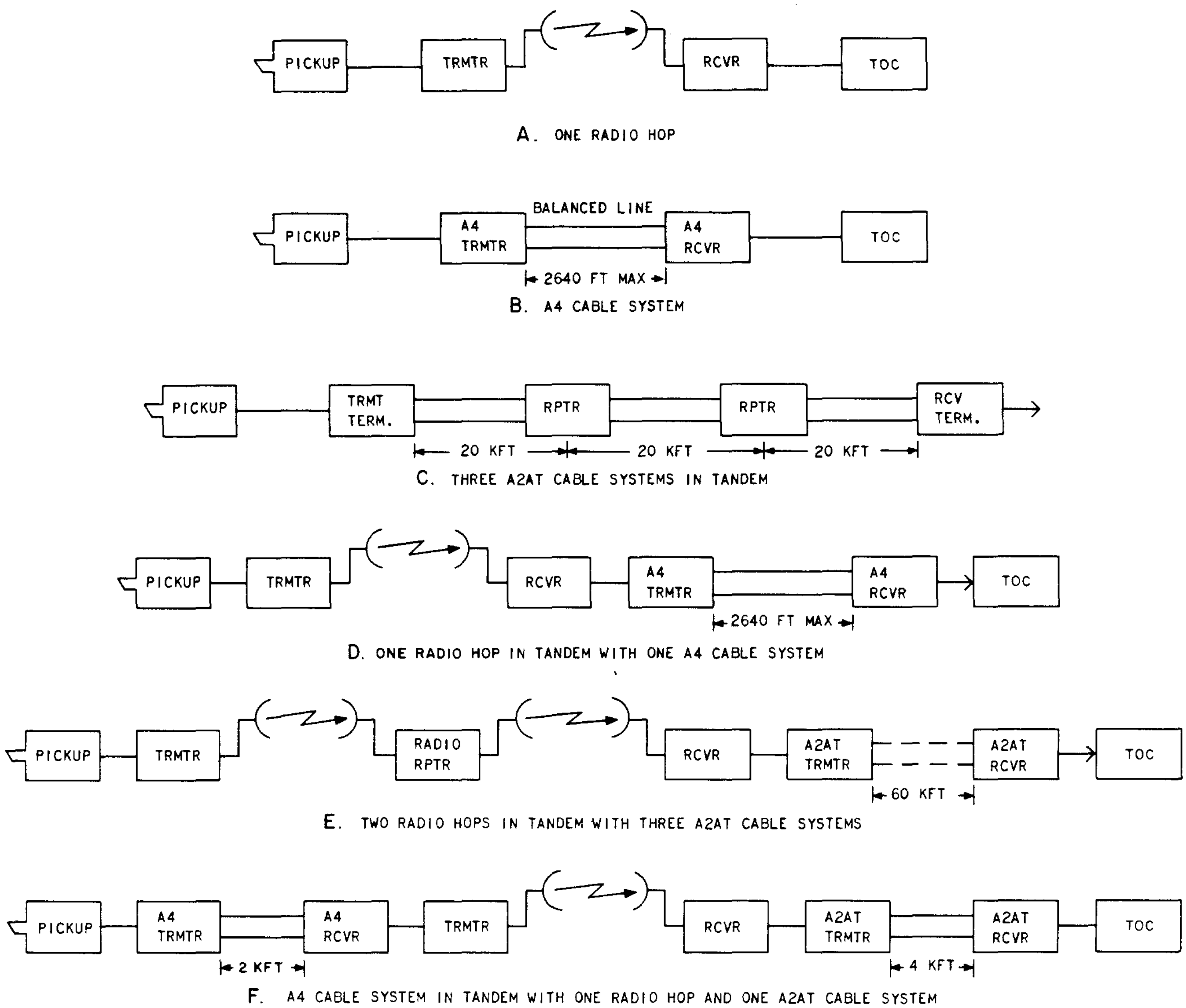


Fig. 1—Typical Local Links

radio is not applicable. The A2AT system is a solid-state replacement for the A2A system. It consists of transmitting and receiving terminals and repeaters. Each piece of A2AT equipment is capable of providing gain and equalization. Section 318-210-100 gives general description and application information. Briefly, the transmitting terminal operates from either a 75-ohm unbalanced or a 124-ohm balanced input. Gain and pre-equalization up to 32.5 dB are provided as required for the 124-ohm balanced cable that follows the transmitter.

1.09 The receiving terminal contains an input amplifier, one to three 24-dB amplifiers, various pads, fixed equalizers, two to three delay equalizers, and a combination clamper and output amplifier. The receiver input and output may be balanced or unbalanced. A repeater consists of an input amplifier, an output amplifier, and equalizers with additional amplification to provide the signal requirements at that point. Tables in Section 318-210-100 provide for operating this system with 16-PEV-L cable or equivalent. While the A2AT system is a transmission entity in itself, it may be required in tandem with radio to meet the particular circuit order (Table A).

1.10 Portable microwave radio equipment operating in the 6- or 11-GHz slots assigned to local video links was used for the measurements shown

TABLE A

TYPICAL VIDEO CIRCUIT ORDER REQUIREMENTS

VIDEO CIRCUIT CONFIGURATION	FIG 1	NOISE (DB)	DIFF GAIN (DB)			DIFF PHASE (DB)			LINE TIME DIST +(DB)	G-FREQ RESP 300 KHZ (DB)	60 HZ SQ WAVE DIST (%)
			*10%	50%	90%	*10%	50%	90%			
One Radio Hop	A	—58	±0.40	±0.50	±0.55	±2.0	±1.0	±2.0	—39	±0.4	+3
A4 Ca Sys (2K ft)	B	—68		0.0			±0.0		—58	±0.05	+1
A2AT Ca Sys (60K ft)	C	—64		±0.2			±0.1		—48	±0.07	±3
Radio Hop & A4 Sys	D	—57.5		±0.5			±0.1		—39	±0.56	±3
2 Radio Hops & A2AT Sys	E	—54.5		±0.54			±1.5		—36	±0.56	+3
A4 Sys & Radio Hop & A2AT Sys	F	—56.3		±0.54			±1.1		—38.5	±0.40	±3

* Average Picture Level (APL)

\+ Measured with J64009A Video Distortion Meter in Table A. The measurements show that in all cases, including tandem systems of radio and cable, most of the noise and distortion is contributed by the radio systems.

Note: Two-hop radio in Table A consists of a baseband patch since, at the time, no equipment was installed for IF patching. However, this feature is available either in new equipment or as options on present equipment.

B. Radio Systems

1.11 All radio transmitters must be operated under suitable licenses or authorization issued by the Federal Communications Commission (FCC). The operation, testing, and adjustment of radio transmitters must be done by or under the supervision of suitably licensed radio operators. Radio frequencies allocated for local radio-television links are contained in the FCC rules and regulations under Part 21, paragraph 21.801. Certain frequencies are allocated for the exclusive use of common carriers.

Note: Under certain conditions or operations, common carriers may use frequencies normally assignable to broadcasters. Before selecting a frequency for a specific application, consult the appropriate rules of the FCC and general letters of the American Telephone and Telegraph Company in the Topical Index Code 1S3.2.

1.12 Most of the radio equipment available for video links is of non-Western Electric manufacture. Some operating companies may still use Western Electric Type TE radio systems; however, at this writing, this equipment should have been phased out. No attempt will be made to describe the characteristics of any manufacturer's equipment; however, typical characteristics of this type of equipment are shown in Table B.

1.13 Microwave radio equipment used for one-way 525-line video transmission generally consists of a transmitter RF unit, a receiver RF unit, and two control units, one at the transmitter and one at the receiver. The transmitting and receiving RF units are normally mounted on the transmitting and receiving antennas. Antennas are installed on roof tops or on high structures where direct point-to-point radiation is possible.

1.14 Typically, the transmitter and receiver assemblies are similar. They consist of the radio frequency unit mounted on a dish antenna, quite often a 4-foot dish with either a vertically or horizontally polarized feed horn. This assembly is sometimes mounted on a pedestal or tripod with a pan and tilt head (Fig. 2).

1.15 DC power and video is connected to the RF unit from the control unit via cable. Normally the control unit is located on a lower floor. It is at these units where measurements and tests of the video performance are made in the field. The video cable from the pickup A2 or A4 systems connects to the control unit. The design of the accessory equipment is such that various types of RF equipment can be mounted on the same pedestal or tripod. All of the necessary accessory equipment along with the radio equipment is available from manufacturers of portable equipment.

2. TRANSMISSION REQUIREMENTS

2.01 Local radio television links are engineered to provide for transmission of video signals at the proper level, with satisfactory margins over noise and nonlinear distortion, to the points of interconnection of the radio link with either the broadcaster's equipment or the Telephone Company's TOC. The radio transmission parameters of Table A were measured on several one-hop radio systems to derive average figures for local television transmission systems. These averages should be used as a guide in engineering these loops.

FREQUENCY BANDWIDTH

2.02 Local video channels are usually required to have essentially flat transmission characteristics up to about 4.5 MHz when measured across the proper terminating impedances. In general, available radio systems will have no difficulty in meeting this requirement unless extensive wire facilities are used between the radio terminal and the interconnection point. In this case, equalization must be provided for the interconnecting wire facilities.

2.03 If a repeating coil is required to match impedances, 124 ohms to 75 ohms or vice versa, the low-frequency response will be degraded by the poor low-frequency response of the repeating coil. The transmitters of some of the available radio systems contain clampers; however, it should be recognized that even after clamping there is

TABLE B

TYPICAL CHARACTERISTICS OF
PORTABLE MICROWAVE RADIO EQUIPMENT

CHARACTERISTIC	PERFORMANCE
Input Power:	115-117 VAC, 57 to 63 Hz —24 VDC optional on some equipment
Weight:	30 to 40 pounds
Environmental	
Temperature: Humidity: Altitude:	—30° to 50°C (average range) 95% 14,000 feet
Circuit Capacity:	600 FDM voice channels, or, 1 NTSC color signal with FM subcarriers
Modulation:	FM, 8 MHz peak-to-peak deviation
Frequency:	6- and 11 -GHz bands
Tuning:	Switchable or continuous within the band
Stability:	.01 to .02% .001 to .005% with AFC
IF:	70 MHz
Transmitter Power Output:	 .5 to 1 Watt at 6 GHz .1 to .5 Watt at 11 GHz
Receiver Noise Figure (Avg.):	9.5 dB at 6 GHz 11.0 dB at 11 GHz
Television Performance	
Baseband Impedance:	Unbalanced 75 ohms input or output
Video Signal:	1.0 volt peak-to-peak input and output
Tilt:	0.7 to 1.0%
Differential Phase 10% APL: 50% APL: 90% APL:	 ±0.5 degree ±0.3 degree ±0.5 degree
Differential Gain 10% APL: 50% APL: 90% APL:	 ±0.50 dB ±0.25 dB ±0.50 dB
Return Loss:	26 dB

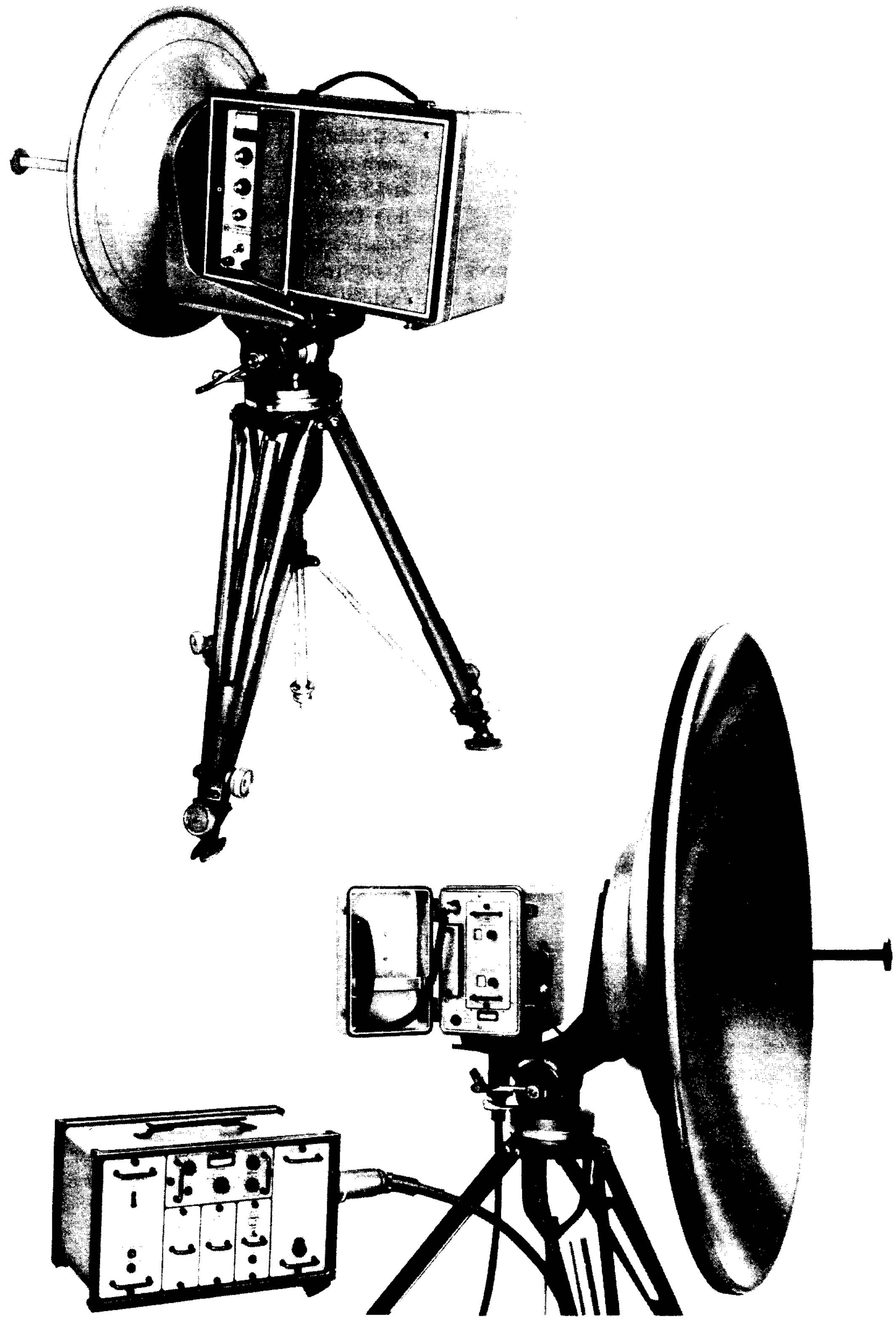


Fig. 2—Typical RF Units Mounted on Dish Antenna

some residual distortion. Consequently, the number of coils used in any circuit must be held to a minimum, particularly since local and intercity links may be involved in the over-all service and each part may include such coils.

IMPEDANCE CONSIDERATIONS

2.04 There are two source and load impedances encountered in video transmission: 75 ohms unbalanced and 124 ohms balanced to ground. In general, broadcasters' equipment operates at a nominal impedance of 75 ohms while network connecton points (TOCs) operate on a 124 ohm balanced impedance basis. The 197-type repeating coil with an impedance ratio of 75 ohms to 124 ohms is available to match these impedances where required; although as mentioned previously, the use of these coils adversely affects the low-frequency response.

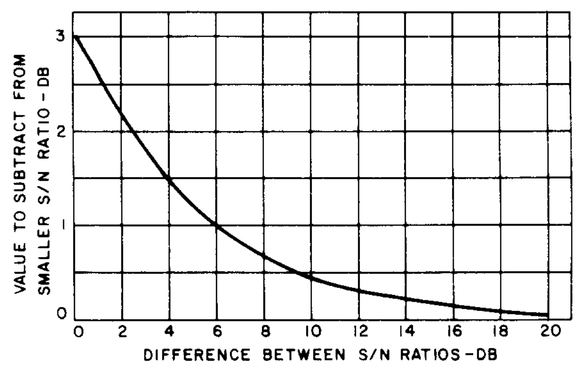
VIDEO LEVELS

2.05 Local video channels should be engineered to deliver and receive a video voltage of 1.0 volt peak-to-peak across a 75-ohm impedance at all broadcasters' locations including studios, transmitters, and pickup points. There are cases where broadcasters will accept less than this and will deliver a higher voltage, but such cases should be considered as exceptions subject to negotiation.

2.06 Television operating centers will deliver to local video channels a 1.0 volt peak-to-peak signal on a 124 ohm balanced impedance basis and will require a balanced input signal of not less than 1.0 volt peak-to-peak from the local loop. The 1.0 volt P-P level is required at the transmitter for substantially full modulation (8 MHz P-P). A 1.0 volt P-P signal is also obtained at the output of the receiver. In many cases, additional voltage gain will be required to provide the specified levels at the points of interconnection of the local radio television link. Additional voltage gain is required if extensive equalized wire facilities are installed between the radio equipment and the interconnection point. For moderate wire extensions or where a flat gain of not over 14 dB is required, the A4 system is available. For longer wire extensions the standard A2AT video transmission system may be used.

SIGNAL-TO-NOISE RATIO

2.07 Bell System total signal-to-noise objective for 4000 miles (including the intercity portion and local loops), expressed as the ratio of composite peak-to-peak signal (picture plus sync) to RMS noise is 53 dB. This total is divided between the intercity line facility and local loop facilities as follows: the total local loop peak-to-peak signal to RMS noise is 58 dB (63 dB per local loop); the intercity line facility allowance is 55 dB. The summation of these is a total of 53 dB (Fig. 3).



TO COMBINE ANY NUMBER OF S/N RATIOS, SUBTRACT THE LOWEST VALUE OF S/N FROM ONE OF THE VALUES TO BE COMBINED AND READ FROM THE CURVE THE VALUE CORRESPONDING TO THIS DIFFERENCE. SUBTRACT THIS VALUE FROM THE LOWEST S/N. USING THIS NEW S/N, FIND THE DIFFERENCE BETWEEN IT AND ONE OF THE REMAINING S/N VALUES, AND AGAIN SUBTRACT THE APPROPRIATE VALUE OBTAINED FROM THE CURVE. CONTINUE THIS PROCESS UNTIL ALL OF THE S/N VALUES HAVE BEEN COMBINED.

Fig. 3—Curve For Combining Signal-To-Noise Ratios

2.08 Throughout this section all values for video signal-to-noise ratio will represent the ratio of peak-to-peak signal (picture plus sync) to RMS noise expressed in dB. The measurement of RF carrier-to-noise will be RMS for both carrier and noise and will also be expressed in dB.

2.09 The RF carrier-to-noise ratio rather than the video signal-to-noise ratio is more convenient to work with in laying out local radio links. The RF carrier-to-noise ratio is obtained by subtracting algebraically the value of the receiver noise output (Table B) from the received power (P_r) as determined by:

$$P_r = P_t + G_t + G_r - A_t - A_r - \alpha$$

where P_r = received power at the receiver input in dBm.

P_t = power output of the transmission into the waveguide or transmission line in dBm. The average power over the band is listed in Table B; however, since maintenance limits permit the output power to drop by 3 dB, it would be conservative to use a value about 2 dB lower than the listed values.

G_t and G_r are the transmitting and receiving antenna gains relative to a half-wave dipole in dB. These gains, relative to half-wave dipole, were computed from the equation:

$$G = 10 \log \frac{A_{eff}}{0.1305\lambda^2}$$

where A_{eff} = the effective area (2/3 the projected area for parabolic reflectors and 0.5 the aperture area for the lens antenna) and λ = the wave length, both in consistent units.

A_t and A_r are the transmission losses in the waveguide or transmission line between the antenna and the radio transmitter or receiver converter in dB.

α = free space path loss between half-wave dipoles in dB, which may be computed from the equation:

$$\alpha \text{ (dB)} = 10 \log \frac{\lambda^2}{64 d^2}$$

where λ and d are the wave length and the path length in the same units of length. For convenience, a curve of free space loss between half-wave dipoles for various path lengths at various frequencies is shown in Fig. 4.

2.10 The objective of 58 dB signal-to-noise ratio for the local link places a limit on its maximum path length. However, the depth of fading of microwave frequencies increases with path lengths and this factor tends to further limit the usable path length even though an average allowance of 4 dB for fading is included in the objective signal-to-noise ratio limits. In order to prevent the complete failure of the system during periods of deep fades, which may reach as much as 40 dB during very brief periods over long paths, it is recommended that maximum path lengths be limited normally to 25 miles regardless of the estimated signal-to-noise ratio. This maximum path length limitation is particularly applicable to full-time services where a high degree of reliability is required throughout all seasons of the year. There may, of course, be cases where temporary or one time services are provided when it may be desirable to exceed these maximum path length limitations. In these cases judgment may dictate considerably longer paths, provided that on test a satisfactory signal can be obtained.

3. RADIO EQUIPMENT INSTALLATION REQUIREMENTS

SITING

3.01 Radio transmitters and receivers should be located so that they are as close as possible to the service or interconnection point at the same time that the antennas have an unobstructed line-of-sight transmission path with suitable clearance over all intervening terrain and obstructions. Station locations must be chosen so as to avoid interference with other microwave stations operating on or near the same frequency. Shelter for equipment and personnel is desirable and it may be required for some of the equipment.

3.02 A source of dependable ac power is required and it may be desirable to back up a commercial ac supply with emergency engine-driven ac power. In some cases, manual or automatic supply voltage adjustment equipment such as Variac or Stabiline units may be required to provide proper supply voltage. Wire facilities to the station location will usually be required for order wires, for alarm leads, and possibly for remote control features to turn the equipment on or off.

3.03 In general, no hazard to aviation will be created by locating the radio equipment on roof tops unless the building is in the immediate vicinity of airports or airways and the radio equipment increases the existing height of the building by more than 20 feet. Antenna supporting structures require obstruction lighting and painting in accordance with Part 17 of the FCC rules and regulations governing antennas and antenna

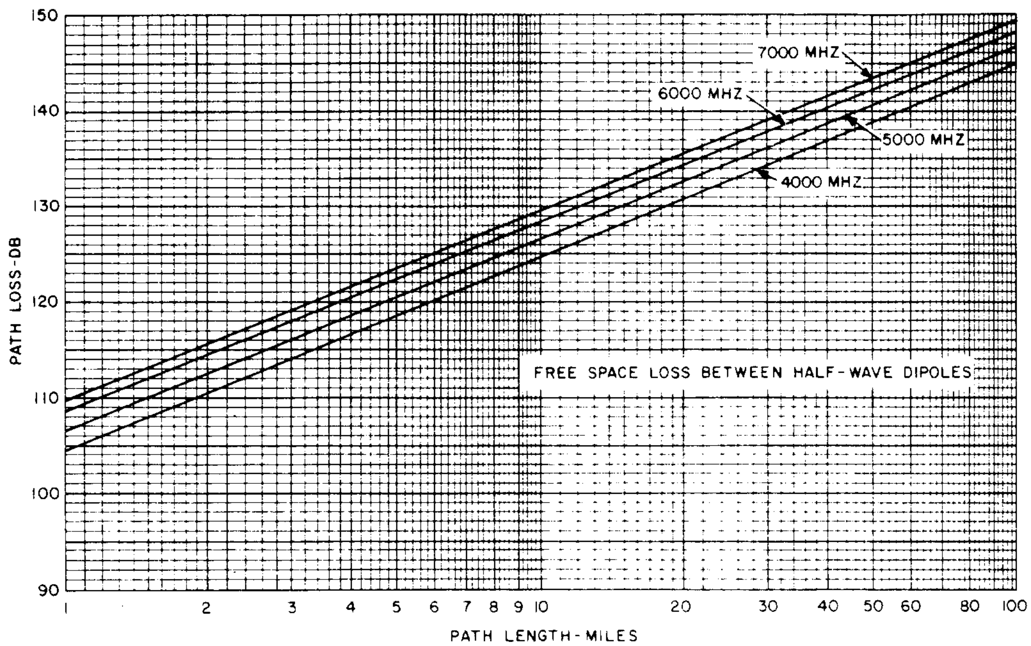


Fig. 4—Free Space Loss Between Half-Wave Dipoles

supporting structures and the latest specifications of the Civil Aeronautics Administration regarding lighting and marking obstructions to air navigation.

Note: A type of signal light which has been particularly suitable at night is the No. 4535 spotlight manufactured by both General Electric and Westinghouse. It is a sealed-beam type of light prefocused for nearly parallel light and is rated at 40 watts, 6-8 volts. It may be equipped with a flashing device to permit positive identification. When viewed at distances of around 30 miles, the light appears reddish due to the filtering action of atmospheric haze.

TRANSMISSION PATH

3.04 A proposed transmission path will usually be checked by reference to a topographical map to be sure that the path is free of obstructions or has adequate clearance over any obstructions. In making this check, allowance must be made for buildings, trees, water tanks, or other obstacles near or in the transmission path. The availability of maps and methods of plotting path profiles is covered in detail in Section 940-300-103, Microwave Radio Siting Considerations.

3.05 Actual visibility over a path from one station to the other will prove a line-of-sight condition, although it will not provide any information about the actual clearances over obstructions. In daylight a heliograph signal is visible over long paths through normal atmospheric haze. At night a signal lamp may be used to check intervisibility provided care is taken to ensure positive identification of the signal light.

3.06 For many paths, particularly the shorter ones, it may be possible to determine optically that satisfactory clearance exists. However, on questionable paths and especially on longer paths where large buildings or groves of trees are in or adjacent to the line-of-sight path, it is advisable to make some form of test radio transmission over the selected path. If the proposed locations are on existing buildings, the path tests can be made using the proposed radio equipment. If, however, an antenna supporting structure is to be erected at the proposed site, then the path testing can be done with equipment described in Section 940-310-104. In any case, regardless of how perfect the path may appear on observation or casual check, path measurements will give added assurance as to its suitability.

FRESNEL ZONE CLEARANCE

3.07 In order to obtain free space transmission over a radio path, it is necessary to provide sufficient clearance over all obstructions including terrain contours. The minimum transmission loss occurs when the clearance at any point equals the first Fresnel zone. The first zone is bounded by points at which the reflected transmission path from transmitter to receiver is greater by one-half wave length than the direct path as indicated in Fig. 5.

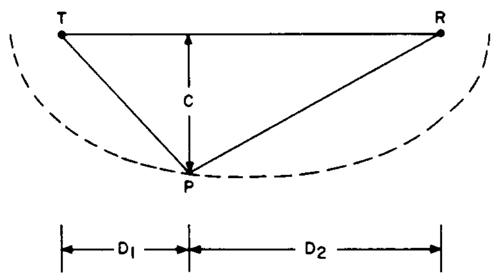


Fig. 5—First Fresnel Zone Clearance

The solid line TPR (Fig. 5) is a path longer than the direct path TR by one-half wave length, and C represents first Fresnel zone clearance at point P. The dashed line is the locus of points having first Fresnel zone clearance. This clearance, C, at any point may be computed from the following equation:

$$C_{(feet)} = 131.5\sqrt{\frac{\lambda D_1\ D_2}{D_1 + D_2}}$$

where D_1 and D_2 are the distances from the ends of the path to the point under consideration in miles, and λ is the wave length in meters. The magnitude of the first Fresnel zone clearance is shown on the curve in Fig. 6 for 4000 MHz and may be converted to any other frequency, F, by multiplying by the factor:

$$\sqrt{\frac{4000}{F\ MHz}}$$

3.08 The effect of clearance on microwave transmission is shown in Fig. 7 for the two extreme cases: Curve A for a rough transmission path with a "knife edge" obstruction in which reflection plays no part, and Curve B a perfectly smooth spherical surface where strong ground reflections play a part. It will be seen that for the rough path (line of sight), just grazing over the knife edge obstruction, the signal field will be 6 dB below the free space field. The maximum field (1 dB above free space field) is not obtained until there is a clearance of approximately first Fresnel zone. In the case of the smooth spherical surface, the obstruction is due to the bulge caused by the earth's curvature, and the path which just grazes the earth's surface is from 12 to 20 dB below the free space field (depending on the ratio of the antenna heights) as a result of the reflected component. The crosshatched area of this curve from near line of sight to well beyond the horizon represents the variation due to different antenna heights at each end of the path. Two antennas of equal height would lie along the right-hand boundary of the curve while the high-to-low antenna case would lie along the left-hand boundary. At first Fresnel zone clearance, in the smooth earth case, the signal field is about 6 dB higher than the free space field because the reflected wave undergoes a 180-degree phase shift on reflection but travels one-half wave length farther so that it is in phase with the direct wave. With greater clearance, the path length of the reflected wave will increase and at some point the two waves will be in phase opposition.

3.09 If the transmission path were stable, it would be possible to select antenna heights so as to work on the peak of the characteristics where the widest maximum occurs at first zone clearance. But the effect of atmospheric refraction varies the effective clearance and results in fading which is more serious as the reflection coefficient becomes higher. The following experimental facts have been observed with respect to fading:

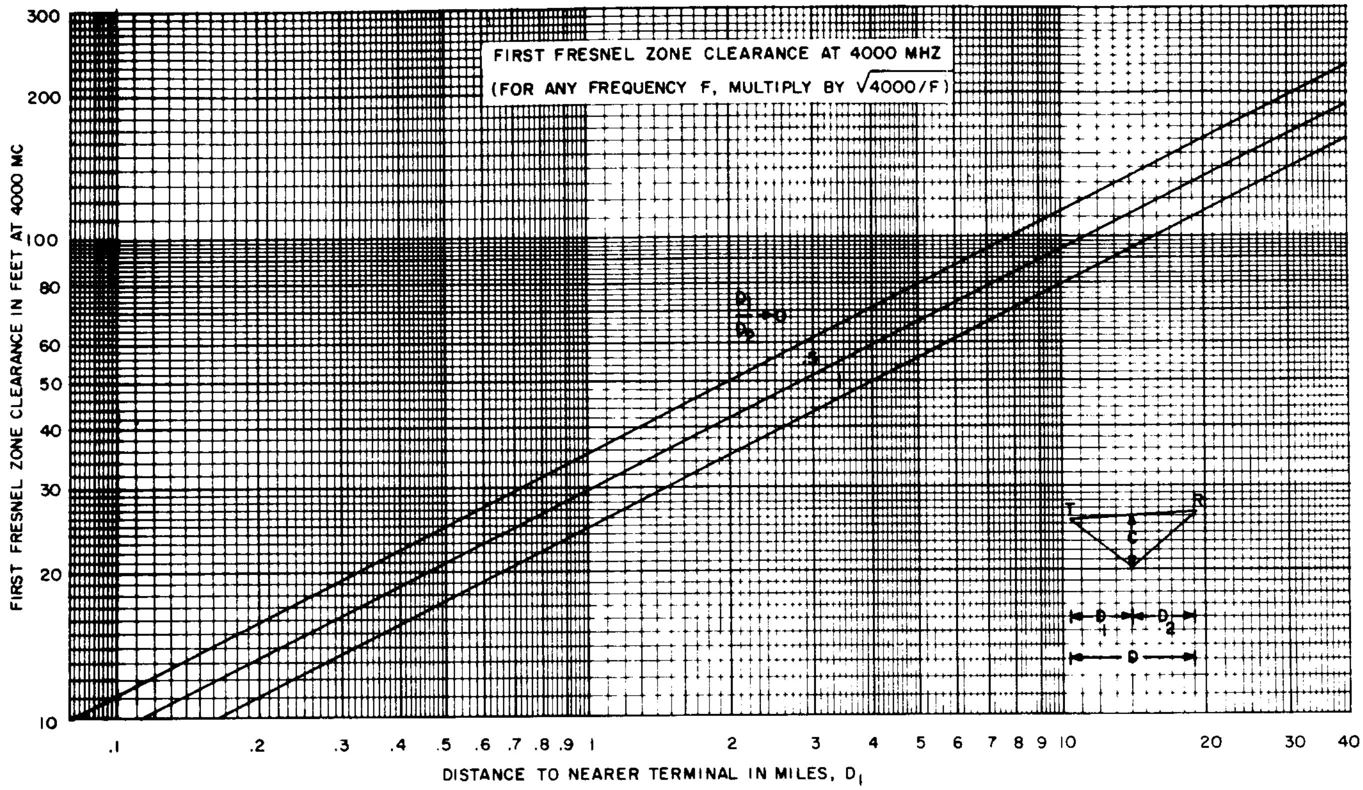


Fig. 6—First Fresnel Zone Clearance at 4000 MHz

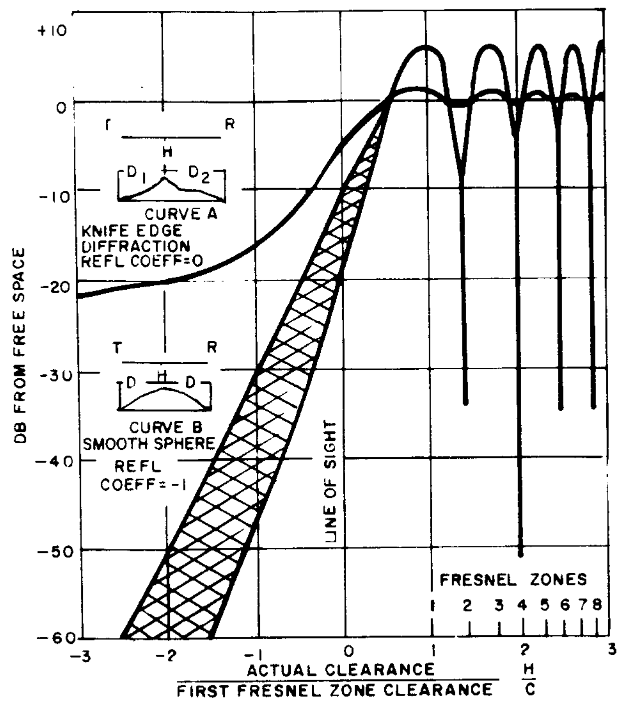


Fig. 7—Effect of Clearance on Radio Transmission

(a) Fading is greater at night than during the day, in warm and humid seasons than in cool and dry seasons, over water or smooth terrain than over rough ground, and is different in different parts of the country.

(b) Ground reflections are usually negligible in rough country, in smooth terrain with numerous trees, and in urban areas with numerous buildings of varying heights.

(c) On paths having strong ground reflections fading can be minimized by using one high and one low antenna (mountain to valley path).

3.10 Based on these facts and other factors which affect fading, such as change in dielectric constant with temperature, humidity and low-lying ground fog, the following empirical rules for path clearances have been developed:

(a) For Paths with High Reflection Coefficients: Paths over water or in smooth barren country and in regions where dense ground fogs (as constrasted with light early morning fogs) are common:

$$\text{Clearance} \quad H = \frac{C}{2} + \frac{D_1 D_2}{2.5}$$

where C = first Fresnal zone clearance in feet and D_1 and D_2 are the distance in miles from the point in question to the terminals.

(b) For Paths with Low or Negligible Reflection Coefficients: Paths over irregular or wooded terrain or urban areas with numerous buildings of varying heights:

$$\text{Clearance} \quad H = \frac{C}{2} + \frac{D_1 D_2}{5}$$

3.11 While rule 3.10 (b) is considered conservative and would be desirable to use in the case of local radio television links in urban areas, cases will arise where less than this clearance may safely be used in moderately built-up urban areas. For short paths of not over 10 miles in urban areas it will probably be satisfactory to reduce the clearance to a just grazing path where greater clearance would be unduly expensive or otherwise impracticable to obtain. The penalty for a grazing path is about 6 dB, or about the same as a path twice as long with adequate clearance.

INTERFERENCE

3.12 It is important to consider the possibilities of interference to a proposed system from various sources as well as interference to existing systems by the proposed system. The magnitude of microwave interference from a disturbing carrier to the disturbed carrier depends upon a number of factors such as antenna discrimination characteristics, relative distance and angle between the disturbing and disturbed carriers, discrimination in the IF amplifiers and RF filters, if used, and power output and frequency difference between the carriers. In addition to microwave interference between systems, multilink systems may be subject to intrasystem interference such as over-reach interference from a transmitter into a receiver in a later link operating on the same frequency. These microwave interference considerations and a method of computation to be used in interference studies are covered in Section 940-330-100. Where feasible, actual tests will provide more accurate information on expected interference.

3.13 Interference may be encountered if the microwave transmitter is located in the immediate vicinity of FM transmitters operating in the VHF range. Such interference may occur in two ways:

(a) Two or more FM transmitters in the immediate vicinity of a microwave transmitter may, because of intermodulation in some nonlinear element, introduce interference as "break through" into the video wiring to the microwave transmitter producing a beat note in the video amplifier of the microwave transmitter. To suppress this interference, a 523A filter which attenuates frequencies above 35 MHz should be inserted at the input jack of the video amplifier of the microwave transmitter.

Note: The 523A filter was designed with a connector to permit plugging into the video jack of a TD-2 FM terminal. When used with other equipments it will be necessary to provide an adapter cord with plugs suitable to accommodate the input jack of the particular transmitter. In any case, the filter should be inserted as close to the video amplifier input as possible.

(b) If a microwave receiver is operating in strong FM transmitter radiation fields, interference may be experienced due to a "break through" into the IF amplifier. Microwave receivers are likely to be sensitive to RF radiation in various portions of the TV or FM radio frequency spectrum. Additional shielding may be required to prevent this interference. The removal of multiplex ground connections which may cause coupling, and the addition of RF filters to the ac power lines is often useful in reducing the RF interference.

3.14 Interference may also be encountered when the microwave equipment is located in strong AM radiation fields. The AM broadcast band is 550-1600 kHz, and interference from this source falls directly in the video band and cannot be filtered out without removing some of the video information.

Note: In one extreme case of this type of interference it was necessary to install the microwave radio in a completely shielded room and apply interference filters to the ac power feed lines.

3.15 An image frequency will cause interference at the desired frequency because the opposite sideband products of the beating oscillator and the image frequency will fall in the IF passband of the receiver. Perhaps the greatest trouble from image frequency interference will occur in the case of multilink and multichannel installations. In such installations, care must be taken to make sure that a transmitter carrier does not fall in the image band of a receiver.

Note: An image frequency is one that is twice the receiver intermediate frequency away from the carrier frequency in the same direction as the frequency of the beating oscillator.

3.16 Another type of interference that may be encountered is caused by reflections from buildings, hills, or other large objects. These reflections are delayed from the direct transmission and cause interference at the receiving terminal. The principal defense against such interference is to raise the antenna or move it about locally over short distances until a point is found where the reflected signal is eliminated by the directivity of the antenna. In an extreme case, if the reflected signal is very strong and cannot be eliminated by this method, it may be possible to operate satisfactorily by pointing the antennas along the path of the reflected signal rather than the direct signal. Except for extreme cases, this latter procedure is not recommended since it is generally better to choose another location where the direct signal is used and reflections are not troublesome.

4. TELEVISION CONSIDERATIONS

Transmission Objectives

4.01 Local radio transmission systems are expected to carry an NTSC color or monochrome signal from the pickup point to the destination with a minimum of distortion at the required levels. Limits on distortion are given in Part 5. The manufacturer's manual for each piece of equipment includes tests and adjustments for aligning the radio equipment. These tests should be performed on a periodic basis determined by use or the manufacturer's recommendations. The tests outlined in Part 5 check baseband-to-baseband transmission without regard to the particular radio equipment. Before describing the test procedures, the following parameters are defined.

A. Gain-versus-Frequency Response

4.02 In order to avoid objectionable degradation of the television picture it is desirable to minimize variations in the amplitude-versus-frequency response in the video band up to about 4.5 MHz. On the basis of subjective tests, the objective for amplitude-versus-frequency response for local loop facilities is as shown in Fig. 8. In practice, external equalization may have to be provided to meet these objectives.

4.03 Excessive baseband response in the low-frequency region below about 500 kHz will cause smearing or streaking in the picture. At the high end (1 to 4 MHz) excessive roll-off will cause loss of picture resolution. In addition, for NTSC color transmission, the response of the color subcarrier (3.6 MHz) is required to be equal to the response at 300 kHz.

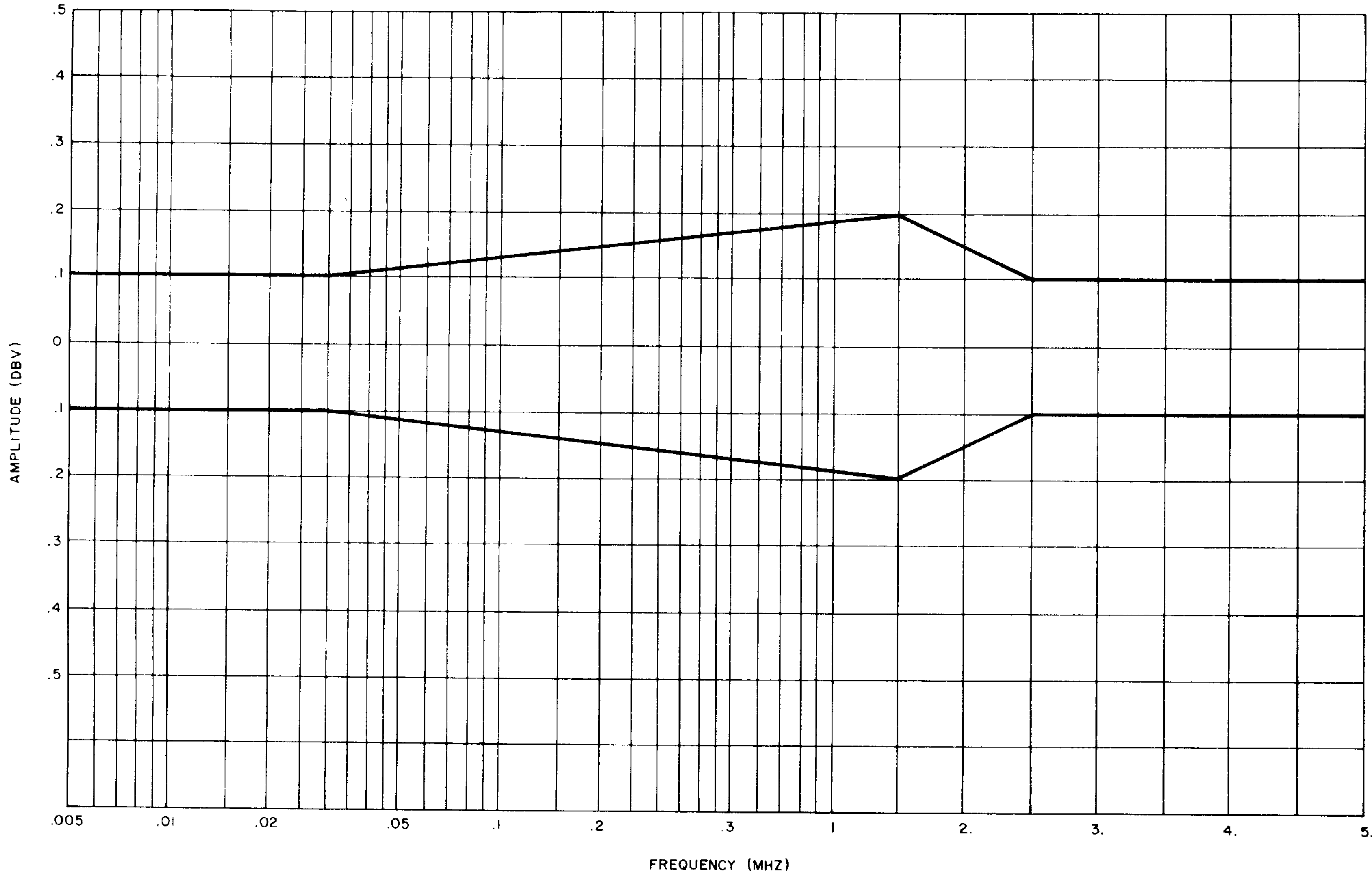


Fig. 8—Amplitude-VS-Frequency Response for Local Loops

B. Differential Gain

4.04 Differential gain is the change in gain of the chrominance signal as the luminance signal varies in amplitude. This characteristic has the effect of degrading the saturation quality (color richness) of the picture. For local microwave facilities, the differential gain with respect to the sync burst is a value less than ±0.5 dB at 50% average picture level (APL); for local wire circuits it is less than ±0.2 dB.

C. Differential Phase

4.05 Differential phase is the change in phase of the chrominance signal as the luminance signal varies in amplitude. This impairment affects the hue quality of the picture. The objective for differential phase is a value less than ±1 degree at 50% average picture level for microwave, and less than ±0.5 degree for local wire circuits.

D. Random Noise

4.06 Random noise is a general term applied to noise generated due to the thermal characteristics of electronic components. Random noise consists of a wide band of indeterminate frequencies at constant amplitude over the band of interest. The shape of the noise characteristic is determined by the shape of the transmission profile of the network. The high frequency components of random noise are more objectionable for color than for monochrome. Section 318-725-512 covers detailed aspects of noise and noise shapes.

TIME DOMAIN MEASUREMENTS

4.07 The video waveform is mostly nonsinusoidal. Recently developed analytical techniques for testing video systems use test waveforms which relate directly to the picture quality. These waveforms can relate, for example, to smear or streaking (low frequency impairments) or to gain and delay distortion which may be observed and corrected in real time.

4.08 The time domain can be broken down into three regions to define distortion in various sections of the transmission frequency band.

(a) Short Time Distortion (0.125 μs to 1.0 μs). Distortion in the high frequency range (500 kHz to 4 MHz) affects picture sharpness and resolution. These distortions are in the short time range and are tested by sine-squared pulses or rise time of the bar signal. Overshoots and ringing occur on the pulse as a result of this distortion. The relative amplitude of the sine-squared pulse with respect to a bar also gives important information about the cutoff of the system.

(b) Line Time Distortion (1-64 μs). This is distortion about the line frequency and its harmonics. This type of distortion causes streaking in a window-type picture.

(c) Field Time Distortion (50 μs to 16 ms). This is distortion at the field rate and causes shading in the vertical direction.

4.09 Time domain testing and some frequency domain testing is done during the vertical blanking interval of the transmitted television signal. Vertical Interval Test Signals (VITS) are inserted during the vertical blanked time of the television picture for measuring the transmission characteristics of the video system. The information provided by VITS relates directly to the subjective quality of the picture.

THEATER TELEVISION

4.10 Transmission objectives for local links engineered for theater television service are generally the same as for standard broadcast service. It is advisable to determine the type of equipment used by the customer to verify compatibility with the local link.

4.11 Local video links for theater television or service other than standard broadcast require suitable FCC authorization. Methods for obtaining such authorization are covered in AT&T general letters Topical Index Codes 1S1.8 and 1S4.1.

5. PERFORMANCE VERIFICATION

TEST EQUIPMENT

5.01 Transmission performance of television links must be verified before links are turned over to the customer. Table C lists test equipment recommended for verifying system performance baseband-to-baseband.

TABLE C

TEST EQUIPMENT

J64061C (61C) Signal Generator or Hewlett-Packard Model 653A Oscillator
J64005A (5A) Noise Weighting Set
400D Hewlett-Packard Vacuum Tube Voltmeter
KS-15512, L5A Oscilloscope or KS19763L1A Waveform Oscilloscope
Model 3508-B1 Telechrome Test Signal Generator
Model 1551 Riker Video Test Signal Generator
J64070B (70B) Power Meter
75-Ohm Termination
J64047A Transmission Measuring System
J64009A Video Distortion Meter

BENCH TESTS

5.02 In the case of radio equipment, tests specified in the manufacturer's manual should be performed before the equipment is installed in the field. Generally, equipment meter readings are good indications of equipment performance. Tests should include the following:

A. Transmitter

(1) Measure transmitter operating frequency with a frequency counter and the transmitter operating in the CW mode.

(2) Measure transmitter power output with a microwave wattmeter.

B. Receiver

(1) Adjust in accordance with manufacturer's instructions; note limiter current.

System Field Tests

5.03 Point-to-point transmission tests include initial line up of a radio hop and verification of transmission parameters (Table A). Abbreviated procedures for these tests follow.

A. Gain-versus-Frequency Response

5.04 Gain-versus-frequency response tests are performed to characterize the transmission profile of a radio channel over the operating bandwidth. On this test, a 653A oscillator is used to insert a series of test signals at the transmitter while a J64070B power meter measures the output signal at the receiver. Fig. 9 illustrates the test layout and Fig. 10 is a sample form used to record test results.

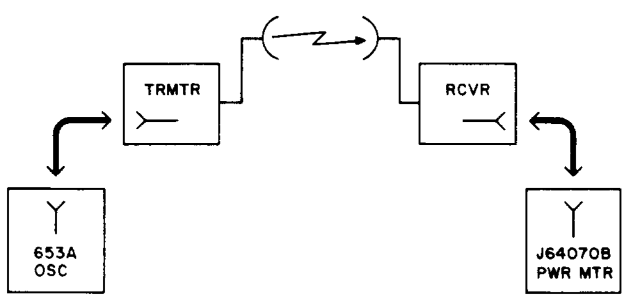


Fig. 9—Test Layout, Point-To-Point Gain Frequency Measurement

Note: The normal baseband input signal level to the transmitting equipment is 0 dBV; however, this value should be verified with the manufacturer's manual.

GAIN-FREQUENCY RESPONSE

TRMTR INPUT FREQ AT 0 DBV	RCVR OUTPUT (DBV)
60 Hz	
5 kHz	
10 kHz	
25 kHz	
50 kHz	
100 kHz	
200 kHz	
300 kHz (Ref)	
400 kHz	
700 kHz	
1.5 MHz	
2.0 MHz	
2.5 MHz	
3.0 MHz	
3.6 MHz	
4.3 MHz	
5.0 MHz	
6.0 MHz	
7.0 MHz	
8.0 MHz	

Fig. 10—Form for Gain Frequency Response Measurements

5.05 On this test, the AFC is disabled and discriminator current adjusted manually to the value normally obtained with a 10-kHz signal and AFC enabled. This value should be kept constant throughout the frequency run.

5.06 The procedure for performing gain-frequency response tests of a single hop may be summarized as follows:

(1) Set up the 653A oscillator and the 70B power meter (Fig. 9) using 300 kHz at 0 dBV as a reference.

(2) With the input level held constant at the transmitter, record the output of the receiver at the frequencies specified in Fig. 10.

(3) Record the output values and compare the values to 5 MHz with the values in Fig. 8.

B. 60-Hz Square Wave Response

5.07 Phase distortion at 60 Hz and its harmonics tilts the top of a 60-Hz square wave. Consequently, the percentage of tilt is a measure of gain flatness and phase linearity at low frequencies. The maximum permissible tilt of a 60-Hz square wave is 2.0% and may be attained through equalization.

5.08 Tilt may be measured with the KS19763L1A oscilloscope. The 653A oscillator develops the test signal. A general test procedure follows:

(1) Set up test layout as shown in Fig. 11.

(2) At the oscilloscope, adjust the trace for 100 IRE divisions peak-to-peak excluding synchronization.

Note: Each IRE division on the graticule equals 1.0% of the total amplitude.

(3) Measure tilt on the top of the square wave (Fig. 11).

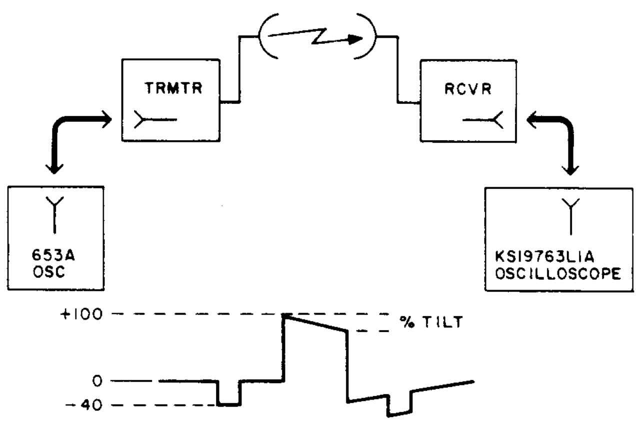


Fig. 11—Test Layout, 60 Hz Square Wave Frequency Response Measurement

C. Random Noise

5.09 Random noise, also called first circuit noise, introduced at baseband is due primarily to the receiver front-end circuits. This noise is wideband in nature and may be measured as follows:

(1) Set up test layout shown in Fig. 12.

(2) On the J64005A noise weighting set (Section 103-734-100), adjust the NOISE control to HIGH FREQ and the WEIGHTING control to COLOR.

(3) At the 5A noise set, connect the H-P 400D VTVM and measure the noise level.

Requirement: Noise level should not exceed −58 dBm.

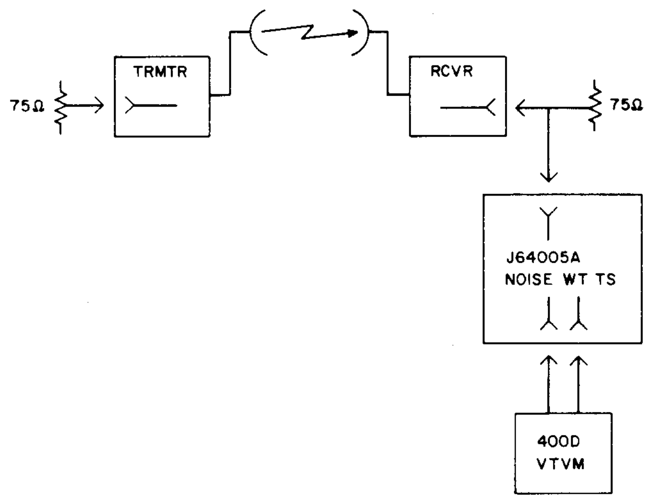


Fig. 12—Test Layout, Random Noise Measurement

D. Multiburst and Window

5.10 Multiburst and window test signals provide quick visual means for determining frequency distortion and smear of a video signal. These test signals are also used by the customer to assess the overall frequency response of a video channel.

5.11 Multiburst test signals consist of a white flag and six bursts of sine-wave frequencies at 0.5 MHz, 1.5 MHz, 2.0 MHz, 3.0 MHz, 3.6 MHz, and 4.2 MHz (Fig. 13). These frequencies are transmitted at 92.5 IRE units (100-7.5) and a drop in level compared to the flag signal indicates a frequency roll off. The white flag provides white level reference.

Note: Most broadcasters are now transmitting half level multiburst test signals (from 25 to 75 IRE) using 50 IRE units peak-to-peak.

5.12 A general test procedure for measuring sync compression and smear using these signals follows:

(1) Condition the video waveform generator (Telechrome Test Signal Generator Model 3508-B1) for a window signal at 0 dBV peak-to-peak.

(2) Set up the test layout shown in Fig. 13.

(3) Observe that the front and back porches of the sync signal are on the 0 IRE scale division line and that the top of the white flag signal is on the 100 IRE line.

(4) Observe that the bottom of the sync pulse is on the −40 IRE scale division line. Sync compression exists if the sync pulse is not within 1 IRE unit of the −40 mark.

(5) Observe that the transmitted signal has no distortion. Smear distortion in the window signal should be observed at the line rate.

(6) Measure the tilt (Fig. 11).

Requirement: Tilt should not exceed 1 IRE unit.

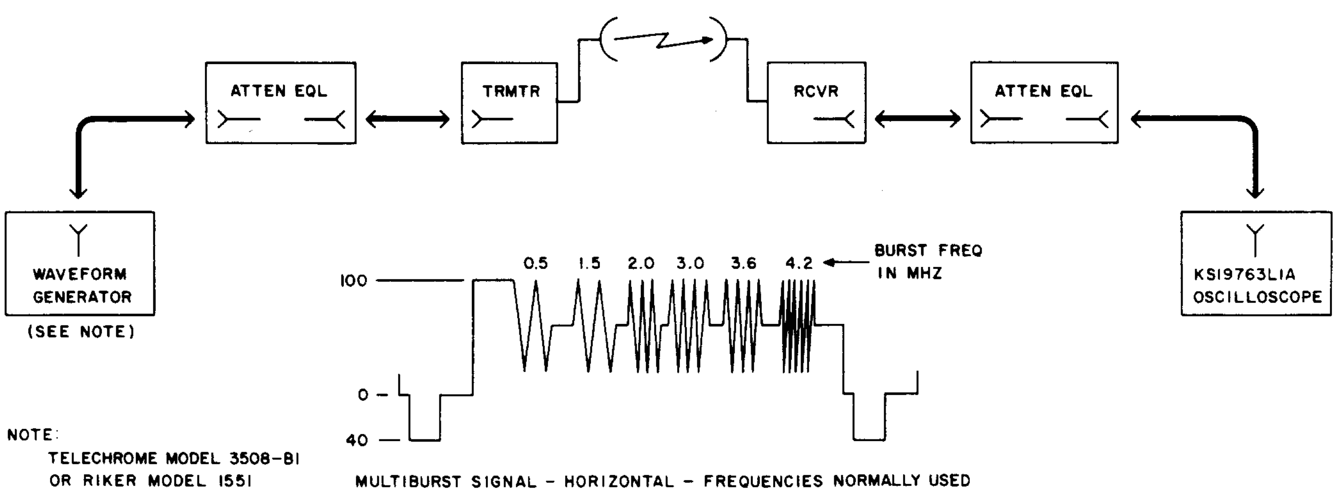


Fig. 13—Test Layout—Multiburst and Window Signal Measurement

E. Vertical Interval Test Signals

5.13 Vertical Interval Test Signals (VITS) are test signals used for in-service monitoring of video transmission quality. These signals are broadcast during the vertical blanking interval between fields and are keyed into designated lines of both fields.

> ***Note:*** CCIR recommendation 473, Annex II, designates lines 17 & 18, and it is expected that this will be a common arrangement, especially for international video service.

5.14 The general form of VITS is illustrated in Fig. 14. Fig. 14A illustrates a line bar, a sine squared pulse, a 12.5 T chrominance pulse, and a 5-riser stairstep.

5.15 Fig. 14B illustrates other test waveforms used: a white flag, multiburst frequencies, and a three-level chrominance signal.

5.16 A detailed description and analysis of VITS signals are contained in NTC (Network Television Committee) report number 7. This document will be issued as a BSP.

6. REFERENCES

Bell System Practices

SECTION	SUBJECT
318-210-100	A2AT Video Transmission System
318-220-100	A4 Video Transmission System
318-220-501	A4 Video Transmission System Lineup
318-725-512	Noise Measurements and Objectives for Video Circuits
857-412-101	A2AT Video Transmission System Application Engineering
857-413-101	A4 Video Transmission System Application Engineering
940-300-103	Microwave Radio Siting Considerations
940-310-104	Microwave Radio Propagation Path Testing
940-330-100	Microwave Radio Interference

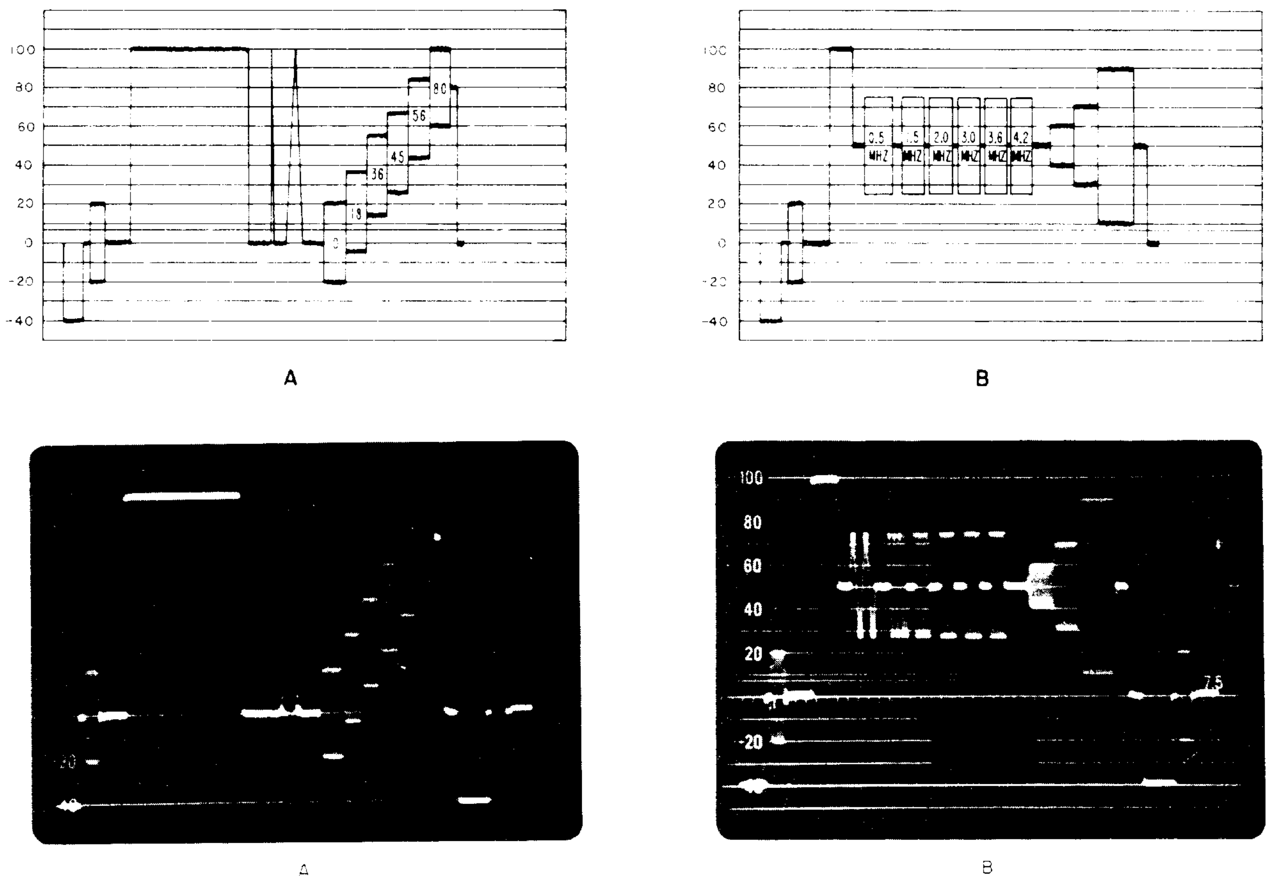


Fig. 14—Proposed Vertical Interval Test Signals