RADIO ENGINEERING
POINT-TO-POINT RADIO
EQUIPMENT CONSIDERATIONS

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1. GENERAL

1.01 When contemplating the design of point-to-point radio systems, it will be found convenient to divide consideration between factors concerning the transmission characteristics of the systems and those factors which are identified principally with the equipment. Other sections of the Bell System Practices discuss the transmission aspects of system design and provide detailed information concerning specific equipment arrangements. It is the purpose of this section to discuss the characteristics of the radio and terminal equipment which are required for satisfactory service and to give general information concerning the other major factors which must be considered in the design of any complete installation.

1.02 Information in this section was formerly covered in Section 940-102-102.

2. EQUIPMENT

A. General

2.01 Radio equipments which will most frequently be used for very light route point-to-point service will be, as was indicated in Section 940-250-100, of the general type designed for mobile radio base station applications. Where the transmission of more than one telephone channel on a single radio frequency is desirable, these radio units must be modified to provide sufficient bandwidth to permit their use with multiplex equipment (usually of the type designed for wire service). Some makers of radio equipment are able to supply modified units which will permit the transmission of two or three telephone channels. The familiarity of Plant people in most operating areas with both the wire carrier equipment and mobile radio units will usually result in some maintenance advantages. The integration of these radio and multiplex units into a system may present certain problems which, in general, stem from the characteristics of the radio and channelizing equipment in combination. Since this is true, and since the equipment available for such applications will vary in type from time to time, this section will discuss individually the principal items of equipment making up a system. The discussion will be aimed at pointing out the factors which must be considered in selecting the separate units and at providing the information necessary for their integration into a system.

B. Radio Units

2.02 Radio equipment used in very light route applications will usually be of a type designed for mobile service base station use. The 150-megahertz transmitters will most often be nominal 50- to 60-watt units (+47 to +48 dBm output) although in some cases transmission requirements (path loss and site noise) may make desirable the use of higher powered transmitters or of low power transmitters equipped with amplifiers. Such increased power will usually be used after other factors including increased antenna height, increased antenna gain, and radio equipment relocation have been fully weighed. The 450-megahertz equipment will most frequently be of nominal 10- to 40-watt output (+40 to +46 dBm) with amplifiers provided as required by a particular situation.

2.03 Radio equipment should be capable of continuous operation. It should be capable of meeting or exceeding FCC requirements regarding frequency stability and spurious emissions. Receiver selectivity characteristics should allow operation of a particular system without interference from other systems or services. Total harmonic distortion, transmitter and receiver, based on single frequency measurements for equipment to be used in single-channel service should not exceed 5 percent at a deviation 6 dB below full modulation (usually ±15 kHz).

2.04 Transmitters to be used in multichannel applications, along with their companion receivers, will usually be factory-modified to provide a baseband sufficiently broad to accommodate a limited number of multiplexed channels. In addition to broadening of the baseband, the modification may provide for:

(a) Removal of peak deviation limiters.

(b) Other necessary measures to provide satisfactory distortion performance.

(c) Modification of the modulator to a frequency-modulated characteristic.

The practical limit to which a radio equipment baseband can be broadened is dictated by equipment design characteristics as they affect frequency response and distortion. It is also influenced by the channel noise performance to be obtained. Since frequency assignments in the mobile services assume a maximum modulation deviation of ±15 kilohertz, the highest frequency to be transmitted within the baseband can not exceed about 11 kilohertz with reasonable top channel noise performance.

2.05 Where it is necessary to determine the suitability of a particular equipment for a multichannel application, the factors which must be evaluated include not only the width of the baseband, but also the slope of the baseband characteristic lying within the spectrum occupied by any derived channel. It is not feasible to assign firm requirements for these quantities since their relative importance depends upon the frequency allocation and other characteristics of the multiplex equipment chosen as well as upon the frequency response requirement of the derived channel. The approximate relationship between baseband characteristics and resulting channel characteristics may be seen by reference to Fig. 1 where the relative responses and losses of the principal system components are shown with their combined effect on channel frequency characteristics. Examination of the response of the three individual channels shows:

(a) In the voice-frequency channel, the lower frequency limit is established by the radio equipment "roll off" while the upper limit is dependent upon the line filter cutoff. Slope within the channel depends largely upon the radio baseband characteristic.

(b) In any carrier channel, upper and lower frequency limits are established by the bandpass filter associated with the channel terminal modified by the carrier line filter characteristic. Slope within the channel will depend upon the slope inherent to the carrier channel terminal, upon the radio baseband characteristic, and upon the choice of sideband (upper or lower) for carrier channel transmission.

2.06 Subsequent discussion will show that the use of compandors is essential in VHF multichannel radio systems using mobile radio base station equipment if satisfactory intermodulation noise performance is to be obtained. Under these conditions, satisfactory performance is obtainable if the radio equipment is capable of meeting single-frequency distortion objectives of 5 percent at a level 6 dB below that causing full transmitter modulation and not in excess of 20 percent at full modulation (customarily ±15 kilohertz). If systems were contemplated which did not include compandors, a far more rigorous distortion requirement would apply in order to limit intermodulation noise to the objective of 34 dBa at the 0TLP for a small percentage of the total time. This objective would be met by equipment having total distortion not in excess of 1 percent (−40 dB referred to the fundamental). Distortion values quoted apply to the overall radio system, not to transmitter or receiver separately.

C. Multiplex Equipment

Type of Equipment

2.07 Multiplex systems used to provide channel multiplexing in VHF light route applications will usually be, as was indicated earlier, those designed primarily for wire transmission purposes. The relatively narrow baseband available in the radio equipment dictates that the multiplex equipment should employ single sideband transmission in the interest of spectrum economy. Single sideband multiplex systems may operate with or without carrier suppression. Single sideband suppressed carrier systems which are available include the Western Electric type H and comparable types of outside manufacture. Systems such as these, having channel frequency assignments which will permit operation of a voice-frequency channel plus two derived channels in the band from 300 Hz to about 11 kilohertz, will provide a practical arrangement for use with available radio equipment. Western Electric type OA carrier is typical of single sideband systems in which carrier is transmitted. From the standpoint of system loading, the use of suppressed carrier units is advantageous, permitting the system load to be adjusted to accommodate only the signal needed to convey the desired intelligence rather than to transmit the desired information plus carriers which convey no intelligence. The effect of this basic difference might vary from zero in the case of a single channel to perhaps 6 to 10 dB in the case of the 2- or 3-channel systems considered in this section. A 4-channel OA system requires a baseband of 18 kilohertz and consequently, the use of modified mobile radio type equipment having a maximum deviation of ±15 kilohertz to obtain four channels is not practicable. In order to provide such a baseband, the radio equipment will normally require a minimum deviation of ±30 kilohertz if satisfactory noise performance is to be obtained.* Because of these factors, this section will consider that only single sideband suppressed

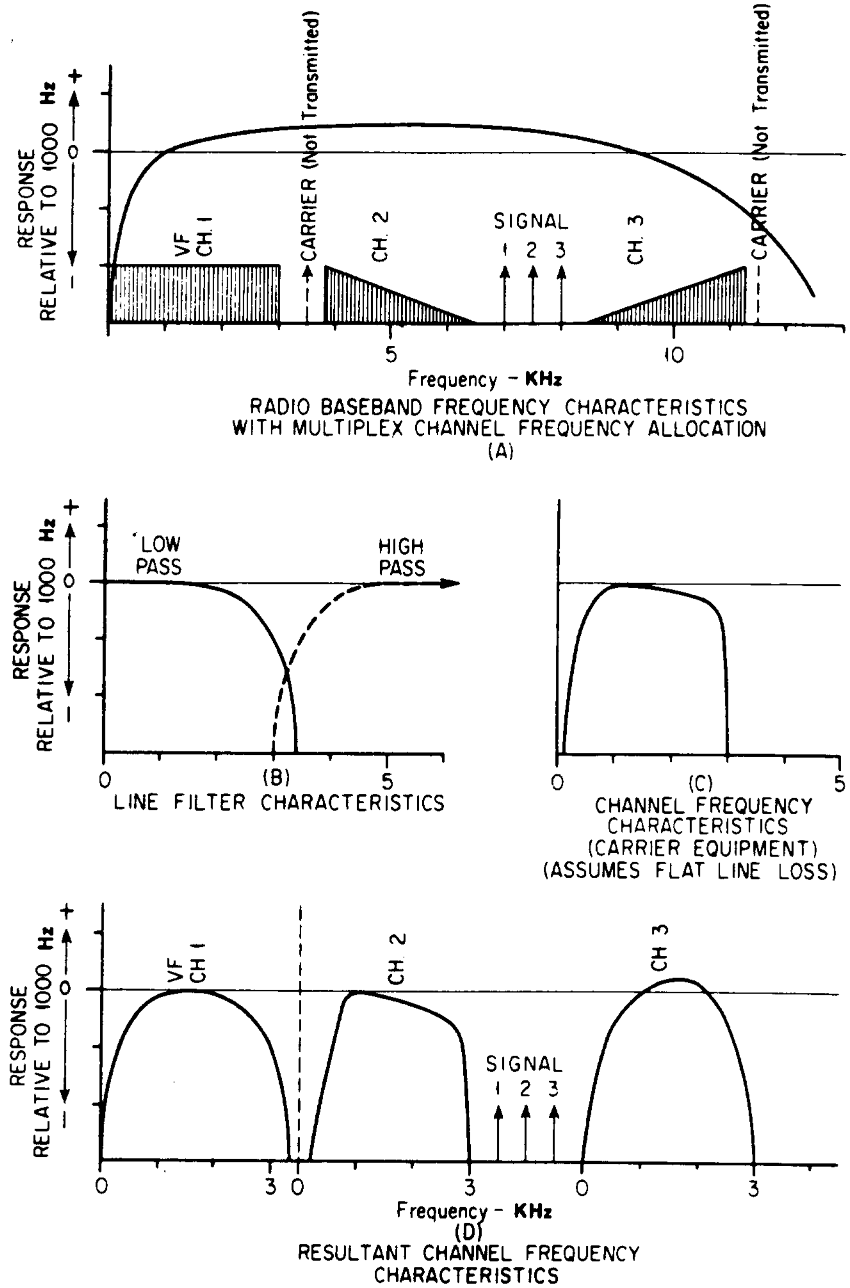

Fig. 1—Relation between Radio Baseband, Carrier Channel Characteristics, and Frequency Characteristics of Derived Channels

carrier multiplex systems will be used for VHF applications. However, if information concerning the use of other types is desired, some of the information in Bell System Practice, Section 940-320-100 may be applicable.

* Use of systems having peak frequency deviation in excess of ±15 kilohertz should be investigated from a license viewpoint before concrete plans for their use are formulated.

2.08 Carrier systems may be arranged for either 2- or 4-wire operation of the voice-frequency drop. Since most multichannel VHF systems will use compandors in connection with the voice-frequency and carrier-derived channels, a 4-wire connection of the channel equipment to the compandor is necessary. Most compandor units will operate at normal 4-wire levels but in any case, the choice of a particular multiplex system should be made bearing in mind the need for compatibility with the compandor.

2.09 The availability of the Western Electric H1 carrier system in most operating areas along with its favorable frequency allocation may make its use for radio multiplex desirable in many situations, especially if dial signaling is not required or if SF or other signaling equipment can be used in conjunction with the H1 units. Bell System Practice, Section AA266.017 describes the modification of the basic H1 carrier panel to permit 4-wire operation of the high-frequency line. Where H1 systems are to be operated on a radio system, they should be arranged as for 4-wire operation of the high-frequency lines.

D. Channel Signaling Arrangements

2.10 Signaling for channels transmitted by multiplexed VHF radio systems will be provided through the use of tone signaling arrangements. Physically, these may be part of the channel multiplex unit or they may be separate panels, depending upon the particular type of multiplex equipment. Signaling may be "in band" employing one or more audio frequency tones transmitted between the voice-frequency drops of the telephone channels or it may be "out of band" employing separate carrier frequencies for each signaling channel. "In band" signaling normally operates on a "tone off for busy" basis while "out of band" installations may be either "tone on" or "tone off".† In either case, the signaling facility represents an additional transmission load factor and as such, must be considered in establishing system operating conditions.

† "Tone off for busy" arrangements are preferred in radio applications because the radio system is not required to transmit both talker and signaling power for any channel simultaneously. Further, since removal of tone creates a "busy channel" condition, the system will, when arranged in this manner, become self-protecting to some degree in the event of equipment failure.

2.11 Typical "in band" signaling arrangements available for VHF radio systems might include the use of Western Electric Single Frequency signaling equipment (SF), 1000-20 Hz signaling, and other similar arrangements. "Out of band"equipments available include those provided by Lynch, Lenkurt, and other suppliers. In addition to the signaling arrangements indicated, use of voice-frequency telegraph or of carrier telegraph systems of either Bell System or commercial types may be desirable in some cases either to provide channel signaling or to provide telegraph, alarm, or telemetering facilities.

E. Compandors

2.12 The compandor is a dynamic device which provides an economical means of improving channel noise performance of voice communications circuits. It is discussed in various Bell System Practices and in other references. Commercially packaged units are available and when applied to voice channels transmitted by radio will frequently permit operation over longer paths, at poorer receiving sites, or with less antenna height than would otherwise be required. Good engineering practice requires the use of compandors on all multiplexed VHF systems using mobile service base station equipment if satisfactory intermodulation performance is to be had. Their use should also be considered in most single-channel installations. Compandors are capable of improving effective noise performance on voice transmission by as much as 23 dB but the improvement obtained tends to fall off as the noise level passes a certain limiting value. This effect will be discussed in succeeding paragraphs.

2.13 The compandor consists of two parts, a compressor and an expandor. These are connected to the transmitting and receiving sections of a facility, respectively, and, operating together at a syllabic rate, insert gain and loss in such a way as to reduce the dynamic speech range applied to the transmission facility and at the same time increase the signal-to-noise ratio. The device is most effective in suppressing single-frequency noise, babble or noise of the thermal or rushing type, but it is only about 2 dB less effective against impulse-type noise.

2.14 Referring to Fig. 2, which is a level diagram for a typical commercial compandor, it will be seen that speech components entering the compressor at a level greater than +5 dBm at the equivalent 0TLP will be reduced in level. This reduction is in the amount of 1 dB for each 2 dB by which the signal exceeds +5 dBm. Those components entering the compressor at a level lower than +5 dBm at the equivalent 0TLP will be amplified. This amplification also is on a 1 dB for 2 basis; thus a signal entering the compressor at a level of–15 dBm (20 dB below +5 dBm) will be amplified by 10 dB with the result that this signal leaves the compressor at a level of–5 dBm at the equivalent 0TLP. The net effect of these operations will be to reduce the dynamic range of speech entering the radio system from perhaps 56 dB to 28 dB, and in turn, to increase the average transmitter modulation level, thus benefiting the lower level talkers.

2.15 The signal applied to the expandor input will consist of noise components and of compressed speech. The action of the expandor on the speech is by design, the reciprocal of the compressor action and thus, any component which was attenuated by the compressor is amplified by the expandor; conversely, any component which was amplified by the compressor is attenuated by the expandor. The effect of this is, of course, to restore to the speech the dynamic range at which it was applied to the compressor.

2.16 The foregoing processes may by themselves account for some small improvement in system noise performance for the average or weak talker. They can not account for the 23 dB improvement claimed in paragraph 2.12. This improvement comes about because any signals which enter the expandor input at a level lower than the critical point (59 dBa at the equivalent 0TLP in this case) are attenuated by 28 dB. It should be expected from this that the noise performance improvement to be obtained from the use of channel compandors would be 28 dB, rather than the 23 dB quoted. This is true so far as the channel noise which would be measured with a 2B noise measuring set in the absence of signal is concerned. In practice, however, it has been found that the effect of noise components adding to the speech during the time that the expandor is "open" along with other effects resulting from the time constants of the compressor and expandor create some effective transmission impairment. This is known as the "hush-hush" effect and has been assigned a value of 5 dB, hence the 23 dB noise improvement mentioned.

2.17 A further reference to Fig. 2 will show that, should noise at the expandor input exceed 59 dBa at the equivalent 0TLP, it would be treated in the same way as speech and would be amplified. As a result, the effective advantage of the compandor is reduced whenever the channel noise at the expandor input exceeds the critical value. Figure 3

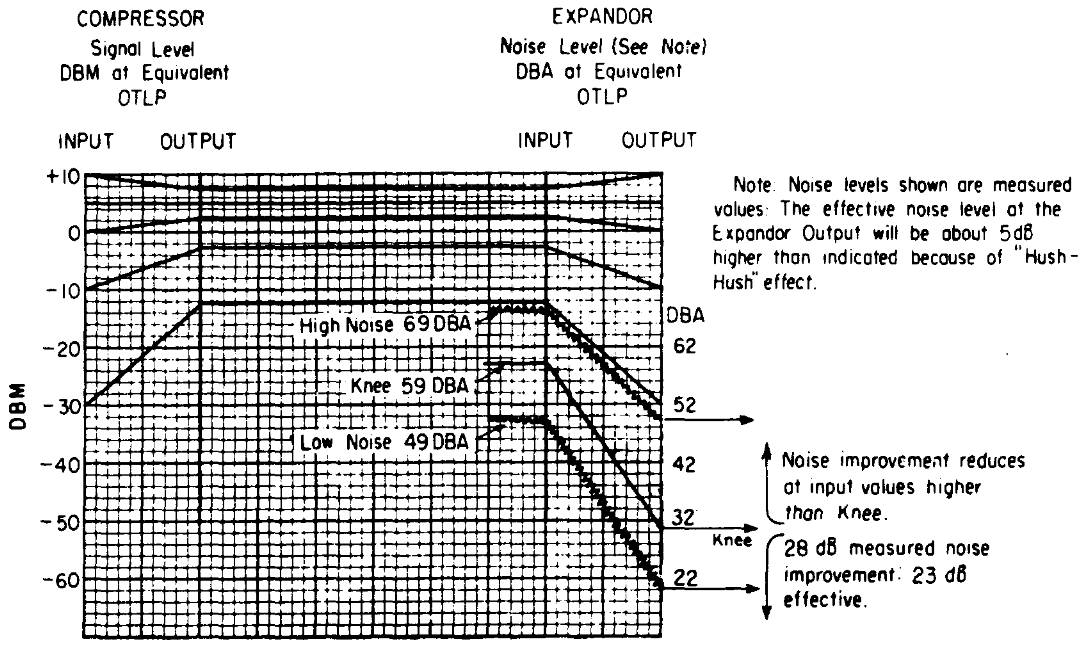

Fig. 2—Operating Levels in System Including Compandor

shows the relation between channel noise at the compandor input and compandor advantage as well as the relation between noise at the expandor input and the effective channel noise at the expandor output. From this it may be seen that the compandor advantage decreases at high input noise levels but for practical conditions it will never vanish.

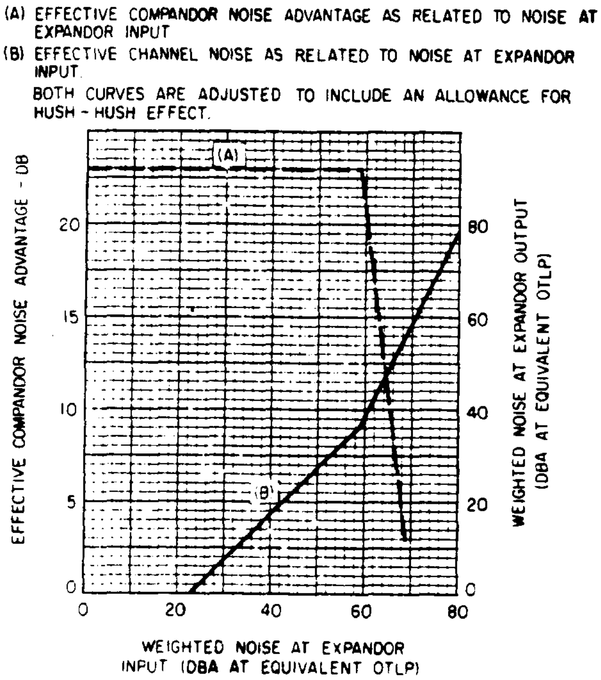

Fig. 3—Expandor Characteristics as a Function of Noise Input to Expandor

2.18 If we apply the foregoing information to a typical case involving a single-channel system, we may plot two curves as shown in Fig. 4 where channel noise is related to RF input to the radio receiver. This curve assumes a noise-free receiving site (see Part 5, Bell System Practice, Section 940-250-100), and shows the practical effect of the compandor in improving system performance. It must be noted that, if site noise rises or receiver input drops because of fading or other reasons to the point where noise in the uncompandored system reaches 59 dBa at the 0TLP, the rate of circuit degradation increases more rapidly in the compandored case than in the uncompandored case. As the result of this, the "break" in system performance is more acute in the compandored system than in the uncompandored and occurs near the operating noise level rather than at a point where channel noise is well above the normal operating point. This should be considered in the design of systems operating with terminals at locations subject to large variation in site noise or with radio paths which are subject to fading. (In such instances a noise objective lower than 34 dBa under "median" propagation conditions will usually be chosen in order to avoid premature system "breaking.")

2.19 Because of the expandor action, the effect of circuit net loss variations is effectively doubled, and this must be taken into consideration when circuit net loss is assigned if singing troubles are to be avoided.

3. TRANSMISSION LINES

A. General

3.01 Transmission lines connecting antennas and radio equipment in VHF installations will usually be chosen from three general categories:

(a) Semirigid (copper-air dielectric).

(b) Semiflexible (Styroflex, Heliax, etc).

(c) Flexible (solid dielectric).

Rigid copper line (as contrasted to (a) and (b) above) will rarely be considered for this service because of the high cost of material, hardware, and difficult installation. General considerations concerning various transmission lines and connectors are discussed in Bell System Practices, Sections 402-100-100 and -200.

3.02 Transmission loss and installed cost are the principal factors to be considered in selecting a line for any particular installation. Such factors as resistance to physical damage, to lightning burns, and to corrosion as well as the overall ease of maintenance will also influence the choice.

3.03 The transmission loss per 100 feet for several of the more commonly used types of transmission line is shown in Fig. 5. These losses, of course, assume that the line chosen is of a type having a characteristic impedance near that of the antenna and consequently, additional losses are not introduced as the result of impedance mismatch.

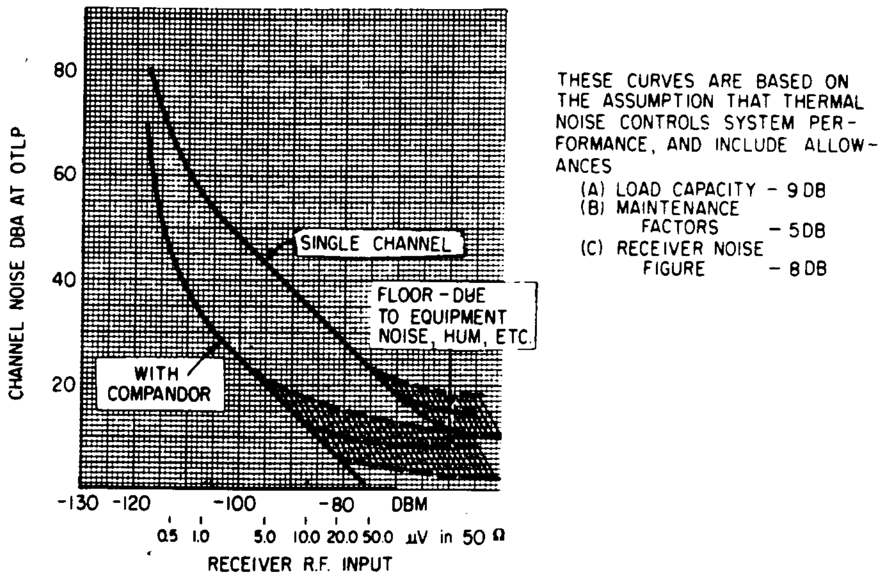

Fig. 4—Effect of Compandor on Single-Channel VHF Radio System Noise Performance

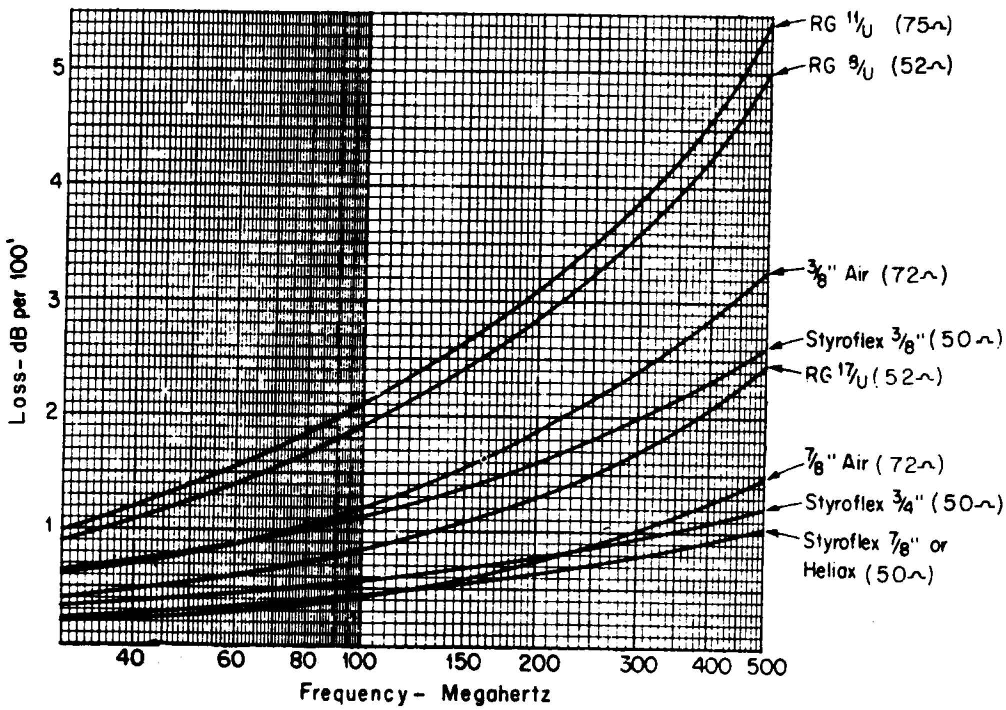

Fig. 5—Approximate Loss of Common Types of Transmission Line

B. Solid Dielectric Lines

3.04 Solid dielectric transmission lines such as RG 8A/U, RG 11A/U, and RG 17A/U are sometimes attractive for VHF installations because of their relatively low cost and the ease with which they can be installed. The comparatively high loss of RG 8A/U and RG 11A/U limits their use to lengths of 50 to 75 feet unless very large transmission margins exist in the system. The RG 17A/U (or the armored version, RG 18A/U) sometimes will be attractive in installations involving longer lines.

3.05 Solid dielectric transmission line may have "contaminating" or "noncontaminating" jackets. These terms refer to properties of the vinyl jacket material which, in some cases, permits chemical reaction with the polyethylene dielectric of the line and results in rapid increases in loss with age. Only "noncontaminating" type cable should be used in point-to-point installations. Most manufacturers identify these by the letter "A" in the code designation of the cable RG 8A/U. It should also be noted that some types of line have a vinyl jacket which loses its flexibility at low temperatures. Where such lines are installed in cold climates, they must be rigidly supported for trouble-free service. Cables having clear polyethylene jackets are not suitable for outdoor service because of the effect of sunlight on the jacket material.

C. Semirigid Lines

3.06 Lines classified as "semirigid" are those having a soft drawn copper outer conductor, air dielectric, and center conductor supported on "beads." These lines, in general, have lower transmission loss per unit length than the solid dielectric line of comparable size and also are useful to higher frequencies. The cost of these lines is higher than the cost of comparably sized solid dielectric lines and they are more difficult to install. Since they are maintained under pressure (dry nitrogen or dehumidified air), these lines are apt to require more maintenance than solid dielectric lines. Where semirigid lines are employed, physical arrangements must include allowance for the rather large bending radius required. The higher loss of 3/8-inch line as compared to that of the 7/8-inch size along with its poorer physical characteristics and greater susceptibility to lightning damage will usually limit the use of 3/8-inch line to installations having towers not more than 100 feet in height.

D. Semiflexible Lines

3.07 So-called semiflexible lines include the Andrew Corporation Heliax Cable and Phelps-Dodge Corporation Styroflex. These cables have a common design feature in that the insulation between conductors consists of a helical wrap of polystyrene ribbon. The Heliax cable has a copper-coated steel outer conductor with a vinyl jacket while the outer conductor of the Styroflex cable is aluminum. Styroflex may be supplied with or without a vinyl outer jacket. Use of the vinyl jacketed cable is recommended whenever Styroflex is to be used in a corrosive atmosphere. Both Styroflex and Heliax cable are designed to be pressurized in normal operation.

3.08 By reference to Fig. 5, it will be seen that the transmission loss of the 3/4-inch and 7/8-inch semiflexible line closely approximates that of 7/8-inch air dielectric line and accordingly, the choice between these types will be made largely upon a basis of availability, cost, and ease of installation. In cases where it is possible to predict accurately the length of line required, the cable can be ordered with connectors attached and it is then shipped under air pressure. In general, it will be found that the relatively flexible construction of the semiflexible line, its light weight, and short bending radius make it convenient to install.

E. Placing of Transmission Lines

3.09 Transmission lines placed on wood poles, buildings, or similar structures will usually be supported in the same manner as small telephone cables, using cable clamps and suitable fastening devices conveniently spaced. Cables on steel towers will usually be fastened using stainless steel "wrap-lock" ties spaced in accordance with the cable manufacturer's recommendations.

3.10 When cables are placed on steel towers or on other conductive structures, care must be taken to avoid differences in potential between the cable sheath and the supporting structure as the result of lightning strokes. This requires that the transmission line sheath and the tower should be bonded electrically at both top and bottom; also, bonds should be made at intervals of about 50 feet between top and bottom. Such bonding is also helpful in reducing the effects of standing waves on the transmission line as well as the effects of local noise fields. The incidental contacts between tower and transmission line are not sufficient to provide the necessary protection in the case of copper-air dielectric lines; good electrical connections should always be provided. In the case of flexible and semiflexible lines, it will be necessary, of course, to remove the insulating jacket, to provide a good electrical bond to the cable sheath, and to provide adequate protection against weather by the use of tape protected with a good weatherproof elastic varnish.

3.11 Many installations will have the antenna supporting structure separated from the building housing the equipment. Where this occurs, consideration must be given to the manner in which the cable is to be supported. The following table will serve as a guide.

TABLE I

RECOMMENDED METHOD OF SUPPORT

TYPE CABLE	SPAN LENGTH IN FEET 0-3	4-6	7-25	26-50	OVER 50
Flexible	A	B-C	B-C	B, C, or D	C, D
Semirigid	A	B	B-C	B, C, D, or E	C, D, E
Semiflexible	A	A	B-C	B, C, D, or E	C, D, E

(A) Aerial — Self-supported.

(B) Aerial — Supported by messenger. (Must be taut — lash or clamp cable firmly — allow adequate loop in cable at each end.) (Note 1)

(C) Aerial — Supported by rigid structure. (May be inverted angle iron or pipe.) (Note 1)

TABLE I (Cont)

RECOMMENDED METHOD OF SUPPORT

(D) Buried = In transit conduit, tile duct, or sewer pipe. (Must be below frost line.) (Note 2)

(E) Buried.

Note 1: The expansion coefficient of transmission line may vary from that of the supporting structure. Therefore, when long runs of line are made in locations subject to wide temperature variations, the means of attaching the line to the supporting structure should be such as to permit the required movement.

Note 2: If for any reason, it is desirable to use steel pipe conduit, care should be taken to make all couplings watertight and to seal the ends. This is necessary to avoid danger of frost damage and electrolysis.

3.12 When semirigid copper transmission line is installed in aerial spans, it is not practicable to use galvanized steel messenger as the supporting medium. This is true because of the probability of electrolytic action which will result in failure of the galvanizing within relatively short periods. It is, therefore, necessary to use copper clad messenger which is available through commercial sources. The transmission line may be secured to the messenger using copper or Monel metal lashing wire. Under no conditions should the standard Bell System No. 430 stainless steel lashing wire be used in situations involving copper since this combination results in electrolytic action. Electrolytic action between the transmission line and galvanized steel tower members is ordinarily of less consequence than between the transmission line and messenger because the zinc surfaces are painted.

3.13 Where aerial cable sections are installed in areas subject to sleet or ice formation, precautions should be taken to protect the cable against damage from ice which may fall from the antenna, tower, or building. This will usually require that a rigid supporting structure should be used and the cable protected by the support.

4. PROTECTION

A. General

4.01 Equipment making up the terminals of VHF point-to-point installations, if not properly protected, is susceptible to damage from lightning strokes to either the antennas or to the connecting power and telephone wire facilities. The avoidance of such damage requires that adequate protective facilities should be installed to meet any conditions likely to be encountered at the particular location. In addition, in order to assure maximum continuity of service from the radio facility, it is necessary to take positive steps to prevent damage to the power and telephone wire serving the radio installation.

4.02 The similarities between VHF point-to-point equipment and mobile base station installations make possible the use at VHF point-to-point stations of protective measures designed for the mobile service base stations. These are described in the Transmission Engineering sections of the Plant Series.

4.03 In addition to the protective measures outlined in the Bell System Practice references, experience indicates that it is frequently necessary to provide protective measures to reduce the effect of surge voltages entering the equipment via the ac power supply. Similarly, it may be desirable to protect the power supply against lightning surges originating at the radio installation. Both of these requirements may be met by the use of protective arrangements connected in the secondary power service leads. Depending upon the individual situation, it may be desirable to provide one of the following protective arrangements on the ac power service:

(a) A "pellet" type of arrestor (such as the GECo 9LA15A4).

(b) A silicon-carbide varistor-protector block arrangement along with (a). (A locally assembled unit consisting of a D159235 varistor in series with a 111A protector equipped with 107B protector (0.006-inch gap).

(c) A combination consisting of a 1600V peak breakdown gap at the service entrance wiring in iron conduit or in steel clad cable (to increase its inductance), and a varistor-protector block combination at the radio equipment cabinet.

In any case, the probability of power interruption due to lightning strokes will be reduced by the use of "slow-blow" fuses in the service leads. Individual consideration will necessarily be given to each situation to determine the most appropriate arrangement.

4.04 Unlike the coaxial antennas often used at mobile radio base stations (which usually include a "star" type gap to protect against excessive voltages between the sheath and center conductor of the transmission line), some directional arrays used in point-to-point service are designed without such protection. Other arrays will have a center conductor of the feed line connected (for dc purposes) to the cable sheath. When antennas having a grounded center conductor type of construction are used or when antennas without an inherent gap are mounted below the top of the antenna supporting structure, no additional protective measures are needed. When "insulated" types of antenna are used at pole top, it is desirable that some form of protection should be provided to prevent excessive voltages across the transmission line. This may consist of a shorted quarter-wave transmission line section or of a "star gap" (locally constructed). In some cases, the transmission line section may be part of a diplexer network (see Bell System Practice, Section 940-250-100, Fig. 19F) or may be a simple filter section (see Bell System Practice, Section 940-250-100, Fig. 19D). In any event, it must be recognized that transmission line sections are of relatively high Q and that, accordingly, such sections can not be connected across the transmission line of 2-frequency systems without special consideration.

5. POWER SUPPLY CONSIDERATIONS

A. General

5.01 Most VHF radio installations will be engineered to operate with commercial ac power supply. In and near large communities, such commercial power sources will usually be very reliable, both from the viewpoint of service continuity and voltage regulation and, unless the service reliability requirement of the facility is extremely high, no "backup" power supply will be required. When telephone equipment is installed in remote locations and, under some conditions, even in small or medium sized towns, commercial power reliability is poorer and service outage due to power failure may contribute a very substantial part of the total outage time.

5.02 In such situations, it will be desirable to provide an emergency power service. This may be an engine alternator (usually gasoline driven in cases requiring only small capacity) or in situations where a battery supply is available,. it may consist of a vibrator converter. Bell System Practices in the equipment series as well as power data sheets, etc, provide detailed information concerning this type of equipment; thus this section will not attempt full coverage of this subject but will attempt only to point out some of the more important general considerations.

B. Vibrator Supplies

5.03 Vibrator converters, where provided, are capable of rapid "pickup" of the load in case of power interruption. They are not primary power supplies, however, and are limited in the duration of outage they can bridge by the capacity of the battery. In situations requiring "backup" power for more than short periods of time (2 to 6 hours), vibrator supplies alone will probably not be adequate, but vibrators supplemented by manually started portable or permanently installed engine sets might be used to provide for bridging long outages. Because of the limited current capacity of the available vibrators, such units will require quite high voltage batteries (64 to 130 volts) and are, therefore, rarely practicable unless the required battery plant is already installed. Where other conditions permit their use, vibrator power supplies may be of the type designed for TD-2 installation (J86450B) or may be locally engineered using "railroad" type converters designed for mobile station applications.

C. Gasoline Alternator Sets

5.04 Gasoline engine driven alternators may be manually started or automatic. Situations permitting the use of "pushbutton" starting installations will frequently result in substantial economies without serious impairment of service. This type of operation may be satisfactory when equipment is installed at manual central offices, at subscribers' premises, or at other locations where full time supervision is possible.

5.05 When it has been determined that an automatic gasoline driven emergency power supply is to be provided for a particular installation, several factors in addition to output rating will influence the choice of the unit to be employed:

(a) The starting arrangement should be sensitive to low voltage as well as to no voltage conditions. (The load should be transferred whenever the voltage drops below the minimum required by the equipment.)

(b) The transfer circuit should be arranged in such a way that the machine will continue to run and to carry the load for a predetermined period after commercial power restoration. (This avoids further service impairment in the event of power interruptions following the original restoration.)

(c) The design of the engine starting circuit should be such that failure of the engine to start will result in a "time out" after a predetermined period. This avoids complete discharge of the engine starting battery under conditions of engine start failure and prevents damage to the starting motor. Arrangements are also available which will make a second attempt at starting after a short delay and these are frequently helpful in avoiding engine starting failures.

(d) Generator sets not having inherent voltage regulation should be arranged to delay the pickup of load until the voltage regulator has stabilized the output voltage.

(e) Fuel storage capacity provided should be adequate to assure continuity of power during any reasonable power outage.

(f) Other desirable features are overspeed trip, high water temperature, and low oil pressure shutdowns.

5.06 Several engine alternator sets have been standardized for Bell System service. These are covered by appropriate Bell System Practices. A few of the most attractive for small VHF installations are as follows:

KS-5667-01 2.8 kW automatic, 4.0 kW automatic

KS-15700 1.3 kW automatic

KS-15650 5.0 kW portable

These machines are all 117-Vac output and the automatic sets provide service features as outlined in paragraph 5.05. The KS-5667 units are designed for fixed indoor installation. The KS-15700 machine, on the other hand, is self-contained in a weatherproof housing. Its use may frequently make practicable the provision of backup power supply at pole mounted installations while in other cases building size and cost may be reduced.

5.07 When emergency power is provided at installations having flashing tower lights, special consideration must be given the problem of voltage regulation of the alternator output. Experience indicates that the use of a compensating resistor, which is connected to the power line during the "off" period of the flashing lights, will usually be satisfactory.

D. Voltage Stabilizers

5.08 In situations where voltage variations in excess of about +3 percent–7 percent are encountered, maintenance costs can be reduced appreciably by the use of voltage stabilizers. Service continuity will be improved by this, and other benefits including a reduction in circuit net loss variation will be realized. Specification KS-15508 describes units of 2.3, 4.6, and 10 kVA capacity capable of regulating an input voltage range from 95 to 130 volts. Where other capacity stabilizing transformers are needed, several commercial types are available. Voltage stabilizing transformers operate most effectively when loaded near capacity; thus it will usually be desirable to select the smallest transformer available for a given installation. When electronic equipment having regulated plate supply rectifiers is connected to the output of a magnetic regulator, it may sometimes be found that satisfactory operation of the combination is not possible because of the waveform of the magnetic regulator output.

5.09 When both an emergency power supply and voltage stabilization are provided at an installation, it will usually be desirable to arrange the transfer circuit to bypass the voltage stabilizer. This will not penalize system operation since the voltage regulation of most emergency machines is satisfactory for most uses over the normal range of loads. This arrangement is made necessary because of frequency, voltage, and waveform characteristics of the individual units which may make their simultaneous operation unsatisfactory.

E. Power Arrangements for Locations without Commercial Power

5.10 When point-to-point installations are to be made at locations not having commercial power service and where it is not feasible to provide such service, it may sometimes be desirable to use equipment of the type designed for mobile service and to modify this for fixed service. Such installations will be powered by storage batteries charged by small gas engine generators or by other means. At some locations, the presence of dc lighting plants may make the use of ac operated units with a vibrator converter desirable. In all cases in order to conserve power, installations at locations not having commercial power supply should be operated with carrier off, except during actual communication.

6. HOUSING FOR RADIO AND TERMINAL EQUIPMENT

A. General

6.01 The relatively low cost of radio and terminal equipment frequently brings about a situation in which parts of a radio system other than those actually required for transmission represent the larger part of the total investment. Where existing buildings are situated in such locations that they can be used for housing radio or terminal equipment, one should weigh the cost of any necessary antenna supports, additional antenna gain, or increased transmitter power which would be required to make such arrangements against the cost of land, buildings, and access roads at other locations. In addition, consideration should be given to maintenance problems which may be experienced at remote locations.

B. Use of Pole Mounted Equipment

6.02 If it is established that radio equipment should not be located in an existing building, a choice may in some cases remain between the use of rack mounted equipment in a small building and the use of pole mounted equipment. The use of pole mounted equipment will frequently permit very considerable savings in the cost of land and buildings in areas where weather conditions permit and where equipment design and maintenance requirements are such that this is desirable. Use of pole mounted equipment may be extended in some cases by providing portable canvas or nylon "tents" or wind shields, thus affording some measure of additional protection against the weather. In areas where deep snow is encountered, maintenance of pole mounted equipment can be simplified by mounting the equipment some distance above ground with a platform to permit comfortable and safe work. Such installations of pole mounted equipment should be so arranged that it is not possible to sustain injury by walking into the cabinet or platform. This objective will require in some cases the use of short "stub" poles, railings, or other means of protection about the cabinet.

6.03 Cabinets chosen for pole mounted installations should be insulated and painted with aluminum paint or with light colored enamel to provide maximum solar heat reflection. Heat generated by the power dissipation of the terminal and radio equipment will usually require cabinet blowers (operating under thermostatic control) if excessive equipment temperatures are to be avoided. Air filters will, of course, be provided at the air intakes to protect against dust, snow, etc. In severe climates, it may also be desirable in some cases to provide small heaters under thermostatic control. (This may apply particularly in situations where signaling is done by carrier control and where power dissipation within the cabinet may thus be quite small under conditions of light traffic.)

C. Buildings for VHF Installations

6.04 Housing for VHF radio equipment will, like repeater buildings for cable installations, generally be located in relatively remote places. The primary design objective is to obtain low cost functional housing, but this does not necessarily mean that the building must be unattractive in appearance. Further, the objective of low initial cost must not result in poor maintenance conditions, such as leaks around eaves, doors, windows, or at the ground line.

6.05 The cost of small functional buildings will depend largely upon three factors:

(a) Type of construction.

(b) Location.

(c) Size.

Since travel time, lodging, and other indirect expenses of construction crews may increase the cost of constructing buildings at remote sites, the use of prefabricated or of portable buildings will prove to be desirable in many cases. These may be of prefabricated metal suitably insulated or they may be of the "portable" precast concrete type. Locally constructed buildings may be wood frame with brick veneer or asbestos shingles, or they may be of tile or masonry construction (brick or concrete block). Either concrete or wood floors may be used, although in cold climates wood floors may be most satisfactory from the standpoint of condensation and also from the standpoint of comfort for workmen. In warm and damp climates, the use of wood frame and wood floors requires that consideration be given to termite protection and to protect against rot and mold. Small buildings of this type may usually be built without windows, thus effecting substantial cost savings.

6.06 Because of the small size of buildings required for VHF radio service, it may, in some cases, be feasible to prefabricate wood frame buildings at a location away from the proposed site and to ship the finished building by truck to its final location. In some cases the radio terminal equipment may be installed prior to shipment, thus shortening the field installation period. This same technique may be applied in cases where radio terminals are to be relocated after having been in service.

6.07 The size of buildings for housing VHF radio equipment should be held to a minimum consistent with providing adequate space for safe maintenance. Sufficient working space both in front and back of the equipment is essential as is adequate space for storage of test equipment, spare parts, tubes, and drawings. Where such storage space can be provided in the base of an elbow height cabinet, this will provide a small work-bench surface which is helpful in many maintenance operations. Where it is possible, equipment racks should be chosen to permit holding ceiling height to a reasonable minimum.

6.08 Certain installations may require consideration of heating facilities, ventilating arrangements, or both. The need is dependent upon climate, power dissipation of the equipment, and the temperature limits which the equipment can tolerate while operating effectively. Manufacturer's recommendations of operating temperatures should be followed in all cases in this regard, but it should be recognized that component failures in electronic equipment may increase in frequency with increased temperature even though the equipment is not operating outside of permissible temperature limits.

6.09 Heating for small buildings may be provided by means of gas, electric, or oil burning units. Selection of an appropriate type of equipment will usually be governed by the relative cost of various types of fuel in the particular area. The unit chosen, in any case, should be adequate in size, should be of a type approved by the Underwriters Laboratories, and should be installed in accordance with local building codes and the Underwriters recommendations. (See also Bell System Practice, Section 760-630-151.) Heaters will usually be thermostatically controlled. It will frequently be found profitable to provide adequate building insulation in order to take advantage of the fuel savings which it makes possible. Such insulation also is valuable in reducing maximum temperatures where these are influenced by solar radiation.

6.10 Ventilation of small buildings, in the simplest case, may be accomplished by the provision of louvers. In areas where temperature ranges are sufficiently great, arrangements to open and shut the louvers either manually or by thermostatic control may be required, while in areas subject to very high temperatures, dusty air, or both, it may be necessary to provide ventilation by the use of thermostatically controlled blowers, protecting the air intake with a dust filter.

6.11 Where radio systems are provided with emergency gasoline generator sets, some economy will result if the part of the building housing the gasoline engine is not insulated. This is usually possible because of the wider temperature tolerance of this equipment by comparison with that of the radio and other electronic equipment. It is also desirable to separate the engine room from the other parts of the installation by a fire resisting wall, where this is practicable, or to use generator sets designed for outdoor use as discussed earlier.

6.12 Sufficient electric lighting facilities should be provided to permit safe, effective maintenance of the equipment. Convenience outlets for test equipment, soldering irons, etc, should be provided and in all cases, these outlets should be fused independently of the equipment. Also, where feasible, convenience outlets should be fused independently of lights. In installations where emergency power sources are provided, care must be taken to assure that at least one convenience outlet and at least one light are connected to the emergency power source. Such outlets should be clearly marked. In structures such as those under consideration, it will generally be economical to use incandescent lights rather than the fluorescent type.

6.13 Where buildings are located in forested areas subject to a fire hazard, it will usually be desirable to provide a cleared area about the building. The size of this area will depend upon local conditions but, if at all possible, the minimum width of the clearing should be equal to or greater than the height of the surrounding trees.

6.14 Such items as fencing and construction of access roads will depend upon local conditions. Particularly in built-up areas, it may be possible to secure satisfactory appearance of an installation by simple plantings of trees or shrubs at a lower cost than would result if architectural modifications were made.

7. MAINTENANCE CONSIDERATIONS

A. General

7.01 Both the service reliability and the operating cost of any radio transmission facility are dependent upon many factors, most of which are governed by the basic design of the individual installation. It is, therefore, essential that the engineer designing the radio system should be constantly alert to those items which may influence system maintenance and should strive to provide the most dependable facility consistent with a reasonable plant investment.

7.02 In many cases, terminals of radio systems are in locations remote from maintenance centers and traveling time to and from the terminal may represent a considerable part of the total maintenance cost. This requires that particular attention be paid to those design features which will help to avoid complete service outages at such remote locations, minimizing the need for unscheduled maintenance visits.

7.03 Specific divisions of this section have indicated many of the items entering into radio system design which will assist in providing greater service reliability and lower maintenance cost, while having only minor effect on the plant investment. The more important of these items include convenient access, reliable and stable power supply, adequate temperature control, and proper protection of the equipment and the connecting plant. Assuming that system transmission design is adequate to the service requirement and that sufficient margins to permit an economical maintenance schedule have been allowed, attention to a few miscellaneous factors may permit substantial maintenance economies. These items will be considered in succeeding paragraphs.

B. Maintenance Information

7.04 As was previously indicated, units making up a VHF point-to-point system will normally be chosen from equipment which is available for mobile radio base station applications and for wire telephone service. It is desirable in choosing these units to select equipment which is familiar to the operating people in the maintenance area and also, to select items which are provided with adequate instruction books and service manuals or which are covered by Bell System Practices. When such information is available, the engineer will usually be able to supply the necessary supplementary instructions in an extremely condensed form, thus accomplishing considerable savings in the cost of providing necessary maintenance information.

C. Use of Long Life Tubes

7.05 Experience indicates that a considerable portion of the total service interruptions which affect radio equipment are brought about by the premature failure of vacuum tube heaters. It is frequently possible to reduce the number of such failures by the use of "ruggedized" or "industrial" type vacuum tubes. These tubes are somewhat more costly than the ordinary receiving tube varieties but in most situations involving radio installations, the saving effected by the avoidance of a single maintenance visit may compensate for the added cost of many of the higher priced industrial vacuum tubes. In addition, some of the premium type tubes will give extended service at optimum performance by comparison with the common varieties and thus will assist in additional savings.

D. Test Facilities

7.06 The reliability of a transmission facility may be increased several fold if it is possible for maintenance personnel to easily perform overall and sectionalized tests designed to detect trends in the system performance. To permit such tests, it is desirable to provide an adequate number of test points. System design should include the necessary arrangements for this, both in the voice-frequency circuits and in the radio frequency portion of the equipment.

E. Test Sets

7.07 The provision of proper test equipment is an important engineering responsibility in the design of any new facility. It will generally be found that the test sets required to maintain properly the voice-frequency portions of the radio system are already available in the operating area, and it will rarely be necessary to provide such units exclusively for the radio installations. It will more frequently be found that the minimum test equipment that is required for the maintenance of the radio equipment must be provided in order to assure satisfactory maintenance results. The minimum test equipment for any given radio installation should include a frequency monitor-receiver testing RF source such as the Budleman type 17A or the GECo type ST13A, a Jones Micromatch or equivalent RF power measuring device, as well as any special test equipment required for the maintenance of the equipment. Where pressurized RF transmission lines are used, both testing and pressurizing equipment should be available. Portable test equipment will generally be provided in a "pool" for each maintenance area, thus permitting the most economical distribution of the various items. At some very remote locations, however, it may be desirable to store necessary minimum test equipment at the station in order to reduce access and transportation problems during times of severe weather.

F. Spare Equipment

7.08 The engineering of any transmission facility should provide spares for the major expendable components (such as crystals, etc) when these are sufficiently specialized to make them difficult to obtain within reasonable periods. It will usually be desirable to provide a spare radio receiver in order to permit shop repair of the regular units when this is required. Since transmitters are more easily serviced in the field and since their overall design is more rugged than that of the receiver, spare transmitters will rarely be required.

G. Alarms

7.09 In many cases it will be desirable to provide some alarms for unattended terminals of point-to-point radio installations. In order to meet specific needs, these may include indications of such conditions as ac power failure, low transmitter output, high and low room temperature, tower light failure, etc. Alarm indications may be transmitted by means of VF or carrier telegraph equipment connected to the radio facility, or where the remote terminal is located at CDO, connection to the office alarm system may be adequate and economical. Installations having one terminal at a manual central office not attended by Plant people may be provided with permanently connected arrangements to meter transmitter output and receiver limiter current. These would be monitored by the operating people. Such arrangements will be materially less costly than transmitted alarms, but will frequently permit the anticipation of troubles and a reduction in the number of service visits required.

7.10 Prior to placing any new radio transmission facility in service, tests should be made to establish the adequacy of the design, and to assure that, as put into service, the system is performing properly. It will generally be desirable to perform these tests with engineering people working in cooperation with people in charge of maintenance of the system. Data resulting from such tests should be maintained as part of the station operating record where it will serve both to satisfy FCC requirements and to provide a basis which Plant personnel can use at future times in determining whether the facility is operating as the designer intended. Also, this information will be useful for a trend record upon which future maintenance can be based.

8. ECONOMIC CONSIDERATIONS

A. General

8.01 Other parts of this section have discussed the technical aspects of radio system engineering; it seems appropriate to devote some time to a consideration of the economics of system planning since the selection of a particular means of providing a service is a responsibility which continually confronts the telephone engineer. He must impartially consider a wide variety of possibilities and must base his selection upon a number of factors, some of which are:

(a) Service requirements.

(b) Date of service availability.

(c) Relative cost of each of the plans considered.

(d) Ease of maintenance.

(e) Other factors which will influence his decision, such as weather expectations, maintenance, and service history.

8.02 In making a selection, it is necessary to study the service requirements of the installation and to reject those plans which do not offer satisfactory fulfillment of the basic service requirements. Those plans which are satisfactory in this respect should be examined to determine whether they offer equality of service. It is improbable that complete equality can be achieved, and it will be helpful to list significant differences as an aid to final evaluation. Some items deserving consideration from this viewpoint include:

(a) Speed, quality, and dependability of service.

(b) Appearance and location of plant.

(c) Effect on the organization. (Cost of training, personnel transfers, etc.)

(d) New money requirements.

(e) Interference with long term plans.

(f) Effect on existing plant (accelerated depreciation, etc).

(g) Diversification of facilities as a service protective measure.

8.03 Where the preliminary examination of plans under consideration indicates that radio may be attractive from a service standpoint, the engineer will wish to prepare a comparative cost study to evaluate the economic aspects of the problem. Such a study will include comparisons of ***First Cost*** and ***Annual Charges*** which would apply to each of the several plans. The basic technique of such studies is treated in Bell System Practice, Section AB91.025, and also in a book "Engineering Economy" which is available in the Bell System.

8.04 The purpose of this section is not to enlarge upon the references mentioned, but rather is to point out some of those items which are peculiar to plans involving point-to-point radio.

B. Plant Investment or First Cost

8.05 Plant investment or first cost of plant is made up of those items which must be available prior to establishing a service. It includes as major items the following:

(a) Material costs.

(b) Shipping and handling charges.

(c) Shop costs.

(d) Miscellaneous and incidental costs.

(e) Cost of engineering.

(f) Cost of installation.

(g) Cost of land.

(h) Cost of buildings.

(i) Cost of antenna supports.

(j) Cost of power and telephone lines.

8.06 Material costs include the cost of material and components, including radio equipment, terminating equipment, antennas, transmission line, emergency power equipment, and other equipment items.

8.07 Shipping and handling charges must be added to the basic cost of radio equipment. Items in this category will include freight or express, demurrage, drayage, rigging, storage, and insurance. In some cases this may be expressed as a percentage of the basic equipment cost, while in other cases, particularly where the equipment will be remotely located, it will be desirable to make a more realistic estimate of these factors.

8.08 Shop costs will include the cost of any modifications to commercial radio units, the cost of assembling terminating equipment, and possibly the cost of lineup activity prior to actual installation.

8.09 Miscellaneous and incidental costs are those which can not be reasonably foreseen and would include such items as last minute price increases, expedited shipping, minor changes, and other contingencies. Such miscellaneous and incidental expenses can be carried in the estimate as a separate item or may be added to the cost of the various components. For the purpose of uniformity and to permit more ready comparison between estimates, it would be desirable to include an amount of about 10 percent of the total material cost as a separate "miscellaneous and incidental" cost item.

8.10 Cost of engineering will include the cost of actual system planning, path testing, site selection, equipment design, and a suitable amount to cover cost of engineering tests of the completed installation. Where data as to time required are not available from previous installations, an estimate may be made on the basis of experience on carrier or other types of systems. Where equipment is remotely located, travel time may add a significant amount to this item.

8.11 Cost of installation will include the cost of plant, Western Electric Company, and contractor labor needed to install the radio and terminating equipment, the antenna and transmission line, the auxiliary power supply where provided, and any supplementary equipment. It will include the cost of testing and lineup of the system. For estimates of a preliminary nature, it is frequently convenient to express the cost of labor as a percentage of material cost and to express engineering costs as a percentage of either total investment or of material cost. Data based upon these assumptions are necessarily rough since it is not necessarily true that more costly equipment is more difficult to install; also installations which involve the use of "packaged" equipment will generally prove to be quite economical so far as both engineering and installation costs are concerned.

8.12 Cost of land required for a radio installation does not necessarily follow the average land cost in the area since desirable radio sites are sometimes narrowly restricted and local circumstances will affect the purchase price. Cost of the land will include the cost of incidental items including options, title search and guarantee, legal and court costs, and surveying as well as the cost of major items such as access roads, parking areas, graveling, fencing, drainage, and retaining walls.

8.13 Where it is practicable, radio systems will usually be installed in existing buildings. Where new buildings are required, estimates of their cost may be based upon recent experience, upon estimate of cost for several types of prefabricated buildings (adequate to the installation), or upon a rule of thumb (X dollars per cubic foot). A small percentage should be included to cover cost of permits, surveys, and other incidentals. Where buildings are to be erected at remote or inaccessible sites, such problems as transportation of men, tools, and materials to the construction site, adequate housing, and sanitary facilities must be given full consideration by the engineer. In some cases, it may be desirable to obtain estimates from contractors or architects, particularly where unusual terrain such as rock or swamp is involved. In those parts of the country where weather conditions permit the use of pole mounted equipment, considerable savings may be realized through the use of available cabinets or of cabinets custom-made to the installation.

8.14 Under some conditions, the cost of antenna supports may comprise a very large part of the total cost of a VHF or UHF point-to-point system.

8.15 Cost of power and telephone lines to serve remotely located installations may involve considerable amounts. Such service may involve either pole line or underground plant over varying distances. In addition to the cost of labor and material, the cost of surveying, right of way, etc, should be included.

C. Annual Charges

8.16 Annual charges are based upon the total plant investment and are made up of factors as follows:

(a) Interest.

(b) Taxes.

(c) Depreciation.

(d) Maintenance.

(e) Operating.

(f) Administration.

(g) Insurance.

8.17 Interest charges on radio equipment investment will be at the rate commonly charged for any class of plant.

8.18 Tax charges will be the sum of applicable income and property taxes increased by the amount of any special taxes or permit fees which may apply.

8.19 Depreciation is the first cost of an installation minus the net salvage obtained upon removal spread over the estimated life of the equipment. Present experience is not sufficient to permit a firm statement as to the life expectancy of particular radio equipment or of a particular installation. Since this is true, it appears proper to examine each case with a view to estimating the period of time over which the installation, as contemplated, can be expected to fill the requirement. For a comparative cost study which may involve the choice between radio and other type facilities, the "sinking fund" method of computing depreciation is generally used.

8.20 Maintenance charges applicable to radio plant will generally be made up largely of labor costs with material, power, transportation, and supply expense contributing smaller portions of the total. A very general estimate might be made by assuming that all maintenance activity will constitute a certain fixed percentage of the initial cost of an installation. Because of the many factors involved, it is suggested that each case be accorded individual attention and then an estimate be prepared on the basis indicated in Table II. Examination of this simple study will point out some of the factors which make generalization difficult in estimating maintenance costs. While values used in the example are felt to be typical, they can not be considered applicable to the wide range of situations encountered in practice. In estimating maintenance labor it is important that a forward-looking viewpoint be taken and that long-term projections of maintenance costs should be developed on the basis of increasing skills, improved components, such as vacuum tubes, and advanced techniques, all of which should act to reduce maintenance costs over a period of time. In addition to the costs included in normal maintenance activities, it may be proper to include an amount to cover such expenses as the cost of moving existing equipment to provide space for new units, cost of modifying equipment to improve performance, etc.

8.21 Operating expense as used herein is defined as the cost of traffic operations. Since this is generally equal regardless of plant arrangement, it may be omitted from a comparative cost study unless a particular plan under consideration causes a significant difference in traffic operating procedures.

8.22 Administration includes the cost of general office supervision which applies to all departments. Since the item applies equally to all classes of plants, it may generally be omitted from comparative cost studies.

8.23 Insurance costs are expressed as a percentage of first cost of plant. Allowance for fire insurance is common in the case of central office equipment; outside plant being widely scattered is not insured.

D. Use of Existing or Rented Facilities

8.24 Certain cases will occur where it is possible to locate radio equipment in existing telephone buildings thus reducing "out of pocket" costs at the time of installation. Similarly, in the case of point-to-point control circuits associated with private mobile systems, it may be possible to make use of land, buildings, antenna supporting structures, and power equipment owned by the customer. Where this is true and where contractual arrangements do not require that the customer should supply these items, the estimated or agreed upon rental will be used in the "annual charge" section of the comparative cost study to the extent that it replaces the costs which would ordinarily be included. Where space in existing Telephone Company buildings is used, available space cost data may be used in the same manner and will include light, heat, and house service as well as other costs in connection with land and buildings. In cases such as these, the "first cost" portion of the comparative cost study will be simplified to the extent that no first cost for rented quarters will be included.

TABLE II

ESTIMATED ANNUAL COST OF MAINTENANCE OF TWO SINGLE-CHANNEL VHF RADIO CIRCUITS — LOCATION A TO LOCATION B

Location A is remote from the central office with the radio equipment in a prefabricated metal house, a 200-foot guyed steel tower equipped with two 100-watt lamps and a 1 kW flashing beacon, a 1.5 kVA emergency gas engine alternator, all located on a 2-acre rural plot. At Location B, the radio equipment is located in an existing central office; the antenna is supported by a 75-foot wood pole adjacent to the building and emergency power is taken from an emergency machine supplying the central office.

At location A, each visit to the station will involve one hour travel time by the maintenance man, while Location B is attended full time by maintenance forces.

LOCATION A

RADIO EQUIPMENT

LABOR

1 inspection per month; 4 man-hours per inspection, 48-man-hours at $4.10 per man-hour	=	$196.80
4.0 trouble per year; 5.0 man-hours per trouble 20.0 man-hours at $4.10 per man-hour	=	82.00
Motor Vehicle; 68 hours at $0.45 per hour	=	30.60

MATERIAL

52 receiving type tubes; estimate 24-month life, thus annual requirement = 26 tubes at $1.25 each	=	32.50
2 output tubes; estimate 1-year life at $15.50 each	=	31.00
Miscellaneous components; resistors, condensers, relays, fuses, etc	=	20.00
Total radio equipment maintenance		$392.90

LOCATION A (Cont)

ANTENNA, TOWER, AND LIGHTS

Replace lights and inspect; 1 per 6 months, labor and material $50	=	$100.00
Paint, inspect and tighten; 1 per 4 years, 200 ft at $2.25 per ft x 25%	=	112.50
Total antenna and tower maintenance		$212.50

EMERGENCY POWER

Inspect and tune once per year	=	$ 7.50
Change oil — 1 per 300 hours operation. (2 times per year minimum)	=	2.40
Gas, test, and operate	=	15.00
Overhaul, estimate once per 5 years $300 x 20%	=	60.00
Total emergency power maintenance		$ 84.90

LAND AND BUILDINGS

Blade access road, twice per year	=	$ 20.00
Plow snow from access road	=	25.00
Janitor service in building	=	20.00
Painting and repairs	=	25.00
Total building maintenance	=	$ 90.00

TABLE II (Cont)

LOCATION A (Cont)

POWER

TRANSMISSION POWER

2 (24 hours x 365) = 17,520 at 0.125 kWh = 2190 kWh at $0.045	= $ 98.55
Full talk; assume 25% duty cycle = 2 x 365 x 24 x 25% 4380 hours at 0.400 kWh = 1752 kWh at $0.045	= $ 78.84

TOWER LIGHTS

2 x 100 watts + 1000 watts = 1.2 kWh x 365 x 10 hours = 4380 at $0.045	= $197.10

HEAT AND LIGHT

Assume 2 kW heater, 5% of year = 2 x 365 x 24 x 0.05 = 876 kWh at $0.045	= $ 39.42
Assume 100-watt light 5% of year. 0.1 kWh x 24 x 365 x 0.05 = 44 kWh at $0.045	1.98
Total power	$415.89

TOTAL MAINTENANCE — LOCATION A $1,196.19

LOCATION B

RADIO EQUIPMENT

LABOR

1 labor inspection per month; 3 man-hour per inspection, 36 man-hour at $4.10 per man-hour	= $147.60
4.0 troubles per year; 4 man-hours per trouble, 16.0 man-hours at $4.10 per man-hour	= 65.60

MATERIAL

52 receiving tubes; estimate 24-month life, thus annual requirement = 26 tubes at $1.25 each	= $ 32.50
2 output tubes; estimate 1-year life at $15.50	= 31.00
Miscellaneous components, including condensers, resistors, relays, fuses, etc	= 20.00
Total radio equipment maintenance	= $296.70

LAND AND BUILDINGS

Special rental 100 sq ft at $1.25	= $125.00

POWER

Transmission power, as at Location A	= $177.39
Tower lights, not required	
Heat and lights (included in rent)	
Total power	$177.39

TOTAL MAINTENANCE — LOCATION B $599.09