RADIO ENGINEERING
MOBILE RADIO
TRANSMISSION
AUXILIARY BASE TRANSMITTER OPERATION

CONTENTS PAGE

1. GENERAL

1.01 This section reviews the radio and land-line transmission considerations for the design of mobile telephone systems using an auxiliary base transmitter(s) in addition to the main transmitter. This arrangement may be required in locations where satisfactory base-to-mobile coverage from a single transmitter is impractical due to limitations of available base station sites or unfavorable terrain features. With two transmitters serving different parts of one service area it will usually be impossible to avoid some overlap of coverage. Where this overlap occurs, a mobile receiver is exposed to both signals, resulting in a special case of cochannel interference. This interference can be minimized by adhering to five basic criteria:

(1) The carrier frequencies of the two transmitters must be maintained at a difference of 2 ± 1 Hz from each other.

(2) The transmitter land-line facilities must have equal envelope delay distortion and absolute delay characteristics.

(3) The transmitter land-line facilities must have similar amplitude response characteristics over the frequency range 300-2400 Hz.

(4) The modulation indices of each transmitter must be identical for all levels of modulation over the frequency range 300-2400 Hz. This implies identical modulation limiter saturation and "just start to limit" points.

(5) The equi-signal area between the base stations should be removed from populous or heavily traveled regions.

1.02 Cochannel interference between two FM or PM carriers of comparable intensity and frequency will produce a beat note of the difference frequency. If the modulation of the two transmitters differs as to the time domain and/or modulation index, the receiver output will contain beat frequencies, intermodulation, and distortion products. With voice-modulated RF carriers the output may be garbled and the output is commonly called "hash" because the signal components producing it are not readily distinguishable. This "hash" degrades the intelligibility of the signal to varying degrees depending on the relative signal field intensities of and degree of difference between the signals producing it. In severe cases, useful reception is impossible.

1.03 Simultaneous transmitter operation may be circumvented by using automatic transmitter switching which will permit only one transmitter to operate at a time. Such switching is usually controlled by base receivers through a voting logic arrangement based on the received signal level or signal-to-noise ratio. This arrangement generally requires a switching system which is not available as standard hardware.

1.04 In a system using simultaneous operation of multiple transmitters, carrier frequencies must be maintained within several cycles of each other to avoid annoying beat notes. Adequate transmitter frequency stability can be achieved by using optional high stability oscillators.

1.05 Another method of achieving carrier frequency synchronization utilizes a centrally generated audio tone to phase-lock the transmitter carrier frequencies. This method has not been standardized.

1.06 The MJ/MK control terminals provide an option for controlling one auxiliary base transmitter in addition to the main base station transmitter. This section, therefore, will limit its consideration to two-transmitter systems only, although the principles involved can be applied to systems of more than two transmitters.

1.07 The information and recommendations in this section represent current judgment on a topic which is not subject to hard-and-fast rules. The section should be used as a guide with local conditions determining specific application.

2. APPLICATION

2.01 A decision to employ an auxiliary site should not be made lightly, because of the attending increase in system costs. It is important to note that the only compensation derived is that of enlarged coverage; traffic handling capacity is not affected.

2.02 The FCC is concerned about indiscriminate use of simultaneously operated transmitters. One reason is the likely degradation of service where competent attention to the technical aspects is lacking. In view of this, applications for authority to construct auxiliary transmitters should include a showing not only of the need for added coverage but also of the steps being taken to avoid transmission impairment. FCC authority must be obtained before making any field tests of auxiliary operation, unless such tests are carried out under the terms of a valid experimental license. A second reason for concern involves Paragraph 21.513 of the FCC Rules regarding the location of the message center for the radio system, and charges for calls placed through the auxiliary transmitter.

2.03 Another primary consideration is that even in a properly adjusted system, some degradation of speech quality may be experienced in areas of equal or near equal signal intensity. Accordingly, it is preferable that such areas not be permitted to fall where customer usage is heavy.

2.04 In situations where terrain features effectively isolate main and auxiliary coverage areas, or where the region in which signals are closely equal in intensity is inaccessible or sparsely traveled, the need for careful attention to the measures outlined in Part 3 is minimized.

2.05 Simultaneous operation with an MK mobile system should be approached with utmost caution. As discussed in Part 3, a principal requirement for satisfactory reception of nearly equal signals is very close correspondence of the two carrier frequencies. This is more difficult to ensure at the higher frequencies of the MK system, primarily because of the threefold increase in the Doppler effect at a receiver in a moving vehicle. A car moving directly toward one transmitter and directly away from the other on a high speed highway could receive signals in the 450-MHz band which differ in frequency by up to 90 or 100 Hz, assuming identical transmitter frequencies. For this reason alone, serious transmission impairment at 450 MHz is much more probable than at 150 MHz.

3. TRANSMISSION THEORY

A. General

3.01 As noted in Paragraph 1.02, voice frequency output of an FM or PM receiver may be seriously degraded when the signals of two (or more) simultaneously operated transmitters are received. The exact nature of and its effect on the intelligibility of the receiver output will vary with the following factors:

(a) Difference in field intensity of the RF carriers at the receiver input

(b) Difference in frequency of the RF carriers at the receiver input

(c) Dissimilarity of modulation of the received signals in the voice frequency range (300-2400 Hz)

(d) Differences in voice frequency propagation time between the base station transmitter land-line facilities (differences in radio propagation time between the base stations and receiver are relatively small, and therefore may be ignored).

3.02 Figure 1 shows some subjective evaluations of speech degradation caused by these factors as observed under controlled laboratory test conditions. Judgments of impairment are plotted against carrier frequency difference, with relative RF signal intensities as the variable parameter. From Fig. 1(B) and 1(C) it is apparent that impairments due to modulations index (transmitted audio level) differences seem practically independent of those due to audio delays, and the presence of one tends to mask the presence of the other. No field data is immediately available for delay equalized audio of different modulation indices. However, mathematical models show significant distortion introduced at the receiver if modulation index differences of greater than 2 dB exist on delay equalized signals. Therefore, if both delay and modulation index differences exist, each must be corrected to achieve significant improvement.

3.03 The data shown by Fig. 1 are applicable if the mobile unit is stopped and no signal reflecting objects in the vicinity are moving. Aircraft in flight or large van trucks moving nearby may cause fluctuations of RF amplitude and apparent received phase or frequency. Similar effects would result if the vehicle were in motion, and may be likened to the effect seen and heard on a TV signal when an airplane is in the area of the receiving antenna.

B. RF Signal Levels

3.04 In areas other than flat open country, the signal from a ***single*** base transmitter to a mobile station normally experiences widely varying received field intensities. The mobile unit is usually out of sight of the transmitting antenna and the signals that get to it may travel over several different paths, each having a different attenuation and RF phase delay. The net result is a series of peaks and valleys as the signals over the different paths combine in or out of phase. Figure 2 shows a typical received signal level along 150 feet of street in a relatively flat area with only low buildings and trees. In an urban downtown area with various height buildings, water tanks, metal street light supports, etc, the magnitude of level variations might be on the order of two to four times those shown by Fig. 2. This generally aids auxiliary transmitter operation.

3.05 When a ***second*** or auxiliary transmitter is added, its RF field intensity pattern will be similarly irregular, but not related to the main transmitter field. Where the carrier from one transmitter exceeds the other by about 10 dB, it will "capture" the receiver, to the complete or nearly complete exclusion of the weaker transmitter signal. At another nearby point, perhaps two to six feet away, the relative received power levels of the carriers may be reversed. Either location would provide good quality reception, but between these locations the ratio of the received power levels varies from 10 to 1 at the first to 1 to 10 at the second. If the received power level difference is less than 6 dB with voice modulation, audio intermodulation and distortion products are created. Signal impairment increases to a maximum where the two signal levels are equal.

3.06 The change in speech degradation as described here assumes a series of observations on a stationary receiver at successive points. If the receiver is in motion, even as slowly as 5 to 10 mph, the distortion caused by change of ***levels*** still occurs, but its influence on signal degradation may be partly or completely masked by changes in the carrier ***frequencies*** and the resultant beats caused by Doppler shift. Casual observation from a moving vehicle will not indicate whether the actual fault is RF level difference or frequency difference or both.

C. Radio Frequency Carrier Difference

3.07 Two carriers of identical frequencies and comparable intensity received at a parked mobile station could combine in phase opposition

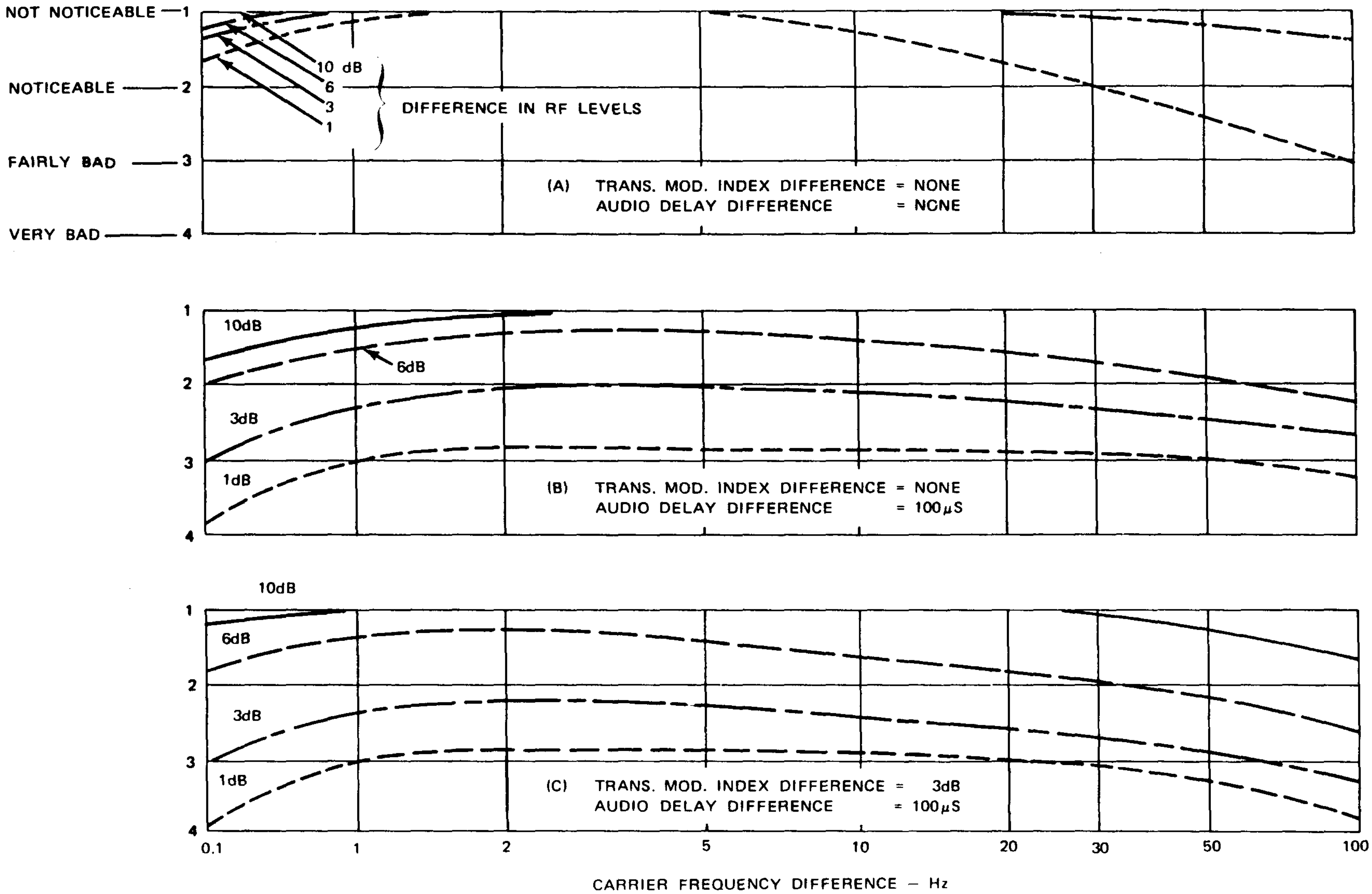

Fig. 1—Subjective Evaluation of Speech Degradation Resulting From Presence of Two Signals at Receiver Input

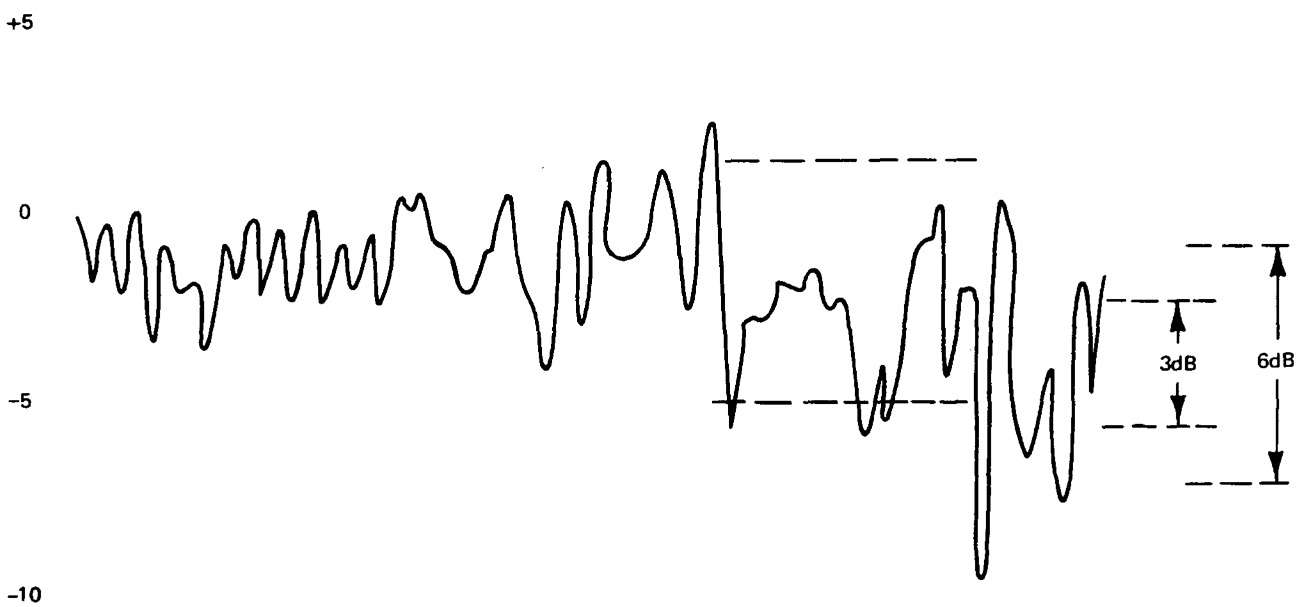

Fig. 2—Variation of 152-MHz Signal Level Along Street in Relatively Level Area

producing essentially complete cancellation. If the frequencies differ slightly, they will produce a beat note at the difference frequency which may be disturbing to the listener. If the frequency difference approaches 100 Hz, limiters or other nonlinear receiver circuits will produce third or higher order distortion products. Many of these products will fall within the voice passband and, when mixed with the desired voice frequencies, can produce severe degradation.

3.08 Transmitters maintained at a frequency difference of 1 to 30 Hz will provide optimum reception at a stationary receiver by preventing complete signal cancellation and limiting distortion. If the receiver is in motion, however, such as in a moving vehicle, the frequency received from each transmitter will be altered by Doppler shift, the worst case being when the direction of travel is on a straight line between transmitter sites. Doppler shift, therefore, places further constraints on transmitter carrier frequency offset.

3.09 For example, a receiver in a vehicle traversing the intersite path described in Paragraph 3.08 at 60 mph will experience a net Doppler shift of about 27 Hz on the two 150-MHz signals. Therefore in order to optimize the received signal quality, transmitter carrier offset ***must*** be limited to between 1 and 3 Hz. A reasonable criterion for carrier frequency offset appears to be about 2 Hz. Under most situations this will cause the net frequency shift to lie within the 1- to 30-Hz limitation.

3.10 Precision frequency control of all transmitters in the system is thus required to maintain this small (2 Hz) frequency differential. MJ base station transmitters are available with a high stability oscillator option having a rated stability of 0.000005% or ± 7.5 Hz at the 150-MHz operating frequency. Field experience indicates that over normal ranges of ambient temperature, the frequency stability of this precision oscillator unit is usually better than ± 1 Hz over a 12-month period. In view of these data, a carrier frequency difference value of 2 ± 1 Hz is suggested. It must be remembered that the objective of precision frequency control in this application is not control of the absolute frequency, but rather, control of the frequency ***difference*** between the two transmitters.

3.11 Perhaps the simplest method of setting the prescribed frequency offset is to station an observer with a receiver for the frequency being adjusted, and some means of communications to both transmitter sites, at a point where the field intensities from both transmitters are equal. After setting one transmitter to the assigned frequency, both transmitters must be placed on-the-air, and the second transmitter frequency adjusted to produce an audible beat of 2 Hz, counted and reported by the observer. It might be wise to note that use of precision frequency counters for the purpose of setting the 2-Hz differential is not advisable due to probable environmental variations between base stations and the resultant possibility of counter error, and the possible introduction of counter error due to counter transportation between locations. Additionally, few counters will read nine significant figures of frequency accurately (eg, 152,750,00*1* Hz).

3.12 With a transmitter frequency difference of 2 ±1 Hz, the undesired condition of zero beat at a mobile receiver is possible only at some single net value of Doppler shift between 1 and 3 Hz depending on the frequency difference of the two transmitters. This value of Doppler shift corresponds to some single value of the component of vehicle velocity parallel to the intertransmitter site line of Paragraph 3.08 between 2 and 7 mph, with the direction of that vehicle velocity toward the lower frequency transmitter. The infrequent case of a net Doppler shift greater than 30 Hz will not cause a sudden deterioration of signal intelligibility in the affected mobile receiver.

D. Modulation-Deviation Level Difference

3.13 Just as intermodulation or beats between unmodulated carriers are inhibited by keeping the carriers at nearly equal frequencies, the ***modulation index*** (ie, frequency deviation) of such carriers should be kept as nearly equal as possible to minimize beats between modulation components of the signals. Control of audio modulation consists of three steps.

3.14 Audio transmit channels from the control terminal to each transmitter should be amplitude ***response*** equalized to within 1.5 dB ***of each other*** from 300 to 2400 Hz. An example of proper amplitude response equalization is shown in Fig. 3. The object of this equalization is ***similarity of response*** of the two channels, not how flat they are. Note that the absolute losses of the two channels need not be equal (Fig. 3) since the transmitter line terminating units contain variable pads to compensate for absolute level differences. For each radio channel it is preferable that these audio channels be provided on similar facilities, whether cable pairs, aerial, underground, or buried, or carrier channels of a given type of carrier, so that equalization will be simplified and variations in frequency and time domain response due to ambient conditions will tend to be similar, thus maintaining the uniformity achieved in the initial equalization.

3.15 With the equal amplitude response audio signals delivered to the transmitters, it is then necessary to adjust the modulation limiter controls (IDC controls on KS/Motorola base station transmitters) of each transmitter to saturate at the same modulator audio input level. This input point is ***after*** any line level controls on the input trunk terminating unit or LTU. With 1000-Hz tone at sufficient level (1 volt rms across the transmitter microphone terminals on Motorola and GE transmitters) to provide saturation of the modulation limiter, each transmitter should be adjusted to precisely the same saturated modulation index (frequency deviation). The saturated value of deviation would be the maximum permissible deviation for the frequency employed. In the MJ system (150 MHz), for example, this value would be ±5 kHz.

3.16 To maintain modulation index (frequency deviation) equality at other than saturated limiter levels, the "just start to limit" point of the transmitter limiters must be set to coincide. Using the line level adjustment on the line terminating unit, Motorola and GE transmitters should be adjusted for identical "just start to limit" points of ±3.3 ±0.2 kHz frequency deviation with 1000 Hz sent from the control terminal at the manufacturer's standard line-up level for producing such a deviation. In the case of the KS IMTS terminal, this level is −4 dBm at the TRSG LINE IN jack. The "just start to limit" point on other transmitters may be detected using a deviation display oscilloscope and observing the point where a minute amount of distortion on the test tone trace appears.

E. Audio Transmission Time Delay

3.17 When the audio input to one transmitter is delayed with respect to the other, the resultant frequency deviation of one carrier is similarly delayed with respect to the other. The instantaneous RF signals are then at different frequencies, and beats will be generated by their interaction. These beats will consist largely of sum and difference frequencies of the non-identical voice frequency components occurring at a given instant and will fall in or near the voice frequency band. Their presence in the audio passband is detrimental to the intelligibility of the modulation

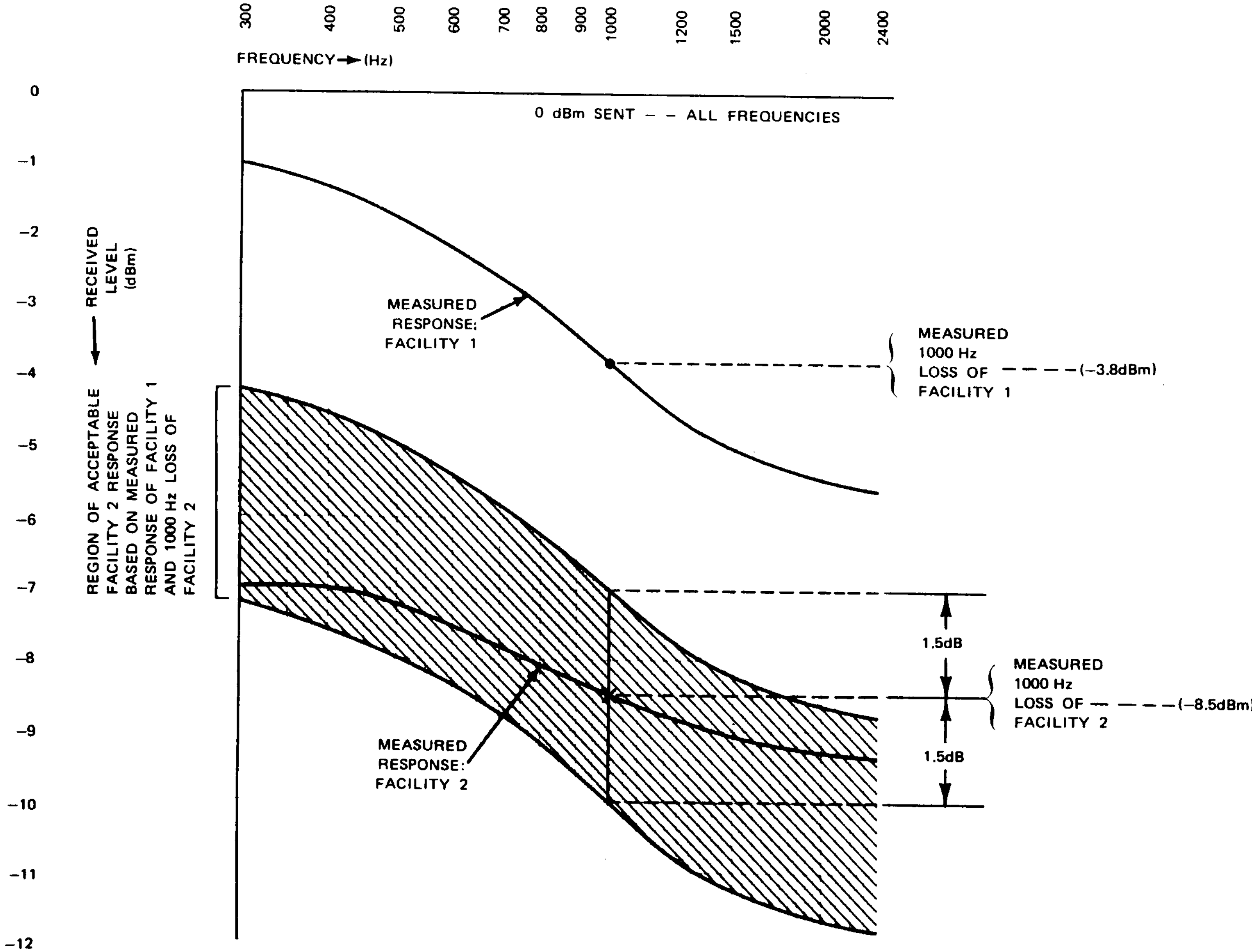

Fig. 3—Measured Amplitude Response of Equalized Transmitter Land-Line Facilities

transmitted and may best be subjectively classified as noise or hash.

3.18 Figure 1 shows a subjective evaluation of voice frequency degradation for an audio frequency delay difference of 100 μs. Field tests indicate that absolute delay differences of less than 60 μs over the voice frequency range of 300 to 2400 Hz will ensure satisfactory transmission, provided the other factors discussed in this section are adjusted and controlled within the limits prescribed. Methods of achieving delay equalization for the transmitter audio land-line channels should be discussed with the local data transmission engineers, since the same equipment and procedures used to delay equalize data facilities are used to delay equalize these audio channels.

3.19 It is important to note that in data applications it is desirable to equalize the envelope delay distortion (ie, the delay at various frequencies of transmission) of the data channel to provide equal delay at all frequencies of transmission over the facility. It is only essential, in the auxiliary transmitter case, that the absolute delay of all transmitter audio channels serving a given radio channel be equal at any frequency in the audio passband. For example, it is not necessary that the absolute delay of transmission of frequency "A" be equal to the absolute delay at frequency "B" on any one facility. However, it is essential that the absolute delay of frequency "A" on facility "1" be equal to the absolute delay of frequency "A" on facility "2." To achieve this in practice it is necessary to cause the envelope delay distortion across the voiceband of facility "2" to be the same (though not necessarily flat) as the envelope delay distortion of facility "1."* This achieved, it only remains to add flat delay equalization until absolute delay is equalized at any one frequency in the voiceband. Since the channels have the same envelope delay distortion, absolute delay must then be the same at ***all*** frequencies of interest.

3.20 In the event that J41646 series "FS" remote signaling units are employed to permit the use of carrier on one but fewer than all of the transmitter audio channels, the transmission delays introduced by these units must be considered in the total delay of the system. In the case of all audio channels having FS units, a uniform delay will be introduced into each audio path resulting in a net difference in introduced delay of zero.

*As in the case of amplitude response, this is most easily achieved if similar transmission facilities are used in each transmitter audio channel.

3.21 On-location testing of the delay equalized system is necessary to achieve proper lineup and system performance. The appropriate testing and lineup procedures described in Part 4 require personnel at the control terminal, each transmitter location, and at the same observation site used to adjust carrier offset frequencies as described in Paragraph 3.11. These personnel must be deployed simultaneously. Note, however, that measurement of only the envelope delay of the transmission facilities may be performed with personnel only at the sending and receiving end of the facility under test.

3.22 It is implicit throughout the foregoing discussion that transmitters with similar modulator and multiplier stages will be used. Use of nonsimilar units would necessitate equalization of the delay and amplitude responses of the transmitters in addition to the connecting circuitry. It is not our intent to describe this procedure.

4. DELAY EQUALIZED AUDIO FACILITY LINEUP

A. Description

4.01 Before any attempt is made to effect the on-location testing described in Paragraph 3.21, the following steps should be completed.

(a) Determine an equal field intensity point per Paragraph 3.11.

(b) Set the transmitter carrier frequency offsets per Part 3C.

(c) Estimate the necessary absolute and envelope delay equalization requirements for each transmitter audio facility. Connect the delay equalization components into the various audio facilities as estimated.

(d) Verify the equality of envelope delay times between the various audio facilities. This test should be coordinated with the data engineers. Verification of the absolute delay of the facilities is not possible with presently available test equipment.

(e) Verify the various facility audio amplitude response characteristics per Part 3D.

(f) Set transmitter modulation controls per Paragraphs 3.15 and 3.16.

4.02 Final adjustment of the system consists of the following steps.

(a) With field forces deployed per Paragraph 3.21, the transmitter carrier frequency offset is checked per Paragraph 3.11, and the individual transmitter modulation indices are checked per Paragraphs 3.15 and 3.16. After the offset and frequency deviations have been ascertained to be correct, the radio field intensity, and audio level as received at the equi-signal observation point are recorded for each transmitter in the system.

(b) Voice tests are made with calculated value of delay in the circuits. The amount of delay is changed by small increments and the audio polarity of one station is reversed for each value of delay. If the effect of the reversal is to severely degrade or attenuate the received audio, the delay equalization is nearing proper adjustment. Proper adjustment occurs with the best audio "canceling" effect occurring with the reversal. For an in-depth discussion of this procedure, refer to Appendix A of this section

(c) The results of (b) above are logged and/or plotted to the field observation point to show the contrast resulting from the polarity reversals.

(d) The results are then analyzed to select that increment of delay equalization which provided the greatest contrast of transmission with reversal of polarity.

(e) In the event that reversal of polarity produces a better signal at the receiver, the audio facility may have been improperly polarized. The facility should be permanently connected to provide the ***best*** signal level and quality.

B. Procedure

4.03 Each mobile telephone transmitter and wire line must meet normal individual transmission requirements before any attempt is made to improve transmission by delay equalization. Throughout the system, each item that affects transmission quality must be verified. This requires that carrier offsets are adjusted per Paragraph 3.11, and modulation indices are equalized per Paragraphs 3.15 and 3.16.

4.04 Careful planning, coordination, and thorough preparation beforehand are essential; otherwise, the transmission contrast which is sought during this procedure will be masked by discrepancies in the performance of the stations and variations in the transmission evaluations of different persons.

4.05 This procedure is based on the assumption that the absolute and envelope delay characteristics have been computed, measured, and analyzed as covered in Paragraph 4.01 and Part 3E.

4.06 The following procedures should be used for delay equalizing the audio facilities serving simultaneously operating transmitters in mobile telephone systems. There are two methods: (1) voice modulation and (2) tone or noise generator modulation. Either method produces proper results, but when there are enough base stations or radio channels to justify the necessary preparation, the second method produces quicker measurements.

4.07 The following equipment is required for this procedure.

(a) A mobile radiotelephone unit adjusted for correct operation on the assigned frequency for the system

(b) A volume indicator arranged to measure audio output from the mobile observation receiver

(c) An arrangement to measure the relative strength of radio signals received at the mobile observation receiver

(d) A tape recorder with a suitable prerecorded tape for test transmission (see Paragraph 4.13). The need for a recorded test message depends on the number of circuits to be equalized.

(e) Audio oscillator

(f) Noise generator equipped with a network for C message weighting

(g) Volume indicator arranged to measure audio input to the system during tests at the control terminal

(h) Two switching keys wired to reverse tip and ring conductors. Each key should be equipped with suitable test cords for patching into each line circuit.

4.08 The entire procedure is directed from the mobile unit which is located per Paragraph 3.11.

4.09 At the mobile unit, the strength of the received radio carrier signal should be measured during alternate operation of each individual radio base station. The mobile unit can easily be positioned at a point where an equal signal strength is received from each separate station by reading a microammeter connected into the first limiter grid circuit of the FM receiver.

> ***Requirement:*** The mobile observation receiver must be at a location at which the same strength carrier signal is received from each base station operated individually.

4.10 A 1000-Hz test tone is applied at the control terminal. It should be employed at such a level that the "just start to limit" point (see Paragraph 3.16) is achieved. Each transmitter must be operated individually and modulated by the same test tone while the volume indicator is used to measure audio output at the mobile receiver.

> ***Requirement:*** At the mobile unit, the audio output level from reception of each station separately must be the same ± 1 dB.

4.11 The requirements shown in Paragraphs 4.09 and 4.10 must be met before proceeding further toward delay equalization. If the audio signals received are not approximately equal, some fault is indicated in the line circuits to each station, or in the radio transmitter, which must be corrected.

4.12 The reversing keys are patched into the transmitter audio facilities at a point after any level adjusting devices but before any dc loop or simplex voltages are applied.

4.13 The tape recorder is patched into the control terminal at a point that is common to the entire system. The prerecorded tape should include the following.

(a) Announcement that a test is being conducted

(b) An indication of the amount of delay that is to be used in the delay equipment. This may be announced manually if desired.

(c) An indication of the position of the reversing key (normal and reversed)

(d) A 10- to 15-second passage of speech and/or tone/noise material (recorded at a uniform level) for normal and reverse positions of the key during each step of delay value employed.

4.14 At the control point, the radio transmitters are both turned on, the tape recorder is started, and the instructions on the tape are monitored and followed as to the delay setting and the position of the reversing key.

4.15 At the mobile unit, the simultaneous modulation of both radio transmitters by the tape recording is monitored and a chart or log record is kept showing an evaluation of each transmission in terms of received audio level contrast between conditions of opposite polarity. When the delay is equal for both stations, audio cancellation will occur with reversed polarity and some reinforcement may be noticeable with normal polarity. A contrast of 10 to 20 dB can be expected from cancellation, while reinforcement will only amount to about 2 or 3 dB.

4.16 Having selected the delay setting causing best cancellation, a test for voice quality and clarity is made by having someone speak to the mobile observation unit. A small readjustment of delay values may produce more favorable results in which case the readjusted value should be retained.

4.17 If cancellation occurred in the normal position of the reversing key, then the audio input lead to the radio transmitter at one of the stations being equalized should be reversed to make the polarity normal throughout the system.

4.18 When all wiring is completed, a further test is made with voice modulation of both transmitters from the control point while the mobile unit is driven through the entire area of interaction between the adjacent stations for overall evaluation of the results.

4.19 The value of delay that is used during these tests should cover at least 50 microseconds above and below the point of maximum contrast, so that the test can be carried through to select the delay increment that is nearest to the center of several increments which provide a contrast with a change in polarity.

4.20 Whenever a good contrast or polarity effect is not detected, a larger increment of delay such as 100 microseconds should be used.

4.21 After changing delay by a major increment as in Paragraph 4.20, the steps covered in Paragraphs 4.13 through 4.16 are repeated as necessary until the correct setting produces an unmistakable contrast with a change in polarity.

4.22 When using tones as a modulation medium, care must be exercised so as not to set the delay equalizers where, although proper reaction is obtained from the given tone, the voice band is not delay equalized. Proper performance may best be ascertained by performing the test with a second, nonharmonically related tone.

C. Maintenance

4.23 To provide the necessary facility maintenance records, the envelope delay characteristics of each line that has been delay equalized must be recorded in a suitable form (for example, that shown in Fig. 4). This information should be retained with the circuit layout card.

4.24 Circuit order work which causes changes in the delay or in the polarity of the audio line will immediately degrade transmission to mobile units in the area between base stations. Degradation of quality may also be due to changes or aging in the radio equipment and associated audio modulation circuits. To keep maintenance expense at a minimum, circuit order work must be coordinated with the radio engineers so that the effects of rearrangement of facilities can be evaluated beforehand. If the facilities are changed for any reason, complete realignment of the delay equalization should be effected.

4.25 Routine tests for satisfactory delay equalization should be scheduled at intervals of three to six months, depending on local seasonal temperature variation—the greater the temperature variation, the lesser the interval. An observer in a mobile unit should check the equalization using much of the same procedure as during the delay equipment lineup above, except that no adjustments are made in the delay equipment during these tests.

4.26 Routine tests should be made throughout the equi-signal interaction area. A strong contrast is expected to result when the polarity of the audio circuit to one of the transmitters is temporarily reversed during a test call. As long as reversed polarity makes transmission ***obviously*** worse for voice messages than normal polarity, the delay equalization may be considered to be satisfactory.

4.27 No unauthorized changes should be made in the adjustment of the delay equipment. The performance of all circuit elements should be verified and any required delay readjustments should be reconciled before delay equalized circuits are rearranged.

5. SUMMARY

5.01 Simultaneous operation of two base transmitters in a mobile system will usually be satisfactory if the system is maintained as follows.

(a) Transmitter carrier frequencies to differ by 2 ± 1 Hz, using high precision oscillators

(b) Relative audio amplitude response characteristics of audio channels from control terminal to each transmitter should be within 1.5 dB of each other from 300 to 2400 Hz.

(c) Absolute delay characteristics of channels from control terminal to each transmitter should be within 60 microseconds of each other from 300 to 2400 Hz. Proper lineup is described in Part 4B of this section.

(d) Maximum frequency deviation and "just start to limit points" of each transmitter at 1000 Hz to be as close to coincidental as possible.

(e) Periodic tests per Part 4C are effected to detect system degradation.

5.02 The values of frequency, levels, and delay prescribed herein are largely empirical, based on limited observations in the field and in the laboratory. Future experience may indicate that some limits are more restrictive than necessary, but they can readily be met with available hardware. There would be little if any economic gain obtainable by relaxing objectives from the prescribed limits.

CIRCUIT LAYOUT RECORD OF ENVELOPE DELAY

THE FOLLOWING DATA SHOULD BE RETAINED WITH THE CIRCUIT LAYOUT LINE CARD.

RADIO LINE NUMBER: C.O. DATE:

DELAY INFORMATION

	CALC (1)	ACTUAL
LINE (2)		
EQUIP (3)		
FAC TOTAL		
DLY NTWK		
SYS DES VAL		
SEAS VAR		

NOTES:
1. AT 1000 CYCLES
2. INCL CARRIER TERMS
3. INCL RPTRS, COILS, FLTRS, EQLZRS, ETC.

LINE EQUALIZERS:

LOCAL DELAY NTWK:

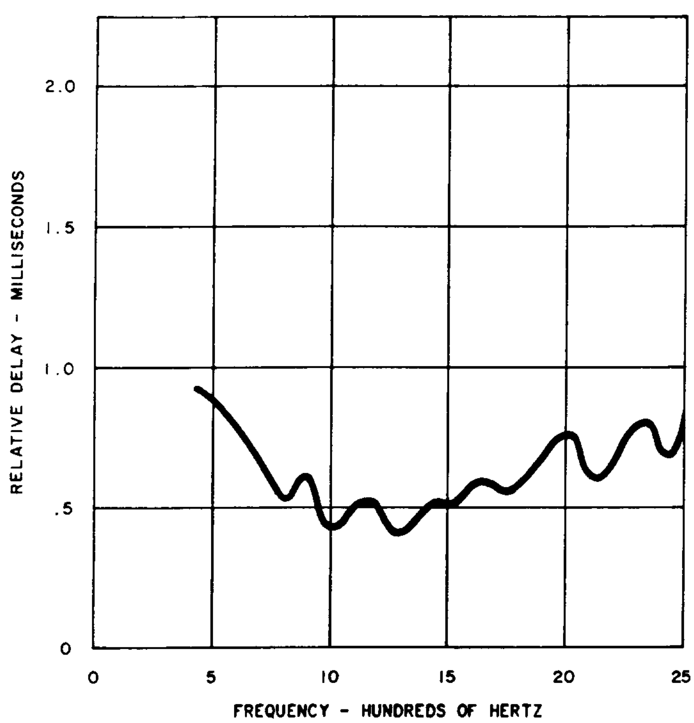

Fig. 4—Circuit Layout Record of Envelope Delay

APPENDIX
AUDIO SIGNAL POLARITY EFFECTS

A.01 Facility design requirements as outlined in Part 3E are directed toward providing equal audio signals. These signals should produce identical modulation simultaneously at both stations. This can be accomplished by adjusting lines to each station to equal relative loss and by building out each line to provide equal delay. A similar envelope pattern must be provided across the voice-frequency band. Once this is done, the modulation at each radio station should be identical and simultaneous. Reversing the tip and ring conductors (audio signal polarity) at one of the adjacent stations should produce an effect at each station that is directly opposite and simultaneous.

A.02 Figure A.1 illustrates the effect on received level in dBm of varying the delay time of one facility while that of the other is held constant. Equalization in this case occurs with 2250 microseconds delay added to one line. The change in received level due to reversal of audio polarity at one transmitter is also illustrated. It can be seen that equalization within ± 50 microseconds of the "true" value is effective.

A.03 Figure A.2 illustrates the change in circuit merit of the received speech signals as a function of receiver location for various conditions of delay and audio polarity.

A.04 Both Fig. A.1 and A.2 show the importance of correct audio polarity. Polarity may be determined only with a receiver located per Paragraph 3.11. When a change in audio polarity at one transmitter produces the changes shown in Fig. A.1 and A.2, proximity to proper equalization is indicated.

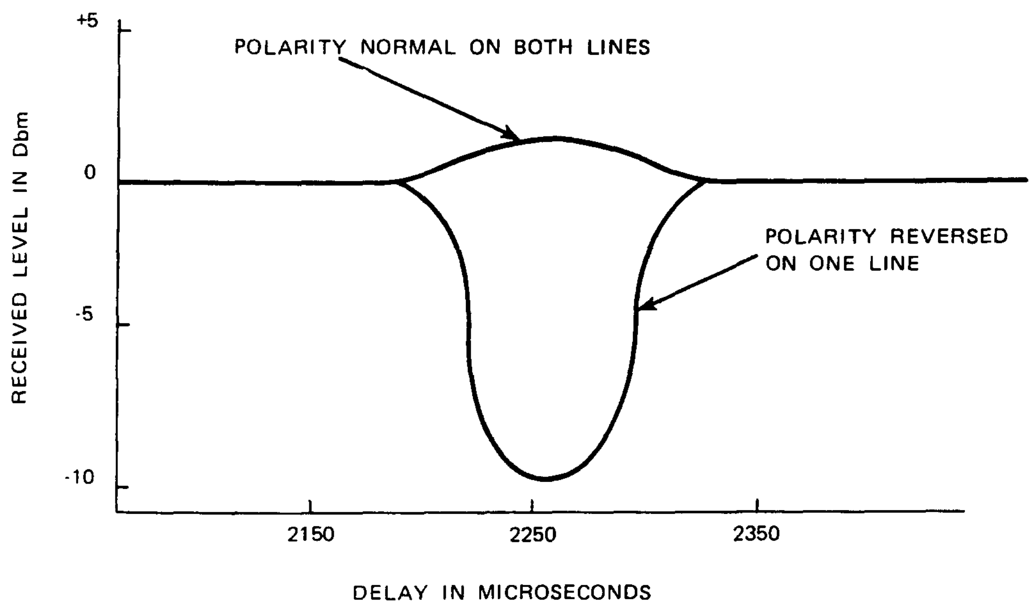

Fig. A.1—Polarity Effect Using 1000-Hz Tone

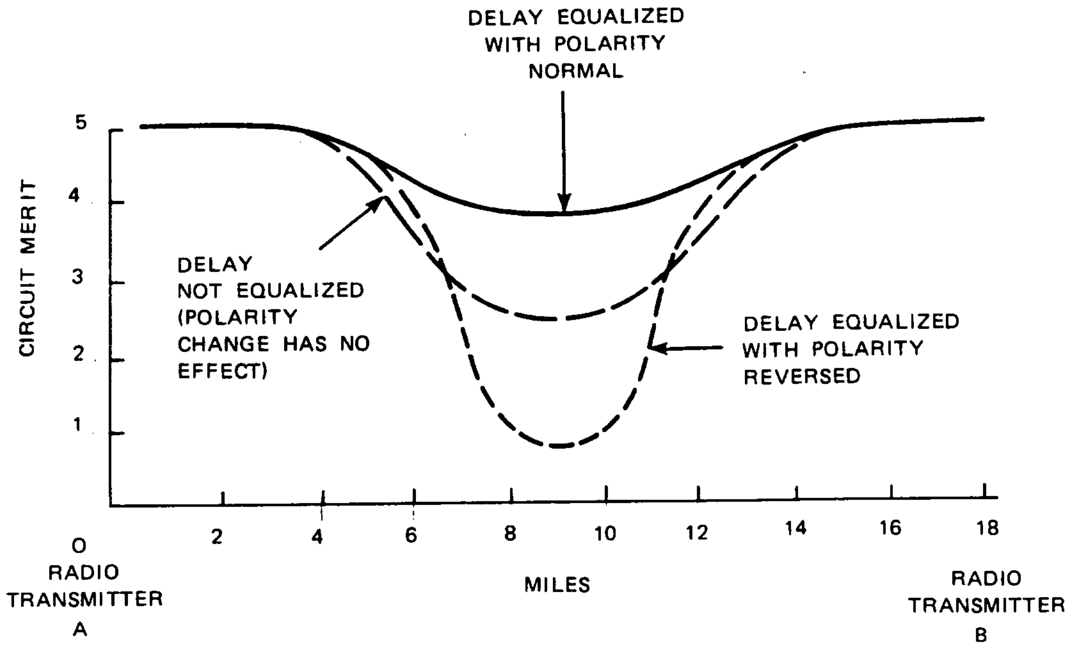

Fig. A.2—Effect of Polarity on Voice Transmission