ENVELOPE DELAY DISTORTION
OVERALL TD SYSTEM TEST
COMMON MICROWAVE RADIO

CONTENTS PAGE

1. GENERAL

1.01 This section contains the procedures for making envelope delay distortion (EDD) measurements on radio channels equipped with TD-type radio bays. It also contains basic procedures for envelope delay distortion trouble investigation and isolation. Procedures are given for using either the KS-20548, L1, L2 test set manufactured by Hewlett-Packard or the KS-20548, L7, L8 test set manufactured by Siemens.

1.02 This section is reissued to add Parts 5 and 6 and Fig. 3, 4, and 5 and to revise Tables A, B, C, D, E, H, I, K, L, and M. Revision arrows are used to denote significant changes. The Equipment Test List is not affected.

1.03 Below is a list of definition of terms provided for this section.

(a) Envelope delay distortion is the departure from constant time delay over the RF and IF passband.

(b) Intermodulation noise refers to the undesirable second-order (eg, A+B) and third-order (eg, A+B−C) products of baseband signal components produced in the radio system as a result of envelope delay distortion across the RF and IF frequency bands.

(c) Waveguide moding is the conversion from the dominant mode to a higher-order mode in the circular waveguide.

(d) Positive envelope delay slope is the rise of the delay trace at frequencies above the channel center frequency as compared to that portion of the delay trace at frequencies below the channel center frequency.

(e) Negative envelope delay slope is the rise of the delay trace at frequencies below the channel center frequency as compared to that portion of the delay trace at frequencies above the channel center frequency.

(f) Positive parabolic delay is the turning upward of the delay trace at frequencies above and below the channel center frequency.

(g) Negative parabolic delay is the turning downward of the delay trace at frequencies above and below the channel center frequency.

(h) The 315A and 918C equalizers have a negative parabolic delay characteristic and are used to correct for positive parabolic delay distortion.

(i) The 319G, -H, and -J equalizers have a specific value of either positive or negative envelope delay slope and are used to equalize the envelope delay slope distortion on TD-2 and TD-3D channels installed on TD-2 routes.

(j) The 918A, 918B, 919A, and 920A equalizers have a specific value of either positive or negative envelope delay slope and are used to equalize the envelope delay slope distortion on TD-3, TD-3A, and TD-3D channels installed on TD-3 type routes.

(k) The prefix nano (n) is used in this section for the multiplier 10^{-9}.

Example: 1×10^{-9} seconds = 1 ns

1.04 The envelope delay distortion test uses the following principle. At the transmitting end, a swept signal over a 16-MHz band (relative to the channel center frequency) is applied to the radio channel. Frequency modulated onto this swept signal is a low-level 277.778-kHz subcarrier, whose modulation index is controlled by the operator. At the receiving end, the test set demodulates the swept signal and examines the phase shift of the subcarrier as it is swept across the band. The test set then visually displays on an oscilloscope screen the channel envelope delay distortion characteristic. The horizontal axis of the display is calibrated in frequency. Frequency markers are usually used to indicate specific frequencies along the horizontal axis. Envelope delay distortion in nanoseconds is displayed vertically on the screen. The operator at the sending end has control of the sweep width. To avoid interference into adjacent channels, care must be exercised so that the sweep width does not exceed ±8 MHz. Although other subcarrier frequencies are available in the KS-20548, L1, L2 test set, 277.778 kHz is a Bell System standard for use in the envelope delay distortion test and the test requirements are based on its use.

1.05 The long-term stability of the radio channel transmission characteristic can be monitored by measuring periodically the channel envelope delay distortion characteristic. A camera should be used or a tracing should be made to record the envelope delay distortion trace for future reference. There will be some hourly and day-to-day variations in the measured delay, and these short-term variations are normal. Short-term variations may affect the ripples of the delay characteristic. For example, a previously identified ripple may shift slightly in amplitude (have a different peak-to-peak height) and/or phase (occur at a different horizontal position on the screen). Fading along the route may also cause short-term variations in the delay trace. Long-term variations, which may occur seasonally and which normally affect all of the channels in the switching section, will appear as shifts of the ripple pattern and/or changes in the delay slope of the envelope delay distortion characteristic. If the delay characteristic changes appreciably over the long term, it is advisable to re-equalize the radio channel, particularly for minimum slope, using the procedures specified in this practice. In some cases, the periodic monitoring of a channel envelope delay distortion characteristic may disclose a trouble condition that has occurred since the last measurement was performed. In such situations, the problem should be located and corrected before any changes are made in the equalization.

1.06 Envelope delay distortion measurements are necessary or useful for the following reasons:

(a) To determine if mop-up parabolic delay equalization is needed on a new radio channel and, if it is needed, to determine the number of equalizers required for installation in the radio bays

(b) To determine if mop-up delay slope equalization is needed on a new channel and, if it is needed, to determine the type and number of equalizers required

(c) To locate defective RF and IF components which are in the signal path, especially in new installations, and to evaluate the performance of the antenna system and air path

(d) To check the time stability of the system transmission characteristic

(e) To identify and isolate trouble conditions that may occur in the system

(f) To help in the interpretation of noise-loading test results.

1.07 The complex envelope delay distortion characteristic typically measured on a radio channel is difficult to accurately project to a resulting transmission impairment such as intermodulation noise or baseband shape. Due to this uncertainty, when establishing limits there is a tendency to lean toward the conservative side. This action is justified considering the complexity of the radio route makeup (types of equipment, number of switching sections, etc). Nevertheless, the limits specified in this section are the maximum which can be tolerated while still maintaining the overall (4000 miles) system transmission objective. Therefore, emphasis must be placed on the importance of accurate test set calibration of both horizontal and vertical axes. An error in calibration may result in an incorrect interpretation of the data. In addition, the measuring equipment must be set to the specified bandwidth because when measuring ripple amplitude, the bandwidth of the delay test set has a direct influence upon the observed ripple amplitude.

2. EFFECTS AND CHARACTERISTICS OF ENVELOPE DELAY DISTORTION

2.01 The departure from constant time delay over the RF and IF passband of a radio channel is called envelope delay distortion. In an ideal radio channel, one without envelope delay distortion, the propagation time for all components of the frequency-modulated signal is constant. However, when envelope delay distortion is present in the transmission path, some of the sideband components in the signal are delayed in time relative to the carrier and other sideband components. These delayed components introduce amplitude and phase distortions into the signal which result in intermodulation noise when the signal is demodulated to baseband by the FM terminal receiver. Both amplitude and phase distortion of the signal must be held within limits if the system intermodulation noise objectives are to be met.

2.02 Because of the complex nature of the modulated FM carrier, there is no simple method of determining the exact intermodulation noise from a complicated envelope delay distortion characteristic. However, it is possible to find from the measurement, by inspection, several predominant components of the envelope delay distortion trace, each of which contribute differently to the intermodulation noise. Basically, there are three envelope delay components—delay slope, parabolic delay, and delay ripple—that must be analyzed on an individual basis. This step is often difficult as the envelope delay slope, ripple, and parabolic characteristics are combined as a complex trace. However, by utilizing available features of the envelope delay test sets, the analysis task is made easier and more accurate. The KS-20548 envelope delay receiver is equipped with a bandwidth switch on the group detector with selectable positions of 1, 5, and 10 or 2, 4, and 10 kHz. When analyzing the envelope delay trace for parabolic or slope distortion, the switch should be in the 1- or 2-kHz position. In this position the higher-order ripple components are filtered out, leaving only the lower-order components, thus making the envelope delay parabolic and slope components easier to analyze. When analyzing the envelope delay trace for ripple, the switch must be in the 4- or 5-kHz position.

2.03 The residual, unequalized delay slope is likely to be the largest single contributor to system intermodulation noise. For example, with 1500-message circuit loading, a delay slope of 1 ns over a ±8 MHz band centered at the channel center frequency, which is a slope of 0.0625 ns/MHz, will produce 3 dBrnc0 of noise in the top message circuit. The noise increases on a voltage basis as the delay slope increases. For example, a 12-ns slope over the ±8 MHz band, or 0.75 ns/MHz, which would not be unusual for a 5-hop switching section, will cause approximately 25 dBrnc0 of noise in the top message circuit. The intermodulation noise objective for five hops is approximately 19 dBrnc0. Thus, the delay slope must be kept well equalized if its contribution to the system noise is to be kept acceptably low.

2.04 Normally, some delay slope will be present in all radio channels before delay equalization is applied. The amount of slope is dependent on the antenna and waveguide system, the channel separating or combining networks in the immediately preceding radio bay, the tuning of the tube-type transmitting amplifier in TD-2 and TD-3D, and temperature change. The delay slope in each channel is equalized in each switching section using fixed delay slope mop-up equalizers. ♦Originally on a TD-2 route equipped with either TD-2 or TD-3D bays, the delay slope equalizers (319-type) were mounted in a mop-up equalizer bay at each receiving main station. In order to control the baseband response with increased circuit loading, it has been found necessary to limit the amount of accumulated delay slope distortion. Therefore, as explained in paragraph 2.05, the delay slope equalizers are now distributed along the route as required.♦ On a TD-3 route equipped with any of the various TD-3 type bays, the 918A, 918B, 919A, and 920A equalizers are used and likewise are distributed along the route.

2.05 ♦Solid-state circuits that have replaced tube-type circuits in the TD-2 receiver and transmitter have a small but significant amount of amplitude modulation (AM) to phase modulation (PM) conversion. An investigation of baseband response and intermodulation noise problems revealed that with the solid-state TD-2 transmitter, the total AM-to-PM conversion of the radio repeater has been increased to the point where changes are necessary in the administration of the delay equalization. Allowing large amounts of delay slope to accumulate before it is equalized in a system having AM-to-PM conversion in each of its active circuits can result in excessive baseband rise or roll-off at the end of the switching section. Lumping the delay slope equalization at the end of the switching section satisfactorily equalizes the delay slope of the channel and thereby removes that component of intermodulation noise caused by the delay slope alone. However, the lumped delay equalization cannot correct for the baseband rise or roll-off, or for the intermodulation noise, that has resulted from the combined effects of the AM-to-PM conversion and delay slope along the radio line. Finally, and this is perhaps one of the most important points, the lumped delay slope equalizers will convert some of the FM sideband power into AM sidebands. This resulting amplitude modulation of the carrier, going into the various AM-to-PM converters in the repeaters of the next switching section, can cause substantial baseband rise or roll-off in the overall tandem switching-section connection. This effect is never seen in the normal radio system testing which involves measuring and equalizing only each individual switching section. However, it can result in out-of-limit transmission levels and noise at the multiplex terminals and the accompanying frustration of trying to locate the problem when each individual switching section within the message unit radio (MUR) appears satisfactory. All of these problems can be eliminated by distributing the delay slope equalization along the radio line rather than lumping it at the receiving end, and by restricting the maximum amount of delay slope equalization that can be used at any one location. For the same reasons, a distributed delay slope equalization plan has always been used on TD-3 radio routes (using TD-3, TD-3A, and/or TD-3D TR bays).♦

2.06 Parabolic delay distortion is not a major source of intermodulation noise in TD radio channels. Parabolic delay distortion followed by a circuit having high AM-to-PM conversion can produce excessive intermodulation noise. However, by either the use of circuits with low AM/PM conversion or careful design of transmission paths to minimize the unequalized parabolic delay distortion preceding a unit with high AM/PM conversion, this mechanism becomes unimportant as a source of noise in the TD system. The intermodulation noise caused by parabolic delay distortion is maximum in the top supergroups. For 1500-message circuit loading, the maximum noise is equal to −10 dBrnc0 for a parabolic delay distortion having a magnitude of 1 ns at ±8 MHz from the channel center frequency. The noise increases on a voltage basis as the amplitude of the distortion increases. As an example, assume that there is a residual parabolic distortion of 5.5 ns at ±8 MHz points for every three radio hops. The noise due to this seemingly large unequalized distortion is only 4.8 dBrnc0. In 30 hops, which corresponds to an approximate 800-mile system, there would be ten times as much distortion, 55 ns, and the noise would be increased by 20 dB, to 24.8 dBrnc0. This is approximately 11 dB below the total system noise expected for an 800-mile, 1500-message circuit channel. Thus, as illustrated by this example, parabolic delay distortion does not have to be well equalized to keep its intermodulation noise contribution sufficiently low.

2.07 The principal reason for equalizing the parabolic component of the delay distortion in each IF switching section to the fullest extent practical is to ease the determination of the required delay slope equalization. Delay slope, as noted previously, is the major source of intermodulation noise and therefore must be minimized. Experience has shown that the presence of a substantial parabolic component, together with the usual superimposed array of delay ripples, makes it difficult to estimate the delay slope component that must be equalized. Therefore, the parabolic component of the envelope delay distortion trace must always be the first component equalized. In TD channels, the 315A (TD-2) and 918C (TD-3, TD-3A, TD-3D) equalizers are used to equalize the parabolic delay component.

2.08 Envelope delay distortion produced by an echo (reflection) or equivalent echo-type mechanism in the signal path will appear as sinusoidal ripple in the measured envelope delay distortion characteristic. Because many small echo paths are encountered within a multihop radio channel, the envelope delay characteristic will display the net effect of all the echo paths. Therefore, a normal delay trace will usually show several randomly spaced ripples of unequal peak-to-peak amplitude. Only if a serious transmission irregularity is present will a single sinusoidal ripple be the outstanding component on a measured envelope delay distortion trace.

2.09 The effects of delay ripple upon live loads (mainly message) is beyond the scope of this practice. However, based on known relationships that exist between the deviated FM carrier and ripple characteristics, reasonable projections may be made as to the effects of such ripple upon the signal in terms of intermodulation noise, thus providing the basis for the limits specified in this practice. A small amount of delay ripple will always be present. The envelope delay distortion ripple requirement is intended to allow delay ripple that is normally present on a radio channel. A trouble condition may cause the delay ripple to exceed this requirement.

2.10 Some sources of envelope delay distortion ripple include the following:

(a) Abnormalities in the waveguide such as dents, punctures due to bullets, foreign objects present, or defective rigid or flexible waveguide sections

(b) Poor return loss of IF components in the radio bay or in the IF cable trunks in the office

(c) Multipath propagation due to radio path fading, reflections, or other transmission problems in the air path

(d) Mode conversion from the dominant to a higher-order mode and back to the dominant mode in the circular waveguide and antenna system

(e) Mode trapping in the circular waveguide sections.

3. SOURCES OF DELAY DISTORTION

A. Parabolic Delay Distortion

3.01 Some of the components of the TD radio transmitter and radio receiver introduce, into each hop, a parabolic component of envelope delay distortion. These components are:

(a) Channel networks (TD-2, TD-3, TD-3D)

(b) Waveguide bandpass filters (TD-2, TD-3, TD-3D)

(c) 416 tube cavities in the transmitter amplifier (TD-2, TD-3D).

Although the channel networks and filters used in TD-3A are self-equalized, some minor variations do occur due to normal manufacturing tolerances. Thus, there may still be some slight distortion contributed by those networks and filters.

3.02 When the tube-type transmitter amplifier is replaced by a solid-state unit, the distortion due to the tube-type unit will disappear because the solid-state unit is broadband and thus contributes no distortion.

B. Delay Slope Distortion

3.03 There are several expected sources of linear delay distortion, commonly termed delay slope, in each TD radio channel. Three of these sources, common to each of the TD bays, are the antenna waveguide system, the channel separating or combining network in the immediately preceding radio bay in a standard bay lineup, and temperature change. The first two sources are predictable and, by means of suitable system modeling, can be taken into account in estimating the amount of delay slope equalization required in a multihop switching section. The third source is a variable which may cause seasonal changes in the delay slope of each channel. In addition, the tube-type transmitter amplifier used in TD-2 and TD-3D bays might be expected to contribute a random variation in the residual delay slope of a channel over a period of time. The replacement solid-state amplifier, being broadband, has no effect on delay slope.

3.04 The antenna system's circular and rectangular waveguides contribute a negative delay slope at RF across each radio channel. This delay slope arises because the velocity of propagation in the waveguide is not constant but instead increases with increasing frequency. The magnitude of the slope, which is proportional to the length of the waveguide, diminishes with increasing frequency. At 3710 MHz, the delay slope is approximately 0.03 ns/MHz per 100 feet of WC281 circular waveguide and 0.035 ns/MHz per 100 feet of WR229 rectangular waveguide. The delay slopes are approximately one-half these amounts at 4170 MHz. The delay slope distortion introduced by the antenna waveguide system accounts for about one-half of the negative slope that can be expected in a typical hop.

3.05 The second expected source of delay slope arises from the through-path delay characteristic of the channel separating and combining networks. In a standard transmitter-receiver bay lineup, the bays are installed in ascending frequency order from the main antenna, with channel 1 or 7 at the antenna end and channel 6 or 12 at the other end. Within each lineup, the receiving channels are separated by 80 MHz, as are the transmitting channels. With this arrangement, each transmitted channel, except the first, passes through the channel combining network of at least one succeeding transmitter before reaching the antenna waveguide run. Similarly at the receiving end of the hop, each received channel, except the first, passes through at least one preceding channel separating network. The networks for the channels further removed in frequency do not contribute any additional delay slope. Therefore, in a standard fully-equipped bay lineup, all channels except the first have an expected slope component due to the channel networks in the immediately adjacent bay in the lineup at each end of the hop. Since this delay slope is negative at RF, it adds directly to the negative slope contributed by the antenna system waveguide.

3.06 The third source of delay slope is temperature change, particularly as it affects the waveguide channel bandpass filters and networks. A change in temperature causes a small change in the center frequency of each filter or network due to the dimensional changes that occur in the cavity elements. This change in center frequency causes the broad, principally parabolic shaped, delay distortion characteristic of the filter to shift in frequency relative to the parabolic shape of the 315A or 918C equalizer, which is almost unaffected by temperature. The net effect, when the shifted filter characteristic is added to the unshifted equalizer characteristic, is a residual, approximately linear delay component.

3.07 The switching-section equalization is very dependent upon the operating temperature and humidity conditions of the microwave networks and filters. To minimize equalization changes due to ▶humidity variations, dry air is supplied to the indoor waveguide runs serving bay lineups equipped with TD-3, TD-3A, and/or TD-3D bays.◀ In addition, invar rather than copper has been used in the construction of the 1418-type channel networks and 1322-type bandpass filters used in TD-3 bays to minimize the effects of temperature variations.

3.08 Temperature change can be expected to cause seasonal variations in delay slope. If initially the switching section is perfectly equalized, an increase in temperature at one or more stations will result in a positive residual delay slope at RF. A decrease in temperature will produce a negative residual delay slope at RF. Delay distortion is measured at IF. At IF, the direction of the slope is the same as at RF for those channels having the local-oscillator (LO) frequency below the channel center frequency (channels 3, 4, 5, 6, 9, 10, 11, and 12). For channels having the local oscillator frequency above the channel center frequency (channels 1, 2, 7, and 8), the direction of slope observed at IF is opposite to that occurring at RF. Thus, in the summer months, it would not be unusual to find a negative slope on channels 1, 2, 7, and 8 and a positive slope on all other channels if all channels had been perfectly equalized in midspring at a time when the ambient temperature was close to the annual average.

3.09 As mentioned before, for TD-2 and TD-3D bays, another expected source of delay slope originates in the tube-type transmitter amplifier. Measurements on a number of the amplifiers show that, on an average, each amplifier introduces a positive slope (at RF) of 0.08 ns/MHz. These measurements also showed that the magnitude of the delay slope can vary considerably with the setting of the amplifier tuning adjustments. Thus, the tube-type transmitter amplifiers constitute a source of delay slope variation in each switching section as tubes are replaced and the cavities are retuned.

3.10 Figure 1 shows the delay characteritic of the 315A parabolic equalizer used in TD-2 radio channels. ➧As can be seen, the equalizer has, in addition to a negative parabolic slope, a delay slope of approximately 7 ns between 62 and 78 MHz. As noted in Part 4, the slope component of the 315A is an important consideration in the overall distributed delay slope equalization plan for TD-2.➧

3.11 ➧The 918C parabolic equalizer, used in TD-3, TD-3A, and TD-3D channels, has no delay slope component and therefore does not affect the delay slope equalization of the channel.➧

C. Envelope Delay Ripple

3.12 The envelope delay characteristic of any radio channel may contain a large number of ripples having random period and amplitude. Delay ripple is often produced by an echo (reflection) in the IF or RF signal path. A small amount of ripple will always be present, but abnormalities such as foreign bodies in the waveguide, dents or punctures due to bullets, and IF coaxial trunking irregularities may often be identified by the outstanding sinusoidal ripple they produce. Assuming that waveguide runs and IF cabling have been properly installed and maintained, excessive delay ripple may be an indication of a trouble condition in one or more transmitter-receiver bays. If this is suspected, IF return-loss measurements should be made on each unit, including the IF equalizer and IF filters, to locate the defective unit. If the antenna or waveguide is suspected, RF return-loss measurements should be made on the waveguide system to locate the irregularity.

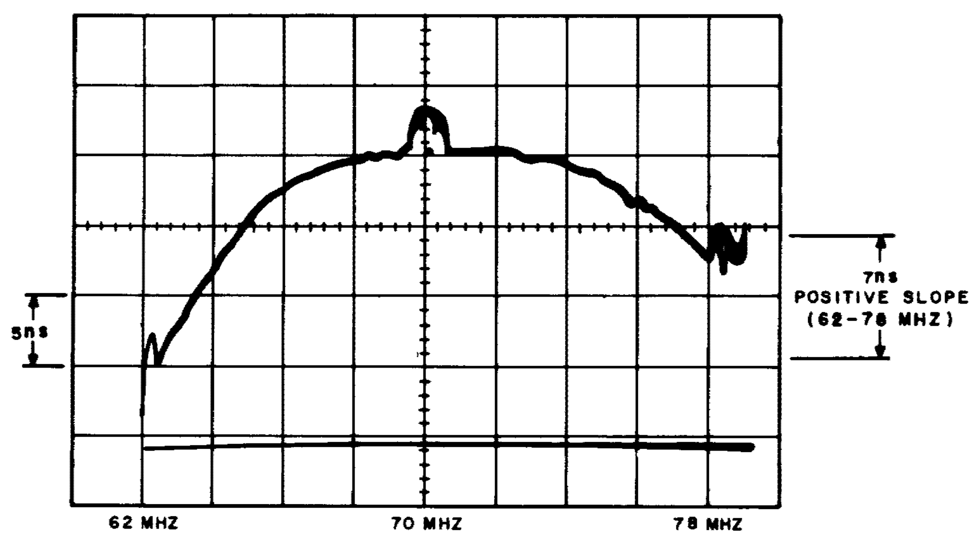


Fig. 1—Characteristic Shape of the 315A Negative Parabolic Equalizer

3.13 The envelope delay characteristic of the 574A filter used in TD-2 radio, exhibits a delay ripple of up to 3 ns peak to peak. The delay ripple is additive on a hop basis and plays a significant role in determining when proper equalization is achieved. When proper slope and parabolic equalization have been applied to radio channels equipped with the 574A filter, the accumulative delay characteristic of the 574A filter will stand out on the delay trace as a low-frequency ripple. As shown in Fig. 2, this low-frequency ripple will be referred to in this practice as primary ripple.

3.14 Antenna multimoding can cause ripple in the envelope delay response which will not show up when performing the RF return-loss measurement. All channels may have ripple or other irregularities caused by conversion of dominant mode (TE_{11}) signal energy into the first higher-order mode (TM_{01}) that can propagate in the circular waveguide runs. Radio channels 5, 6, 11, and 12 can exhibit additional distortions caused by waveguide moding not found in lower-frequency channels sharing the same circular waveguide due to conversion of energy into the second higher-order mode (TE_{21}), which can propagate in the circular waveguide above approximately 4080 MHz. Envelope delay ripple produced by moding may take on a uniform ripple characteristic or may be a few ripples or appear as a suck-out of energy in a specific area of the delay trace. Envelope delay ripple producing mechanisms at lower channel frequencies may or may not produce moding in the higher-frequency channels. Likewise, mechanisms producing moding in high-frequency channels may or may not cause envelope delay ripples in the lower-frequency channels.

3.15 The mechanical deformation and misalignment of the inside surface of the circular waveguide determine for the most part which channel or channels are affected by moding problems and to what degree. This type of fault is more often noticeable on an envelope delay ripple characteristic than on a return-loss characteristic. This is due to the fact that energy converted to a higher-order mode can flow only in the circular waveguide, and of this energy which is reconverted to the dominant mode, only a small portion may be returned as a reflected-type signal that will affect a return-loss measurement.

3.16 Round-trip, higher-order mode echo is the mechanism whereby energy is converted from the dominant to a higher-order mode at the top of the circular waveguide run (horn-reflector and/or flexguide) and then travels down the waveguide in the direction of the polarizing networks. The energy traveling in this spurious mode is then reflected at the bottom of the waveguide run, returns to the top,

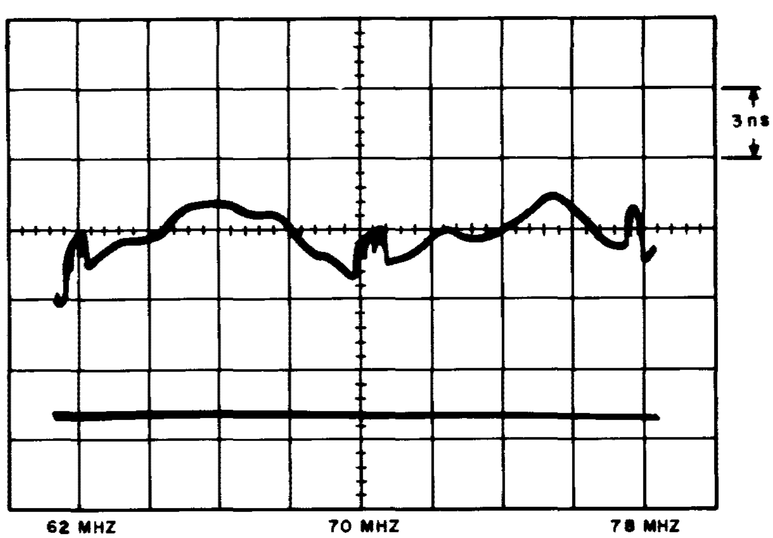


Fig. 2—Characteristic Shape of the 574A IF Filter Used in TD-2 Radio

and is reconverted to the dominant mode. Differential higher-order mode echo involves conversion of energy from the dominant mode to a higher-order mode at one end of the circular waveguide and reconversion of some of this energy to the dominant mode at the other end of the circular waveguide. Both of these echo-producing mechanisms can occur in both the transmitting and receiving waveguides. The envelope delay ripple characteristic produced by either of these forms of moding is, for most cases, a fairly uniform ripple period and amplitude across any 20-MHz radio channel. The ripple period, which may be anywhere from 1 to 10 MHz or greater, that results from this type of moding depends on which of the two mechanisms and higher-order modes are involved and on the length of the circular waveguide run. The ripple amplitude is dependent on the mode conversion and reconversion losses that are encountered.

3.17 Trapping is a particular form of high "Q" echo in which a small portion of the frequency band of a generated higher-order mode cannot be propagated. Trapping can occur within the circular flexguide, or within the solid circular waveguide between the circular flexguide and the polarizing networks. All that is required to trap a mode is a section of circular waveguide having an effective (electrical) diameter that is larger than the diameter of the waveguide on either side of that section. The frequency at which trapping can occur is the lowest frequency at which the higher-order mode can exist in the particular section of waveguide. This frequency, termed the cutoff frequency, is directly dependent on the effective diameter of the waveguide section. In the 4-GHz band, trapping may occur in the vicinity of 4080 MHz, which is the nominal cutoff frequency for the TE_{21} mode in WC281 waveguide. Thus channel 11B, centered at 4070 MHz, and channel 5B, centered at 4090 MHz, may be affected by mode trapping. The mechanical tolerances of waveguide are such that above about 4098 MHz, all of the rigid and flexible sections of the circular waveguide should be above cutoff and mode trapping should not occur. The envelope delay ripple characteristic produced by this form of moding results in sharp notches or a suck-out of energy at a specific frequency on the envelope delay trace.

4. GENERAL DESCRIPTION OF EQUALIZATION PLANS

TD-2

4.01 The positive parabolic delay distortion of the radio channel is equalized by the use of 315A equalizers. ➧The 315A was designed originally to be used in each radio receiver to equalize the delay distortion introduced by the tube-type circuits in the receiver and preceding transmitter. For this reason, the 315A not only provides a parabolic shape but, as stated in paragraph 3.10, has a delay slope of about +0.5 ns/MHz which was built-in to compensate for slope contributed by the tube-type circuits. Solid-state TD-2 receivers and transmitters have reduced the residual parabolic delay distortion of each hop and have eliminated the delay slope component that was being introduced by the tube-type circuits. As a result, the 315A is now needed in approximately every third radio hop to equalize the parabolic delay distortion. However, everywhere the 315A is used it also introduces its built-in delay slope (+0.5 ns/MHz). This slope adds to or subtracts from the delay slope appearing at IF from the other sources of delay slope previously described, depending on whether the channel has a high or low LO frequency. Under the new equalization plan, described in the next section, the slope component of the 315A is taken advantage of for the low LO channels but is equalized for the high LO channels.➧

4.02 The envelope delay slope characteristic of the channel is corrected by the use of 319-type delay slope equalizers. These equalizers are added or removed according to the plan given in Part 5.

TD-3

4.03 Each radio bay is equipped with a basic amplitude and delay equalizer which should make each radio hop exhibit a flat delay characteristic. Residual parabolic distortion may be present in some radio channels. This is due to a slight difference between the delay distortion characteristics of some basic equalizers and some of the microwave networks and filters. This distortion can be reduced by distributing 918C parabolic mop-up equalizers along the radio route.

4.04 The residual delay slope distortion in a radio channel is brought within limits by distributing 918A, 918B, 919A, or 920A mop-up delay slope equalizers along the radio route as described in Part 6. Provision is made for mounting one mop-up equalizer (of any type) in each radio receiver.

TD-3A

4.05 Microwave networks and filters are self-equalized and thereby avoid some of the problems associated with the use of a basic equalizer at IF. Still, some delay slope and parabolic distortion will be present on the channel due to normal manufacturing tolerances. These distortions, as well as the delay slope introduced by the antenna waveguide system and channel networks, are equalized by distributing 918C parabolic mop-up equalizers and 918A, 918B, 919A, and 920A mop-up slope equalizers along the radio route as described in Part 6.

TD-3D

4.06 The initial TD-3D radio bays were factory-equipped with a 918C equalizer for the intended purpose of equalizing the expected parabolic delay distortion of the radio hop. However, tests showed that the parabolic delay distortion is equalized adequately using, on an average, two 918C equalizers for every three radio hops. Therefore, the equalizer is no longer shipped with the bay but instead is considered to be a mop-up equalizer. The proper number of equalizers are distributed along the route as described in Part 6.

4.07 The delay slope in each channel is equalized in each switching section using fixed delay slope mop-up equalizers. The type of equalizers used depends on whether the TD-3D bays are added to existing TD-2 routes or are installed on new or existing TD-3 routes.

4.08 When TD-3D bays are used to build out an existing TD-2 route, the 319-type delay slope equalizers are used. These equalizers are distributed along the route according to the plan given in Part 6.

4.09 For existing TD-3 or new TD-3D routes, the 918-, 919-, and 920-type delay slope equalizers are used and are distributed along the route as described in Part 6.

5. ♦DISTRIBUTED DELAY-EQUALIZATION PLAN FOR TD-2 RADIO CHANNELS

5.01 This distributed delay-equalization plan replaces the equalization plan that was previously used with TD-2 in which all delay slope equalization required for each radio channel was installed (i.e, "lumped") at the receiving end of the switching section. The reasons for distributing the delay slope equalization are discussed in paragraphs 2.04 and 2.05.

5.02 In this plan, the delay slope equalization required for each channel in a switching section is distributed along that channel in accordance with the following rule:

> The maximum amount of delay slope equalization that may be installed at any radio receiver location (including at the receiving main station) is ±0.5 ns/MHz.

This rule thus eliminates the use of the 319A (+1.8 ns/MHz), 319B (−1.6 ns/MHz), and 319C (−0.8 ns/MHz) equalizers formerly used in TD-2 and allows only the following to be used:

319G −0.5 ns/MHz

319H +0.5 ns/MHz

319J −0.25 ns/MHz.

Delay slope equalization involving a change of only ±0.25 ns/MHz in the total equalization required is, in general, a final or trimming adjustment made only at the receiving main station. There is no +0.25 ns/MHz delay slope equalizer currently coded in the 319-series, and there is no plan to provide this size. When necessary, a 319H and 319J may be used in tandem in the equalizer panel in the receiving main station to obtain +0.25 ns/MHz of slope equalization.

5.03 As noted in paragraph 4.01, the 315A parabolic delay equalizer has a delay slope component of approximately +0.5 ns/MHz. Because the 315As are distributed along the radio line, their delay slope is used to advantage to provide some or all of the distributed positive delay slope equalization needed in the low LO channels (3, 4, 5, 6, 9, 10, 11, and 12). On the other hand, the positive delay slope of the 315A will add to the expected positive delay slope inherent in the high LO channels (1, 2, 7, and 8). Allowing this to occur would cause excessive delay slope (more than 0.5 ns/MHz per hop) to accumulate in those channels. Therefore, in the high LO channels it is necessary to equalize the delay slope of the 315A and then distribute additional (negative) delay slope to equalize the slope of the radio line. The 315A is delay-slope equalized by connecting it in tandem with a 319G equalizer. To mount the 319G in tandem with the 315A requires an 843364548 bracket and two 840059067 screws. An 842816134 cable assembly is required to interconnect the two equalizers.

5.04 The 319( ) equalizers needed for distributed delay slope equalization of the radio line can be installed only in radio receivers that are not equipped with a 315A equalizer (or a 315A/319G combination). This is because the 319( ) equalizer is mounted where the 315A was previously installed when all receivers were equipped with a 315A. The 319( ) equalizer is mounted in the receiver by means of two 840542187 brackets and two 840059067 screws; thus two of these brackets and screws must be available for each 319( ) equalizer that is to be installed in a radio receiver along the route. No new cable assemblies are required since, electrically, the 319( ) is being inserted where a 315A was previously connected.

5.05 Table A gives an estimate of the number of 315A parabolic-delay equalizers that may be required for each TD-2 channel in the switching section. The estimated number and types of 319-type delay slope equalizers are given in Tables B and C.

A. Equalizer Locations — Channels 1, 2, 7, and 8

5.06 The 315A/319G pairs are installed at locations denoted by P/G-( ) in Fig. 3, starting with location P/G-1 (the radio receiver at the receiving main station) and then in radio receiver location P/G-2, P/G-3, etc, as required.

5.07 The 319G equalizers are installed at locations denoted by S-( ) in Fig. 3, starting with S-1 (the equalizer panel in the receiving main station) and then in radio receiver S-2, S-3, etc, as required.

5.08 If an additional ±4 ns (across 16 MHz) equalization is desired, it can be obtained as shown in Table D.

♦TABLE A♦

NUMBER OF PARABOLIC DELAY EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD CHANNEL IN AN IF PROTECTION SWITCHING SECTION

	NO. OF HOPS IN SWITCING SECTION									
	1	2	3	4	5	6	7	8	9	10
No. of 918C Parabolic Equalizers for TD-3 and TD-3A Bays			1	1	1	1	1	2	2	2
No. of 918C Parabolic Equalizers for TD-3D Bays	1	1	2	2	3	4	4	5	5	6
No. of 315A/319G Parabolic Equalizers for TD-2 Bays in Channels 1,2,7,8		1	1	2	2	2	3	3	4	4
No. of 315A Parabolic Equalizers for TD-2 Bays in Channels 3,4,5,6,9,10,11,12			1	1	1	2	2	3	3	4

♦TABLE B♦

NUMBER OF 319-TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-2 CHANNEL IN A TD-2 ROUTE IF PROTECTION SWITCHING SECTION WHERE THE RADIO BAY IS EQUIPPED WITH A TUBE-TYPE TRANSMITTER (NOTE)						
	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, OR 12	
NO. OF HOPS IN SWITCHING SECTION	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319H +0.5 ns/MHz	319J −0.25 ns/MHz
1				1	1	1
2		1		1	1	1
3		1	1			
4		1	1			
5	1		1	1	1	1
6	1		2			
7	1		2			
8	1	1	2	1	1	1
9	1	1	3			1
10	1	1	3			

Note: This table assumes that a 315A/319G equalizer, (channels 1, 2, 7, and 8) or 315A equalizer (channels 3, 4, 5, 6, 9, 10, 11, and 12) is used in the bays.

B. Equalizer Locations—Channels 3 Through 6, and 9 Through 12

5.09 The 315A-type equalizers are installed at the locations denoted by P/S-( ) in Fig. 4, starting with P/S-1 (the radio receiver at the receiving main station) and then in radio receiver locations P/S-2, P/S-3, etc, as required.

5.10 If after installation of the 315A equalizers, additional positive delay slope equalization is required, and the amount needed is equal to or greater than +0.5 ns/MHz (+8 ns across 16 MHz), add 319H equalizers as required. The 319H equalizers are installed in the P/S-( ) receiver sequence shown in Fig. 4 starting in the next receiver location after the last one used for a 315A equalizer location in paragraph 5.09.

> ***Example:*** Locations 1 and 2 are used for 315As. Therefore, 319Hs can be added starting in location 3 and continuing to 4, etc.

5.11 If after installation of the 315A equalizers some negative delay slope equalization is required, and the amount needed is equal to or greater than −0.5 ns/MHz (−8 ns across 16 MHz), add a 319G equalizer in tandem with the 315A at each location, starting with the numerically highest location in Fig. 4 that was used for a 315A, and continuing in descending order as required.

Example: Locations 1 and 2 are used for 315As. Therefore, the 319Gs can be added starting with location 2 followed (if necessary) by location 1.

Note: Trouble should be suspected if a channel requires more than one 319G added in this manner.

5.12 If an additional ±4 ns (across 16 MHz) equalization is desired, it can be obtained as shown in Table E.

6. DISTRIBUTED DELAY-EQUALIZATION PLAN FOR TD-3, TD-3A, AND TD-3D RADIO CHANNELS

6.01 The distributed delay-equalization plan for the TD-3, TD-3A, and TD-3D radio channels is very similar to the plan used with TD-2 channels. However, one significant difference arises because, unlike the 315A parabolic equalizer used in TD-2, the 918C parabolic equalizer used in the TD-3 type channels does not have any delay slope component. As a result, the same delay slope equalization plan can be used for the high LO and low LO channels. This distribution plan is shown in Fig. 5.

6.02 As stated in paragraphs 4.03 and 4.05, each TD-3 and TD-3A bay includes basic delay equalization, and the 918C equalizer is used only as mop-up for any residual parabolic delay distortion. Thus, the number of 918C equalizers required for these channels is minimal as shown in Table A. Any 918C equalizers that are needed should be mounted in P/S-1 and P/S-2, as required, as shown in Fig. 5. The other P/S-( ) positions would be used for the delay slope equalizers. The estimated quantities required are given in Table F for TD-3 and Table G for TD-3A. For each equalizer required, either an ED-50970-30, G1 mounting kit (TD-3) or an ED-50970-31, G1 mounting kit (TD-3A) is needed for proper mounting of the unit in the bay.

6.03 Unlike TD-3 and TD-3A, the parabolic delay of TD-3D channels is equalized entirely by distributing 918C equalizers along the line. Thus, the estimated quantity of 918C equalizers required for TD-3D are greater than for TD-3 and TD-3A as shown in Table A. Equalizer mounting arrangements in the radio bay permit the mounting of one parabolic equalizer and one delay slope equalizer in each bay. It is suggested that the 918C equalizers be mounted in numerical order, starting with P/S-1, with the delay slopers mounted in numerical order in the same bays as shown in Fig. 5. The 918C parabolic delay equalizer should always be used in TD-3D channels on either TD-2 or TD-3 type routes. An ED-50970-32, G9 mounting kit is required to properly install a 918C equalizer in the TD-3D bay. The kit includes the necessary screws, brackets, and connecting cables.

6.04 For TD-3D channels in TD-2 type stations, it is recommended that 319-type slope equalizers, rather than 918-, 919-, and 920-type slope equalizers, be used for the delay slope equalization. This recommendation does not exclude the use of the TD-3 type slope equalizers in those channels, but just recognizes the coincidental use of the 319-type equalizers in the TD-2 channels in the same stations. Tables H and I list the number of delay slope equalizers expected to be required. For repeater station bays, an ED-50970-32, G11 mounting kit is required for each 319-type equalizer to be mounted in a TD-3D bay. This kit contains the necessary screws, brackets, and cables to permit proper mounting of the equalizers. In main station, it is recommended that the dalay slope equalizers be mounted in the equalizer panel customarily used with TD-2 bays.

6.05 Delay slope equalization for TD-3D channels on TD-3 type routes is done by distributing 918-, 919-, and 920-type equalizers. Tables J and K give the estimated number of slope equalizers expected to be required. An ED-50970-32, G10 mounting kit is required for each 918-, 919-, or 920-type equalizer to be mounted in a TD-3D bay.

♦TABLE C♦

NUMBER OF 319-TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-2 CHANNEL IN A TD-2 ROUTE IF PROTECTION SWITCHING SECTION WHERE THE RADIO BAY IS EQUIPPED WITH A SOLID-STATE TRANSMITTER (NOTE)

NO. OF HOPS IN SWITCHING SECTION	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, OR 12	
	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319H +0.5 ns/MHz	319J −0.25 ns/MHz
1		1		1	1	1
2		1	1		1	
3	1		1	1	1	1
4	1	1	2		1	
5	1	1	2	1	1	
6	2		3		1	1
7	2	1	3	1	1	
8	2	1	4		1	1
9	3		4		1	
10	3		4	1	1	1

Note: This table assumes that a 315A/319G equalizer, (channels 1, 2, 7, and 8) or 315A equalizer (channels 3, 4, 5, 6, 9, 10, 11, and 12) is used in the bays.

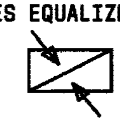
♦TABLE D♦

CONDITION	TO REMOVE	DO THE FOLLOWING
319G at S1 (Equalizer panel)	4-ns positive slope	Add additional 319G on the line per paragraph 5.07 and replace 319G at S1 with 319J.
	4-ns negative slope	Replace 319G at S1 with 319J.
No. 319G at S1	4-ns positive slope	Add 319J at S1.
	4-ns negative slope	Add 319H plus 319J at S1.

SWITCH SECTION LENGTH IN HOPS — LOCATE THE REQUIRED DISTRIBUTED EQUALIZER AT THE RECEIVING STATION OF HOP NUMBER.

SWITCH SECTION LENGTH IN HOPS	1	2	3	4	5	6	7	8	9	10
1	P/G 1 / S1 (NOTES)									
2		P/G 1 / S1								
3	S2		P/G 1 / S1							
4	S2	P/G 2		P/G 1 / S1						
5	P/G 3	S2	P/G 2	S3	P/G 1 / S1					
6	S3	P/G 3	S2	P/G 2	S4	P/G 1 / S1				
7	P/G 3	S3	P/G 2	S2	P/G 4	S4	P/G 1 / S1			
8	S4	P/G 3	S3	P/G 2	S2	P/G 4		P/G 1 / S1		
9		S3	P/G 3	S2	P/G 2	S4	P/G 4		P/G 1 / S1	
10	S5	P/G 3	S3	P/G 2	S2	P/G 4	S4	P/G 5		P/G 1 / S1

NOTE 1: IN A MAIN STATION ONLY,
DENOTES EQUALIZER IN THE RADIO BAY



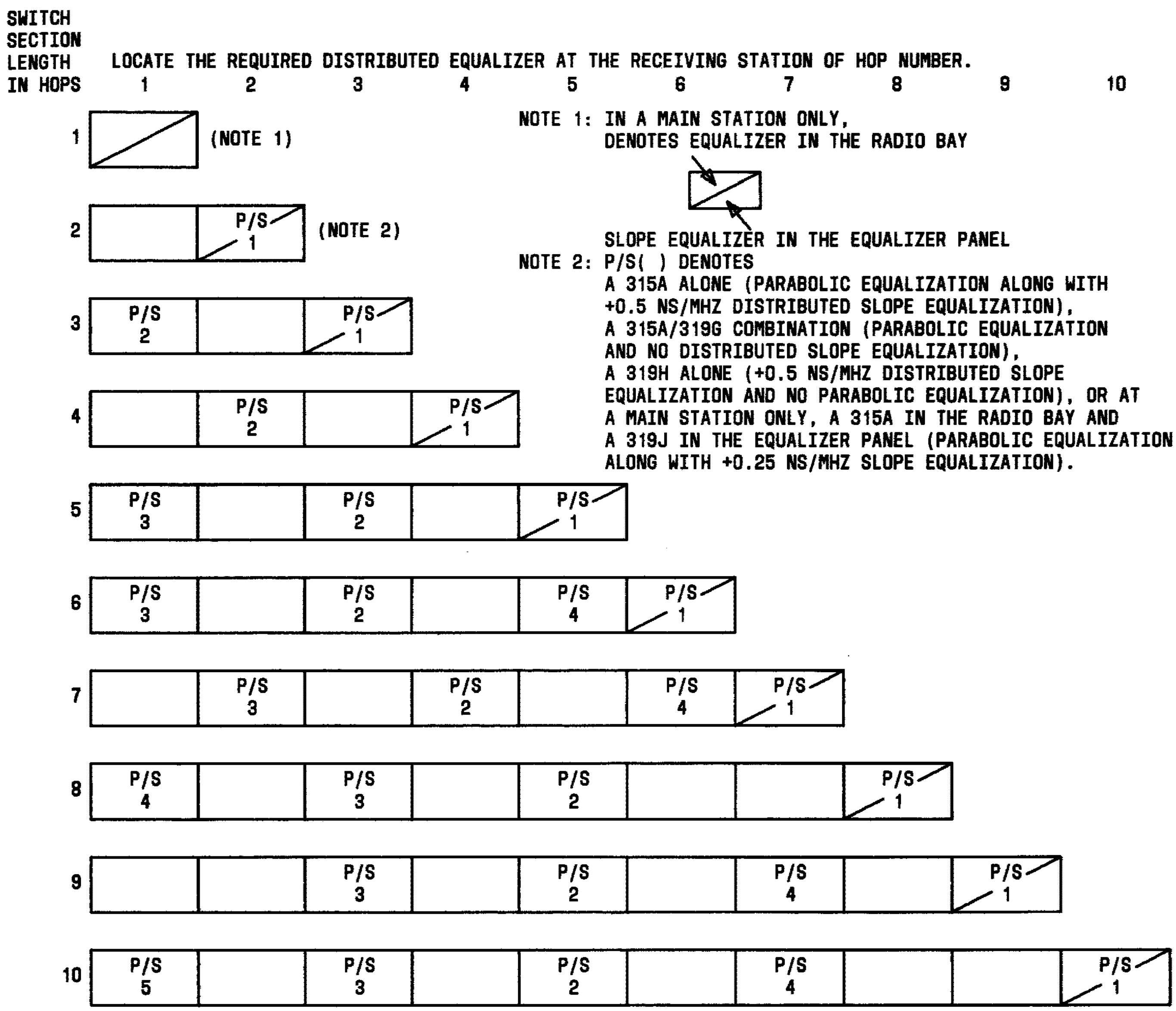
DENOTES EQUALIZER IN THE EQUALIZER PANEL

NOTE 2: P/G( ) DENOTES A 315A/319G EQUALIZER COMBINATION AT LOCATION ( )

NOTE 3: S( ) DENOTES A 319G SLOPE EQUALIZER AT LOCATION ( )

NOTE 4: FOR S1 ONLY, EQUALIZER MAY BE EITHER A 319G OR A 319J

Fig. 3— Equalizer Locations for TD-2 Channels 1, 2, 7, and 8



◆Fig. 4—Equalizer Locations for TD-2 Channels 3, 4, 5, 6, 9, 10, 11, and 12◆

SWITCH SECTION LENGTH IN HOPS	LOCATE THE REQUIRED DISTRIBUTED EQUALIZER AT THE RECEIVING STATION OF HOP NUMBER. 1	2	3	4	5	6	7	8	9	10
1	P/S 1									
2		P/S 1 (NOTES 1 AND 2)								
3	P/S 2		P/S 1							
4		P/S 2		P/S 1						
5	P/S 3		P/S 2		P/S 1					
6	P/S 3		P/S 2		P/S 4	P/S 1				
7		P/S 3		P/S 2		P/S 4	P/S 1			
8	P/S 5		P/S 3	P/S 2	P/S 6		P/S 4	P/S 1		
9	P/S 5		P/S 3	P/S 2	P/S 7		P/S 4	P/S 6	P/S 1	
10	P/S 5		P/S 3		P/S 2	P/S 7	P/S 4		P/S 6	P/S 1

NOTES:
1. P/S DENOTES A 918C PARABOLIC EQUALIZER ALONE, A 918A, 918B, 919A, OR 920A (ALL TD-3 TYPE BAYS) OR 319G, H, OR J (TD-3D ONLY) SLOPE EQUALIZER ALONE, OR FOR TD-3D ONLY, BOTH 918C PARABOLIC EQUALIZER AND A DELAY SLOPE EQUALIZER IN THE SAME BAY.
2. FOR TD-3D BAYS IN TD-2 STATIONS ONLY, THE DELAY SLOPE EQUALIZERS IN A RECEIVING MAIN STATION SHOULD BE MOUNTED IN THE EQUALIZER PANEL.

Fig. 5—Equalizer Locations for TD-3, TD-3A, and TD-3D Channels

♦TABLE E♦

CONDITION	TO REMOVE	DO THE FOLLOWING
315A only at P/S1 (Radio Receiver)	4-ns positive slope	Install 319J in equalizer panel.
	4-ns negative slope	Add 319H on line per paragraph 5.10 and install 319J in equalizer panel.
No. 315A or 315A/319G At P/S1	4-ns positive slope	Install 319J in equalizer panel.
	4-ns negative slope	Install 319H plus 319J in equalizer panel.

TABLE F

NUMBER OF 918-, 919-, AND 920-TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-3 CHANNEL IN A TD-3 ROUTE IF PROTECTION SWITCHING SECTION						
NO. OF HOPS IN SWITCHING SECTION	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, 12 (NOTE)	
	918A −0.5 ns/MHz	918B −0.25 ns/MHz	918A −0.5 ns/MHz	918B −0.25 ns/MHz	919A +0.25 ns/MHz	920A +0.5 ns/MHz
1		1		1	1	
2	1		1	1		1
3	2		2			1
4	2	1	2	1	1	1
5	3		3			2
6	3	1	4		1	2
7	4		4	1		3
8	4	1	5			3
9	5	1	6		1	3
10	6		6	1		4

Note: Channel 3 and 9 bays manufactured before 1968 should be included in the channel 2 or 8 column.

TABLE G

NUMBER OF 918-, 919-, AND 920-TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-3A CHANNEL IN A TD-3 ROUTE IF PROTECTION SWITCHING SECTION

NO. OF HOPS IN SWITCHING SECTION	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, 12	
	918A −0.5 ns/MHz	918B −0.25 ns/MHz	918A −0.5 ns/MHz	918B −0.25 ns/MHz	919A +0.25 ns/MHz	920A +0.5 ns/MHz
1		1		1	1	
2	1		1			1
3	1		1	1	1	1
4	1	1	2			2
5	2		2	1	1	2
6	2	1	3			3
7	3		4		1	3
8	3	1	4	1		4
9	3	1	5		1	4
10	4		5	1	1	4

♦TABLE H♦

NUMBER OF 319-TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-3D CHANNEL IN A TD-2 ROUTE IF PROTECTION SWITCHING SECTION WHERE THE RADIO BAY IS EQUIPPED WITH A TUBE-TYPE TRANSMITTER						
	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, 12	
NO. OF HOPS IN SWITCHING SECTION	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319H +0.5 ns/MHz	319J −0.25 ns/MHz
1				1	1	1
2		1	1		1	
3		1	2		2	1
4		1	2	1	2	
5	1		3		3	
6	1		3	1	4	1
7	1		4		4	
8	1	1	5		5	1
9	1	1	5	1	5	
10	1	1	6		6	1

TABLE 1

NUMBER OF 319–TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-3D CHANNEL IN A TD-2 ROUTE IF PROTECTION SWITCHING SECTION WHERE THE RADIO BAY IS EQUIPPED WITH A SOLID-STATE TRANSMITTER

NO. OF HOPS IN SWITCHING SECTION	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, 12	
	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319G −0.5 ns/MHz	319J −0.25 ns/MHz	319H +0.5 ns/MHz	319J −0.25 ns/MHz
1		1	1		1	1
2		1	1	1	2	1
3	1		2	1	2	
4	1	1	3		3	
5	1	1	4		4	1
6	2		4	1	5	1
7	2	1	5	1	5	
8	2	1	6		6	
9	3		7		7	1
10	3		7	1	7	

TABLE J

NUMBER OF 918-, 919-, AND 920-TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-3D CHANNEL IN A TD-3 ROUTE IF PROTECTION SWITCHING SECTION WHERE THE RADIO BAY IS EQUIPPED WITH A TUBE-TYPE TRANSMITTER

NO. OF HOPS IN SWITCHING SECTION	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, 12	
	918A −0.5 ns/MHz	918B −0.25 ns/MHz	918A −0.5 ns/MHz	918B −0.25 ns/MHz	919A +0.25 ns/MHz	920A +0.5 ns/MHz
1				1	1	
2		1	1			1
3		1	2		1	1
4		1	2	1		2
5	1		3			3
6	1		3	1	1	3
7	1		4			4
8	1	1	5		1	4
9	1	1	5	1		5
10	1	1	6		1	5

♦TABLE K♦

NUMBER OF 918-, 919-, AND 920-TYPE DELAY SLOPE EQUALIZERS REQUIRED, ON THE AVERAGE, FOR EACH TD-3D CHANNEL IN A TD-3 ROUTE IF PROTECTION SWITCHING SECTION WHERE THE RADIO BAY IS EQUIPPED WITH A SOLID-STATE TRANSMITTER

NO. OF HOPS IN SWITCHING SECTION	CHANNEL 1 OR 7		CHANNEL 2 OR 8		CHANNEL 3, 4, 5, 6, 9, 10, 11, 12	
	918A −0.5 ns/MHz	918B −0.25 ns/MHz	918A −0.5 ns/MHz	918B −0.25 ns/MHz	919A +0.25 ns/MHz	920A +0.5 ns/MHz
1		1	1		1	
2		1	1	1	1	1
3	1		2	1		2
4	1	1	3			3
5	1	1	4		1	3
6	2		4	1	1	4
7	2	1	5	1		5
8	2	1	6			6
9	3		7		1	6
10	3		7	1		7

7. TEST PRECAUTIONS

7.01 The following precautions should be adhered to during routine delay equalization of TD radio facilities to ensure that the minimum envelope delay distortion is achieved.

7.02 The receiving switch-section control office should know the number and location of the 315A or 918C parabolic delay distortion equalizers as well as the number, type, and location of any delay slope equalizers that are installed in the channel before making the initial overall equalization measurements on a new channel or remeasuring a previously equalized channel. Form E-6120A has been designed for use by the receiving switch-section control office for recording the number and location of the equalizers in each radio channel in each switching section. When performing switch-section equalization, the envelope delay distortion should be checked at the specified test points without disturbing the equalization already in the channel. Should a change in equalization be required, Form E-6120A should be reviewed in order to determine existing radio channel equalization. In general, the addition of a delay slope equalizer that is opposite in sign to those already being used, thereby negating the slope of a previously installed equalizer, should be avoided.

7.03 Equalization must be accomplished on a switching-section basis. Side-leg channels should be equalized at the same time as the associated normal main route feed.

7.04 Final equalization should be performed only during periods free of fading conditions. For most locations in the U.S.A., the least fading conditions occur from 10 a.m. to 4 p.m. local times. Should there be any indication of a changing delay characteristic during the envelope delay measurements, the test should be stopped and if the condition persists rescheduled for a later date. The varying of the delay characteristic is probably due to fading on the route.

7.05 Always check the envelope delay characteristic of the radio channel after parabolic or delay slope equalizers have been added or removed or when extensive maintenance or modification work has been performed on the radio channel.

7.06 ▶TD-2 and TD-3D radio channels equipped to transmit 45-megabits per second (Mb/s) digital signals include an ADP1 or ADP2 adaptive slope equalizer. This equalizer is used to automatically correct any amplitude slope in transmission through the radio bay. When a signal with a swept carrier, such as used in the EDD test, is applied to the ADP1 or ADP2 equalizer, the control circuit in the equalizer cannot maintain normal control, and this causes an erratic distortion of the signal to occur. This distortion renders the EDD signal unusable. To eliminate this distortion, all ADP1 or ADP2 equalizers on the channel under test must be disabled. This can be done remotely by the alarm center.◀

7.07 Interpretation of the envelope delay trace is, to a large degree, individual judgment. When analyzing the delay trace, one should first look at the entire trace and then mentally separate the components such as parabolic, slope, and ripple. This analysis procedure is necessary in order to minimize the delay distortion and avoid overequalization of the channel.

8. GENERAL TEST PROCEDURES AND REQUIREMENTS

8.01 For uniformity of tests and analysis purposes, it is recommended that the following test points be used. (Service precautions and specified levels must be observed.)

(a) TDAS Switching (Section 410-600-100)

RAD IN (transmitting) (nominal +5 dBm)

RAD OUT (receiving) (nominal +3 dBm)

(b) 100A Switching (Section 420-610-101)

TRUNK IN (transmitting) (nominal −4 dBm)

AMPLIFIER OUT (receiving) (nominal +9 dBm)

(c) 400A Switching (Section 420-620-101)

RAD IN (transmitting) analog FM channel and FM only protection channel (nominal +8.0 dBm)

Protection channel for combined analog FM and 45-Mb/s digital service (nominal +4.0 dBm)

AMPLIFIER OUT (receiving) (nominal +10 dBm)

(d) 45-Mb/s modulator-demodualtor (MODEM)

IF TRK IN (transmitting) (nominal 0 dBm)

IF TRK OUT (receiving) (nominal −7 dBm).

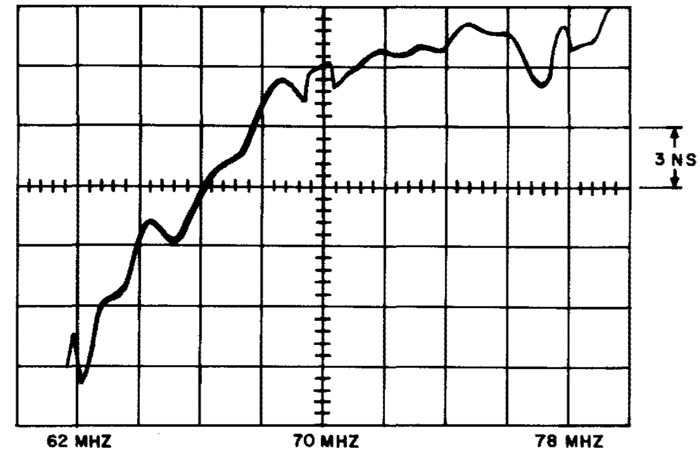
(e) Chart 1 contains the test setup and operation information when using the KS-20548, L1 and L2, distortion test set manufactured by Hewlett-Packard. For detailed information concerning this test set, refer to the manufacturer's instruction manual.

(f) Chart 2 contains the test setup and operation information when using the KS-20548, L7 and L8, sweep generator and selective detector manufactured by Siemens. For detailed information concerning this test set, refer to the manufacturer's instruction manual.

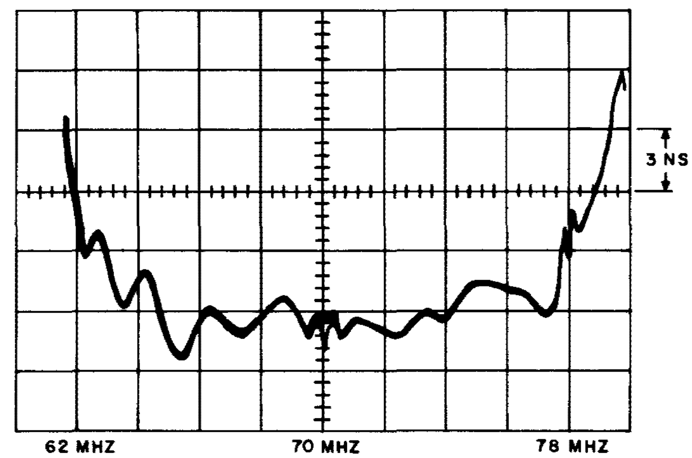
8.02 With the transmitting office sending, the receiving measuring equipment should be terminated on the radio channel. Normally there will be only one receiving point; however, when side-leg channels are involved, it would be desirable to include these channels with their associated main route.

8.03 At the receiving point, record the initial results (preferably with an oscilloscope camera or a suitable overlay on which the display can be traced) and analyze the delay characteristic. Typical presentations are illustrated in Fig. 6, 7, and 8.

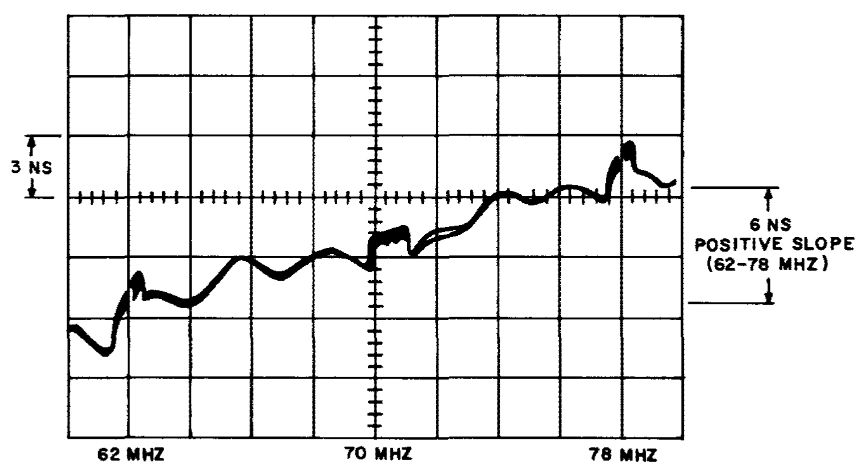
> ***Note:*** It is recommended that the bandwidth switch on the group detector be switched to the 1- or 2-kHz position during parabolic and slope equalization procedures.



TYPICAL ENVELOPE DELAY DISTORTION BEFORE APPLYING CORRECTIVE EQUALIZATION

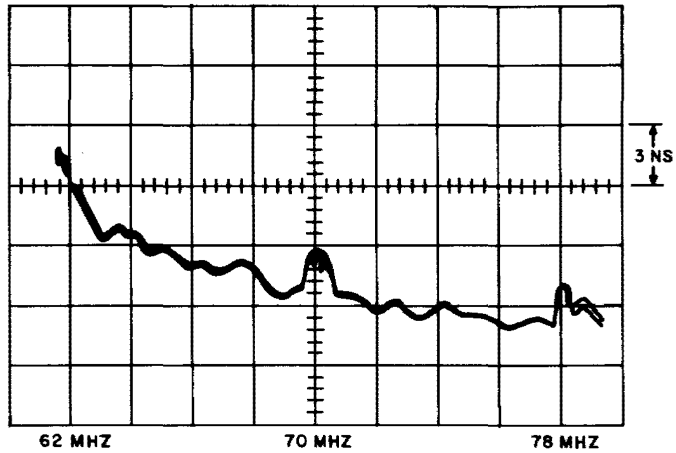


TYPICAL ENVELOPE DELAY WITH POSITIVE PARABOLIC DELAY

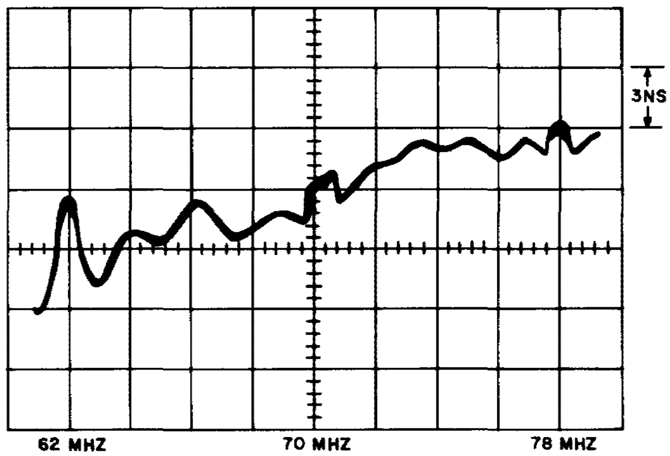


POSITIVE ENVELOPE DELAY DISTORTION (AFTER PARABOLIC DELAY EQUALIZATION)

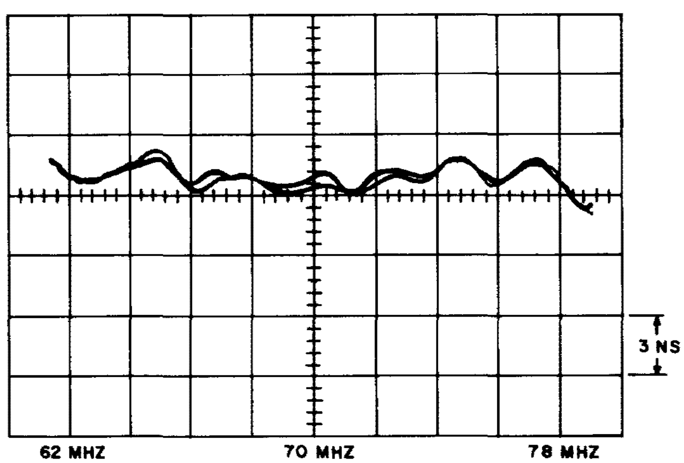
Fig. 6—Typical Envelope Delay Presentations With Parabolic Delay



TYPICAL ENVELOPE DELAY WITH NEGATIVE DELAY SLOPE



TYPICAL ENVELOPE DELAY WITH POSITIVE DELAY SLOPE



TYPICAL ENVELOPE DELAY CHARACTERISTIC (AFTER DELAY EQUALIZATION)

Fig. 7—Typical Envelope Delay Presentations With Delay Slope

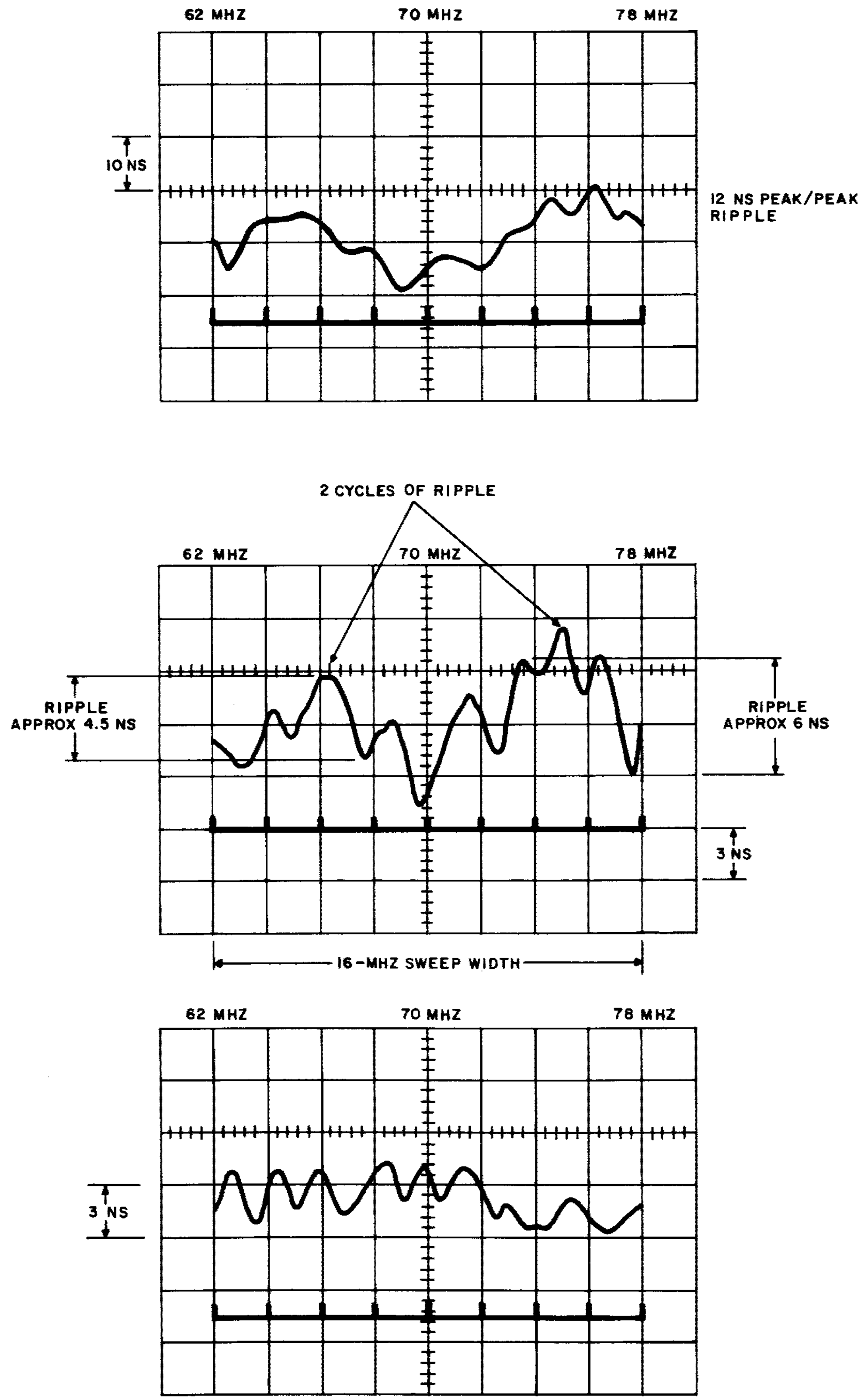


Fig. 8—Typical Envelope Delay Presentations With Delay Ripple

A. Parabolic Delay

8.04 The parabolic distortion is the first delay component to be equalized. For the initial parabolic equalization of a new radio channel (new TD-3D or reused TD-2, TD-3, TD-3A bays), it is suggested that 315A or 918C parabolic equalizers as required, in the applicable quantity specified in Table A, be installed along the route during the initial lineup and testing on the individual TR bays. The equalizers should be distributed along the route as directed in Part 5 or 6. For subsequent switch section equalization tests, it should only be necessary to add or remove one 315A or 918C equalizer to equalize the parabolic distortion component.

> ♦*Note:* The parabolic-type delay distortion in many channels has sharply upturning tails at 62 and 78 MHz. In these cases, to keep from overcompensating the distortion at the channel center frequency, it is recommended these "tails" be disregarded and the parabolic distortion over the ±7 MHz range be examined in determining the parabolic equalization.♦

8.05 In some cases there may be a high magnitude of delay slope combined with the parabolic delay. In these cases it is suggested that the delay slope be temporarily equalized at the receiving end for a more accurate analysis of the parabolic characteristic.

8.06 Remove or install sufficient 315A or 918C equalizers until the parabolic shape meets the following requirement.

> ***Requirement (TD-3, TD-3A, TD-3D):*** Less than ±2.5 ns at 63 and 77 MHz.

> ***Requirement (TD-2):*** Less than ±4 ns at 63 and 77 MHz.

B. Delay Slope

8.07 The next delay component to be minimized is the delay slope. Add or remove delay slope equalizers until the channel meets the following requirement.

> ***Requirement:*** Less than ±2 ns of slope between 62 and 78 MHz.

Tables L and M give the characteristics of the delay slope equalizers used in the TD-2 and TD-3 systems.

8.08 When performing the initial delay slope equalization test on a radio channel, measure the envelope delay distortion of the overall channel between switching stations with no slope equalizers installed anywhere. The slope equalizers may be temporarily inserted ahead of the KS-20548 test set at the receiving end of the channel to determine the total number and type of equalizers required. Having determined the slope equalization actually required, the equalizers then should be distributed along the route as directed in Part 5 (TD-2) or Part 6 (TD-3, TD-3A, TD-3D).

8.09 To aid in the determination of whether or not an envelope delay slope characteristic is influenced by an abnormal slope or trouble condition, Table N has been developed and indicates the expected delay slope on a per-hop basis for each TD channel. Should the measured envelope delay slope, when averaged on a per-hop basis, appreciably exceed the expected delay slope, the cause or trouble condition should be investigated. Tables F through K, B, and C can be used as a guide to determine the number and types of equalizers required to equalize the expected delay slope of each TD radio channel. These tables are not intended to set hard limits but should be used as a guide to indicate a possible trouble condition. Every effort should be made to avoid equalizing out a delay slope trouble.

8.10 Some radio channels may exhibit a delay slope characteristic for which the equalization must be compromised at various frequencies between 62 and 78 MHz to obtain satisfactory intermodulation noise performance. An example would be a channel exhibiting severe slope in the vicinity of 70 MHz but considerably less slope between 62 and 78 MHz. Generally, to minimize the intermodulation noise, the most important portion of the delay characteristic to optimally equalize is the portion between approximately 66 and 74 MHz. The next order of priority should be given to the remainder of the delay characteristic. Such cases, if suspected or actually encountered during noise investigations, should be referred to engineering.

C. Delay Ripple

8.11 The third and last component to be examined is the delay ripple. Unlike the parabolic and delay slope componets, the delay ripple cannot be corrected by the use of equalizers. The ripple requirement varies, depending on the number of radio hops in the test section as shown in Table O.

> ***Requirement:*** The delay ripple shall not exceed the limits given in Table O.

♦TABLE L♦

CODE	CHARACTERISTIC	MAGNITUDE		ABSOLUTE DELAY AT 70 MHz	MINIMUM RETURN LOSS 60 TO 80 MHz		MAXIMUM INSERTION LOSS AT 70 MHz
		ns	OVER THE RANGE MHz	ns	INPUT dB	INPUT dB	dB
315A	Negative Parabolic (with positive slope)	*		57	21	20	0.8
315A/ 319G	Negative Parabolic	10.5	†	80.5	28	20	1.3
319E	Flat	0	60-80	38.5	30	30	0.5
319F	Flat	0	60-80	24.6	30	30	0.4
319G	Negative Slope	8	62-78	23.5	28	28	0.5
319H	Positive Slope	8	62-78	23.5	28	28	0.9
319J	Negative Slope	4	62-78	23.5	28	28	0.5

* –14 ns at 62 MHz, –7 ns at 78 MHz } Referred to 70 MHz.

† At 62 and 78 MHz, referred to 70 MHz.

♦TABLE M♦

CODE	CHARACTERISTIC	MAGNITUDE		ABSOLUTE DELAY AT 70 MHz	MINIMUM RETURN LOSS 60 TO 80 MHz		MAXIMUM INSERTION LOSS AT 70 MHz
		ns	OVER THE RANGE MHz	ns	INPUT dB	INPUT dB	dB
918A	Negative Slope	8	62 to 78	23.5	33	33	0.45
918B	Negative Slope	4	62 to 78	23.5	33	33	0.45
918C	Negative Parabolic	6	*	25	33	33	0.7
919A	Positive Slope	4	62 to 78	23.5	33	33	0.7
919B	Flat Delay	0	60 to 80	23.5	33	33	0.6
920A	Positive Slope	8	62 to 78	23.5	33	33	0.85

* At 62 and 78 MHz, referred to 70 MHz.

TABLE N

AVERAGE EXPECTED DELAY SLOPE IN ns PER HOP, MEASURED AT IF BETWEEN 62 AND 78 MHz						
	TD-2 RADIO		TD-3D			
CHANNEL	SOLID-STATE TRMTR	TUBE-TYPE TRMTR	SOLID-STATE TRMTR	TUBE-TYPE TRMTR	TD-3 RADIO	TD-3A RADIO
1	+2.5	+1.2	+2.5	+1.2	+4.6	+3.2
2	+3.7	+2.5	+6.1	+4.8	+5.1	+4.2
3	–3.5	–2.2	–5.9	–4.6	–3.5*	–4.0
4	–3.3	–2.0	–5.7	–4.4	–3.2	–3.8
5	–3.1	–1.9	–5.5	–4.2	–3.0	–3.7
6	–3.0	–1.7	–5.3	–4.1	–2.9	–3.5
7	+2.7	+1.4	+2.7	+1.4	+4.8	+3.4
8	+3.9	+2.6	+6.2	+4.9	+5.3	+4.3
9	–3.6	–2.3	–6.0	–4.7	–3.5*	–4.0
10	–3.4	–2.1	–5.8	–4.5	–3.2	–3.8
11	–3.2	–2.0	–5.6	–4.3	–3.0	–3.7
12	–3.1	–1.8	–5.4	–4.1	–2.9	–3.5

* +5.0 ns/16 MHz for pre-1968 bays where the BO frequency was above the signal frequency.

Note 1: The primary ripple requirement in Table O is for the 574A IF filter used only in TD-2. Thus, that requirement applies only to TD-2 and should be disregarded for the TD-3, TD-3A, and TD-3D channels.

Note 2: The bandwidth switch on the group detector must be in the 4- or 5-kHz position during ripple tests.

When the requirements are exceeded, an investigation is warranted. Trouble investigation and isolation procedures are given in Part 10 of this section.

8.12 The final envelope delay characteristic should be recorded and retained for future reference. The location of each equalizer and the type used should be recorded using Form E-6120A.

D. Systems Protected by Hot Standby or Hot Standby/Space Diversity Switching

8.13 For an established hot standby or hot standby/space diversity channel where service is being carried, the channel must be removed from service in order to perform the envelope delay distortion (EDD) test. This is a difficult procedure because a spare protection channel over the route usually is not readily available. In most cases, restoration procedures will have to be used in order to free the channel for test. Once the channel is available, the EDD tests may then be performed.

TABLE O

PEAK-TO-PEAK RIPPLE (NANOSECONDS)			
NUMBER OF HOPS IN SWITCHING SECTION	PRIMARY RIPPLE (TD-2 ONLY)	SECONDARY RIPPLE (ALL TD CHANNELS)	
		LOW FREQ. RADIO CHAN'S	CHAN'S 5, 6, 11, AND 12
1	3	2.6	4.8
2	4	3.6	6.8
3	5	4.5	8.3
4	6	5.2	9.6
5	7	5.8	10.7
6	8	6.3	11.7
7	9.5	6.8	12.7
8	11	7.3	13.6
9	12	7.8	14.4
10	13	8.2	15.2
11	14	8.6	15.9
12	15	9.0	16.6
13	16	9.4	17.3

8.14 Because of the difficulty involved in freeing an established hot standby or hot standby/space diversity channel for test, these tests will usually be performed only when the channel is installed initially.

8.15 For a new radio facility protected by a hot standby or hot standby/space diversity switching system, if the channel is being tested for the first time and service has not been initiated, all radio hops should be included in the overall EDD test. With all the IF and RF switches at each station force-switched to the REGULAR position, measure the channel's EDD and install the appropriate mop-up delay slope and parabolic equalizers as required into the REGULAR radio bays. For each REGULAR radio receiver having an equalizer, install an identical equalizer code in the corresponding STANDBY radio bay.

8.16 An additional test may be performed, if desired, to evaluate the performance of the channel when individual IF or RF switches operate. The EDD measured when individual IF or RF switches are operated to STANDBY may not meet the delay slope requirement given in paragraph 8.07. For example, differences between antenna waveguide runs may alter the delay slope. Therefore, for this mode of operation, the requirement may be relaxed as follows.

Requirement: Less than ±2.5 ns of slope between 62 and 78 MHz.

The test should be performed only after the procedure of paragraph 8.15 has been completed and applicable requirements met for the new channel. A suggested sequence for performing this test is as follows. Operate the IF and RF switches at each station to the REGULAR position, and measure the channel's EDD. Then force-switch only the RF switch at the transmitting end to the STANDBY position, and compare the measured EDD to the original (reference) EDD characteristic. If a satisfactory comparison is obtained, force-switch the RF switch back to the REGULAR position. Proceeding down the radio route, operate each individual receiver IF switch and transmitter RF switch one at a time and in sequence to the STANDBY position; compare the EDD to the reference condition; and return the switch to REGULAR. In most cases, the switching will be performed remotely from a central control point by utilizing the remote switching features of the hot standby or hot standby/space diversity system. By comparing the EDD for each individual switch operation to the all-REGULAR EDD characteristic, any trouble condition associated with a particular radio bay may be uncovered. In addition, since for normal operation of the channel, at most only one switch at a time is operated to the STANDBY position, this test shows the EDD performance of the hot standby or hot standby/space diversity channel under normal switching conditions.

8.17 When measuring with the KS-20548 test sets (Chart 1 or 2), perform the measurement from the CH A IF IN jack on the transmission bay patch panel (transmitting end) to the CH A IF OUT jack on the transmission bay patch panel (receiving end). If the test described in paragraph 8.16 is to be performed, measure between the CH A IF IN and CH A IF OUT jacks, respectively, for all switching operations except when the transmitting-end RF switch is force-switched to the STANDBY position. In the latter case, it will be necessary to move the EDD signal to the CH X IF IN jack at the transmitting end. It may be more convenient to provide a split pad arrangement to dual-feed the EDD signal into both the CH A IF IN and CH X IF IN jacks at the transmitting end and, thus, avoid transferring the signal between the two jacks.

E. Frequency Diversity Switching Sections Equipped With Space Diversity Switching

8.18 One or more hops in a frequency diversity protection switching section may be equipped with space diversity switching. In such cases, the requirements for parabolic delay, delay slope, and delay ripple given in paragraphs 8.06, 8.07, and 8.11, respectively, should be met when each receiver is switched to the main antenna.

8.19 Because of differences in the antenna waveguide runs, the delay slope requirement of paragraph 8.07 may not be met if one or more of the receivers are switched to the diversity antenna. An additional test may be performed to evaluate the envelope delay distortion of the channel when individual space diversity switches are manually operated, one at a time, to the diversity antenna. For each such measurement, the requirement for delay slope is relaxed as follows.

> ***Requirement:*** Less than ±2.5 ns of slope between 62 and 78 MHz.

This additional test is recommended when a space diversity equipped channel is installed initially, or at the time when space diversity switches are added to an existing channel. It also may be desirable to perform this test at any time when trouble, such as excessive intermodulation noise, is reported if it appears that the problem may occur when one of the receivers is operated from the diversity antenna. Such a measurement may disclose a faulty antenna, antenna waveguide system, or space diversity switch.

9. TEST SET ARRANGEMENT

A. Chart 1—Envelope Delay Distortion Measurements Using the KS-20548, L1 and L2 Test Set (Hewlett-Packard)

9.01 The following apparatus is required to perform this chart.

Transmitting Station

1—KS-20548, L1 Transmitter

1—P2BJ Cord (6 feet long)

1—372A Patch Plug.

Receiving Station

1—KS-20548, L2 Receiver

1—P2BJ Cord (6 feet long)

1—Oscilloscope Camera (optional).

9.02 The switching-section over which this test is to be performed should be free of alarms. Call the alarm center prior to performing this test, and verify that no alarms are present. Monitor the channel for fading activity. Do not perform this test if fading is present.

♦*Note 1:* For TD-2 and TD-3D channels equipped to carry 45-Mb/s digital signals, the alarm center must remotely disable the ADP1 or ADP2 equalizers in each station of the switching section under test.♦

Note 2: The KS-20548, L1 and L2 test set is provided with a Bell System approved instruction booklet which contains information on specific control adjustments. Refer to the instruction booklet when necessary.

STEP	PROCEDURE
1	***Caution: In order to avoid unnecessary interference into other radio channels, do not exceed the ±8 MHz sweep range specified in this chart.*** ***Caution: This test is performed on an out-of-service basis. The control office should be informed so that service may be switched to protection, rerouted, or reassigned. Failure to observe this precaution could result in a service interruption or impairment. Verify that the channel is not being used for other tests.***
2	Adjust the test set controls at the transmitting and receiving stations for the initial settings indicated in Fig. 9. Allow 15 minutes for the transmitter and receiver units to warm-up before proceeding.
3	At the transmitting station, determine the IF level at the transmitting-end IF test access point and operate the appropriate ATTENUATOR (dB) pushbuttons for the proper IF level. Then connect the P2BJ cord to the transmitting-end IF access point. *Note 1:* Test access points may be resolved by referring to Part 8. *Note 2:* With all the ATTENUATOR (dB) pushbuttons in the out position, the IF level at the end of the P2BJ cord is +10 dBm. Operate the pushbuttons as required to reduce the IF level to that required for the particular test access point used.
4	At the receiving station, connect the P2BJ cord to the receiving-end IF test access point. Operate the IF LEVEL pushbuttons for an on-scale indication of the IF/BB LEVEL meter. Note that the AFC LOCK lamp lights.
5	Operate the Y1 DISPLAY switch to BB, and adjust the BB POWER (−dBm) controls for an on-scale indication of the IF/BB LEVEL meter. Then operate the Y1 DISPLAY switch back to DELAY.
6	Adjust the PHASE LOCK control for a steady on-scale PHASE LOCK/LEVEL meter indication. Adjust the SET LEVEL control to center the meter in the green region.
7	Adjust the Y1 POSITION and Y2 POSITION controls to display the two test traces on the oscilloscope screen, with the Y2 trace two divisions below the Y1 trace. Frequency markers at 2-MHz

STEP	PROCEDURE
	increments will be visible on the Y2 trace. Adjust the INTENSITY control for proper brightness. Adjust the X GAIN SPECTRUM WIDTH control until the display covers approximately two-thirds the width of the screen.
	Note: The two test traces should be symmetrical about the center of the oscilloscope screen. If not, adjust the X POS control on the rear of the receiver unit as required to center the display.
8	Place the UNBLANK switch (located at the rear of the receiver unit) in the up position, and adjust the X PHASE SHIFT control for coincidence of the markers on the Y2 trace. Then return the UNBLANK switch to the down position.
	Note 1: With the UNBLANK switch in the up position, it may be necessary to adjust the INTENSITY control to see the display.
	Note 2: As the X PHASE SHIFT control is adjusted, two sets of markers will appear to shift relative to each other. The proper control setting is when the two sets of markers on the Y2 trace are coincident over the entire display.
9	The purpose of this step is to identify the 70-MHz marker on the Y2 trace. Adjust the MARKER OFFSET (±MHz) control to 1, and observe that variable-frequency markers appear on the Y2 trace near the center of the oscilloscope screen. The frequency marker midrange between the two variable markers is the 70-MHz marker. Return the MARKER OFFSET (±MHZ) control to OFF.
10	At the transmitting station, slowly adjust the FREQUENCY (MHz) FINE control until the 70-MHz marker appears exactly at the center of the oscilloscope screen at the receiving station. The center frequency of the sweep signal is now properly set to 70 MHz.
11	The purpose of this step is to adjust the sweep signal for a sweep range of 70 ±8 MHz. At the transmitting station, slowly increase the SWEEP WIDTH (MHz) FINE control until four frequency markers appear on each side of the 70-MHz marker on the oscilloscope screen at the receiving station. The end markers represent 62 and 78 MHz. At the receiving station, adjust the X GAIN SPECTRUM WIDTH control to place the 62- and 78-MHz frequency markers at the extreme left and right graticules, respectively, on the screen.
	Note: It may be necessary to operate the SWEEP WIDTH (MHz) COARSE switch to 20 and then readjust the SWEEP WIDTH (MHz) FINE control to obtain the desired 70 ±8 MHz sweep range. To avoid an excessive sweep range, first set SWEEP WIDTH (MHz) FINE to 0 before positioning SWEEP WIDTH (MHz) COARSE to 20.
12	At the receiving station, calibrate the vertical sensitivity of the Y1 trace as given below. Operate the DELAY CALIBRATION (ns) switch to 1, 3, or 10, depending on the desired sensitivity. Then adjust the Y1 GAIN control until the two Y1 test traces appear one division apart vertically. The calibration procedure is simplified if the Y1 POSITION control is used in conjunction with the Y1 GAIN control to center the two Y1 traces on adjacent horizontal graticules. Return the DELAY CALIBRATION (ns) switch to OFF. The Y1 trace is now calibrated in 1, 3, or 10 ns/division, depending on the above setting of the DELAY CALIBRATION (ns) control. It will be necessary to readjust the Y1 GAIN control each time the vertical sensitivity is changed.

STEP	PROCEDURE
	Note 1: The desired vertical sensitivity will depend on the type of EDD characteristic measured. It is best to use the greatest vertical sensitivity that will allow the Y1 trace to be visible over the entire sweep range. For measurements spanning fewer than about five radio hops, 1 ns/division usually will be used. For measurements spanning more than five radio hops, it may be necessary to calibrate the Y1 trace to 3 or 10 ns/division, depending on the particular EDD ripple present.
	Note 2: Other vertical sensitivities besides 1, 3, or 10 ns/division are possible. For example, 2-ns/division sensitivity is attained by operating the DELAY CALIBRATION (ns) switch to 10 and adjusting Y1 GAIN for the two Y1 traces to appear five divisions apart vertically.
13	The Y1 trace on the oscilloscope screen represents the EDD of the system under test over a ±8 MHz sweep band. Frequency markers at 2-MHz increments are shown on the Y2 trace. Observe the display for at least 5 minutes for changes in shape to assure that air path fading is not occurring. If air path fading is present, defer further measurements until the fading ceases.
14	Perform the general test procedures as prescribed in Part 8 of this section to meet the applicable requirements. Take the photograph or make a tracing of the oscilloscope display before and after inserting the equalization to obtain a permanent record of the measurements. Equalizers installed or removed must be recorded on Form E-6120A.
15	If no other tests are to be performed, re-establish all connections and restore the equipment under test to service. Follow normal practices to verify that the equipment is operating properly, and notify the proper control office.
	♦*Note:* On 45-Mb/s channels, all ADP1 or ADP2 equalizers (in one direction of transmission), at a repeater station are disabled by one remote command. If additional channels on the same switch section are to be tested, the equalizers should not be restored. When the last channel has been tested, the alarm center should be directed to restore the ADP1 or ADP2 equalizers to normal.♦

B. Chart 2—Envelope Delay Distortion Measurements Using the KS-20548, L7, L8 Test Set (Siemens)

9.03 The following apparatus is required to perform this chart.

Transmitting Station

1—KS-20548, L7 W2005 Sweep Generator 70-MHz Unit manufactured by Siemens

1—P2BJ Cord, 8 feet long

1—368A Termination (needed for some test arrangements).

Receiving Station

1—KS-20548, L8 D2005 Selective Detector 70-MHz Unit manufactured by Siemens

1—C2005 Display Unit manufactured by Siemens

1—P2BJ Cord, 8 feet long

1—Oscilloscope Camera (optional).

9.04 The switching section over which this test is to be performed should be free of alarms. Call the alarm center prior to performing this test, and verify that no alarms are present. Monitor the channel for fading activity. Do not perform this test if fading is present.

◆*Note 1:* For TD-2 and TD-3D channels equipped to carry 45-Mb/s digital signals, the alarm center must remotely disable the ADP1 or ADP2 equalizers in each station of the switching section under test.◆

Note 2: The KS-20548, L7 and L8 test set is provided with a Bell System approved instruction booklet which contains information on specific control adjustments. Refer to the instruction booklet when necessary.

STEP	PROCEDURE
1	***Caution: In order to avoid unnecessary interference into other radio channels, do not exceed the ±8 MHz sweep range specified in this chart.*** ***Caution: This test is performed on an out-of-service basis. The control office should be informed so that service may be switched to protection, rerouted, or reassigned. Failure to observe this precaution could result in a service interruption or impairment. Verify that the channel is not being used for other tests.***
2	Adjust the test set controls at the transmitting and receiving stations for the initial settings indicated in Fig. 10. Allow 15 minutes for the transmitting, receiving, and display units to warm-up.
3	At the transmitting station, determine the IF level at the transmitting-end IF test access point. Connect the P2BJ cord to the appropriate jack on the transmitter unit in accordance with option 1 or option 2, depending on the desired IF level as shown in Table P.

TABLE P

OPTION	IF LEVEL RANGE	W2005 TRANSMITTER
1	0 to +12 dBm	J7
2	−10 to 0 dBm	J8*

* When option 2 is used, terminate J7 with a suitable IF termination. Use a 368A termination, a 20-dB 19A pad, or a 20-dB 63A pad and 187A adapter.

STEP	PROCEDURE
4	Adjust the IF LEVEL (P6) control for the desired level. Then connect the P2BJ cord to the transmitting-end IF access point. ***Note 1:*** Test access points may be resolved by referring to Part 8.

STEP	PROCEDURE
	Note 2: With the P2BJ cord connected in accordance with option 1, the IF power level in dBm at J7 is indicated directly on the meter. With the P2BJ cord connected in accordance with option 2, the IF power level at J8 is 10 dB less than indicated on the meter.
5	At the receiving station, connect the P2BJ cord to the receiving-end IF test access point. Note that the AFC lamp lights. Observe the meter indication.
	Requirement: The meter shall indicate in the region of the black line.
	If the requirement is met, operate the MEAS'G MODE switch to LEVEL/GROUP DELAY DIST and proceed with Step 6. If the requirement is not met, the IF level at J1 is too low. Measure the IF level using a power meter, and verify that it is greater than −10.0 dBm.
	Note: With the MEAS'G MODE switch in LEVEL/GROUP DELAY DIST, the meter will not indicate a reading but traces should be visible on the oscilloscope display.
6	On the display unit, adjust the V. POS control to display the two test traces. On the receiver unit, use the OSCILLOSCOPE P6 control to adjust the relative position of the two test traces.
7	On the receiver unit, adjust the OSCILLOSCOPE LEVEL (P4) control until the display covers ±5 divisions of the screen. Then adjust the OSCILLOSCOPE PHASE (P5) control until two distinct test traces are visible. One test trace will be a straight-line reference trace. The other test trace represents the channel's EDD characteristic.
	Note: As P5 is adjusted, the test traces will appear to shift relative to each other. The proper control setting is when a single pair of distinct traces is visible over the entire display.
8	The purpose of this step is to adjust the sweep signal for a sweep range of 70 ±8 MHz. At the transmitting station, slowly increase the IF SWEEP RANGE (P5) control until a total of four frequency markers appear on each side of the 70-MHz marker on the oscilloscope screen at the receiving station. The center marker represents 70 MHz, and the end markers represent 62 and 78 MHz. If necessary, slowly adjust the IF CENTER FREQ (P4) control for a symmetrical display and readjust IF SWEEP RANGE (P5) so the 62- and 78-MHz markers appear at the ends of the trace.
	Note: The level of the frequency markers on the reference trace is adjusted by using the FREQ MARKERS P3 control on the receiver unit.
9	At the receiving station, if necessary, readjust OSCILLOSCOPE PHASE (P5) for two distinct test traces.
10	At the receiving station, calibrate the vertical sensitivity of the EDD trace as given below. On the receiver unit, operate the SENSITIVITY CAL (S4) switch to ON and the SENSITIVITY GROUP DELAY DISTORTION (S3) switch to 2 ns. Both test traces will appear double on the display. Then adjust the V. GAIN control on the display unit until the two EDD test traces appear one division apart vertically. The calibration procedure is simplified if the V. POS control is used in conjunction with the V. GAIN control to center the two EDD traces on the adjacent

STEP	PROCEDURE
	horizontal graticules. Return S4 to OFF. The EDD trace is now calibrated in 2, 5, or 10 ns/division, depending on the setting of S3. Once initially calibrated, the vertical sensitivity may be changed simply by repositioning S3. Operating S3 automatically changes the vertical sensitivity without readjustment of the V. GAIN control on the display unit.
	Note 1: The desired vertical sensitivity will depend on the type of EDD characteristic measured. It is best to use the greatest vertical sensitivity that will allow the EDD characteristic to be visible over the entire sweep range. For measurements spanning fewer than about five radio hops, 2 ns/division usually will be used. For measurements spanning more than five radio hops, it may be necessary to select 5 or 10 ns/division, depending on the particular EDD ripples present.
	Note 2: Other vertical sensitivities besides 2, 5, or 10 ns/division are possible. For example, sensitivities of 1, 2.5, or 5 ns/division are obtained in the following manner. On the receiver unit, operate S3 to 2 ns and S4 to ON. On the display unit, adjust V. GAIN for the two EDD traces to appear two divisions apart vertically. With the display calibrated as above, the vertical sensitivity will be 1, 2.5, or 5 ns/division corresponding to S3 positions of 2, 5, or 10 ns, respectively.
11	The trace on the display represents the EDD of the system under test over a ±8 MHz sweep band. If necessary, readjust the oscillocope P6 control to separate the EDD and reference traces. Observe the display for at least 5 minutes for changes in shape to assure that air path fading is not occurring. If air path fading is present, defer further measurements until the fading ceases.
12	Perform the general test procedures as prescribed in Part 8 of this section to meet the applicable requirements. Take a photograph or make a tracing of the oscilloscope display before and after inserting the equalization to obtain a permanent record of the measurements. Equalizers installed or removed must be recorded on Form E-6120.
13	If no other tests are to be performed, re-establish all connections and restore the equipment under test to service. Follow normal practices to verify that the equipment is operating properly, and notify the proper control office.
	♦***Note:*** On 45-Mb/s channels, all ADP1 or ADP2 equalizers, (in one direction of transmission), at a repeater station are disabled by one remote command. If additional channels on the same switch section are to be tested, the equalizers should not be restored. When the last channel has been tested, the alarm center should be directed to restore the ADP1 or ADP2 equalizers to normal.♦

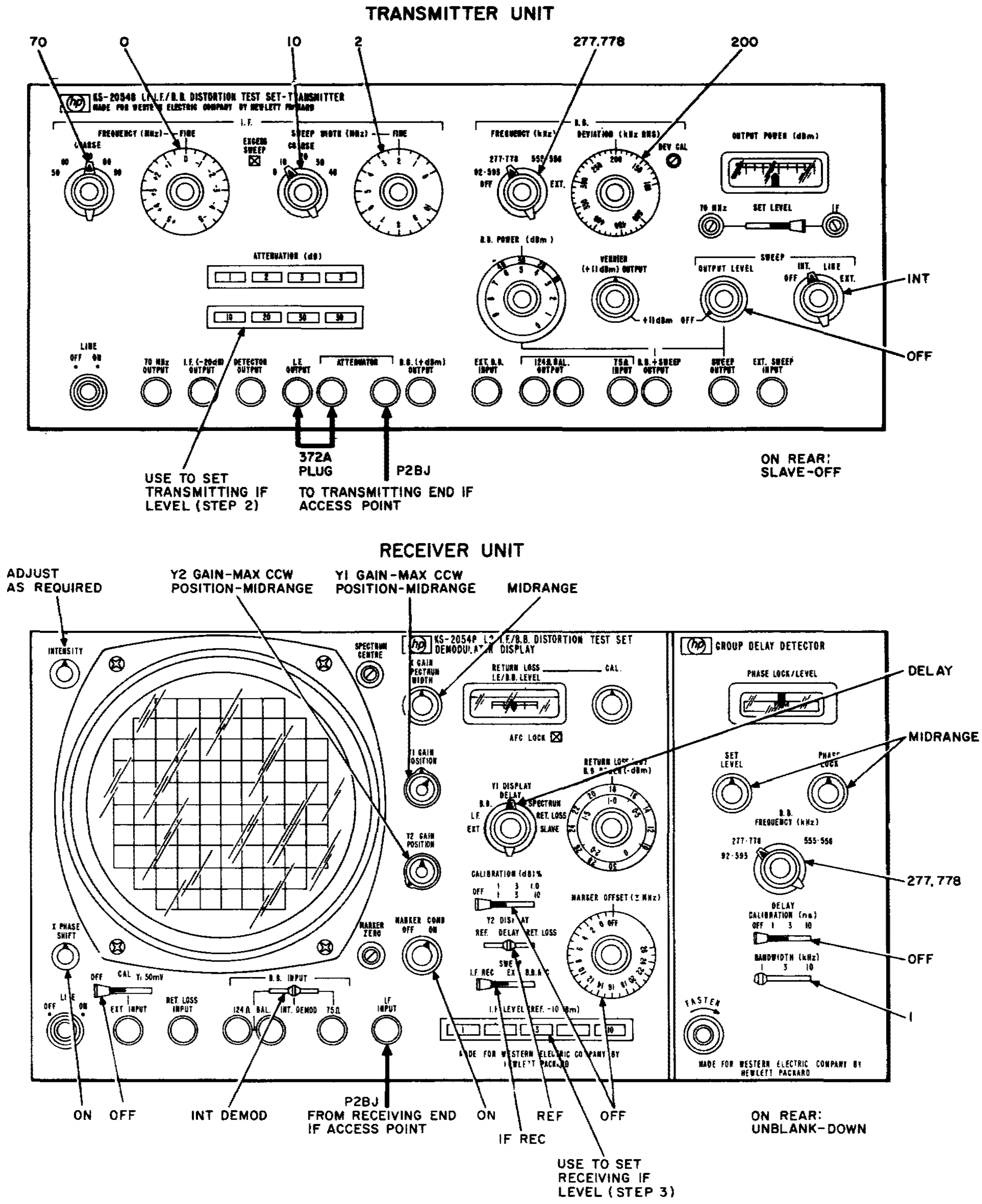


Fig. 9—Test Setup for IF—IF Envelope Delay Distortion Measurements Using the KS-20548, L1 and L2 Test Set

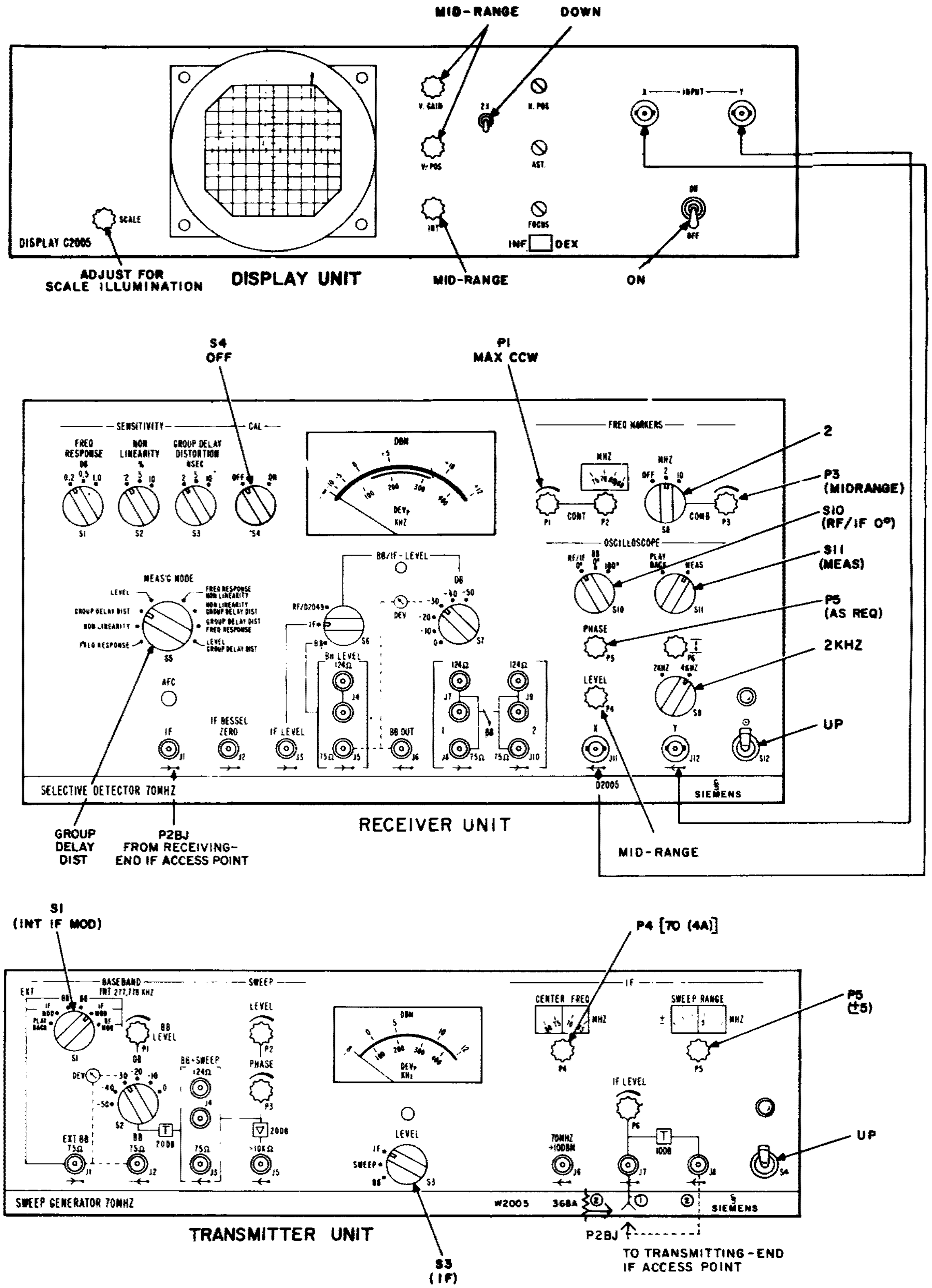


Fig. 10—Test Setup for IF—IF Envelope Delay Distortion Measurements Using the KS-20548, L7 and L8 Test Set

10. TROUBLE INVESTIGATION

10.01 Few equalization problems should be encountered in the area of parabolic equalization. For that reason, no trouble investigation guide has been developed for parabolic distortion.

10.02 When the envelope delay slope limits specified in this practice are exceeded, one or more of the following conditions may be the contributing factor.

(a) RF impedance mismatch (poor return loss)

(b) Improper tuning of the tube-type transmitting amplifier in TD-2 and TD-3D bays

(c) IF impedance mismatch (poor return loss) at any of the following points:

- IF preamplifier out
- IF filters and equalizers
- IF main amplifier input
- IF main amplifier output
- IF driver amplifier input.

10.03 When it is suspected that a poor IF return loss is producing excessive envelope delay slope, the return loss of the unit should be checked by the standard procedures. There will be occasions when a quick method of checking the impedance of the IF units is desirable. The following procedure should never be used for alignment of the units but only as an indication of the impedance condition of the units. Add 50 feet of IF cable between the IF units suspected of having a poor return loss while observing the envelope delay ripple characteristic on the test set. Should a serious IF impedance mismatch exist, the envelope delay characteristic should now show an additional ripple component with a spacing of approximately 6.6 MHz. This means that across the 16-MHz delay sweep there will be approximately 2.4 ripples. If the return loss of the units is properly adjusted, no appreciable difference will be noted in the delay characteristic after the cable is inserted.

10.04 The procedure to check the envelope delay characteristic of an individual IF unit is relatively simple. To reproduce the actual envelope delay characteristic that an individual IF unit contributes to the overall envelope delay characteristic of a specific channel, the delay test of the unit must duplicate as nearly as possible the normal operating conditions of the unit. This is especially important for any active circuit, which should be tested at the same input and output power at which the unit operates in the bay. The delay test should be made using the same sweep width as that used on the radio channel. When checking an IF main amplifier, the AGC level of the amplifier must be duplicated. To accomplish this, note the AGC level on the bay meter panel. After the delay test set is connected to the input of the IF main amplifier, adjust the IF attenuator on the delay transmitter until the same AGC level is indicated on the bay meter. After viewing the envelope delay characteristic on the test set, a judgment can be made as to the envelope delay contribution of the individual unit to the total envelope delay characteristic of the channel.

10.05 The antenna and waveguide system is the major location where an RF impedance mismatch will exist. Therefore, the craftperson must be familiar with the makeup of the waveguide system. The common waveguide runs for TD-2 and TD-2/TD-3D radio bay lineups may contain either an isolator or a circulator with a termination. The electrical design characteristic of the isolator or the circulator and its termination is to present low loss in the direction of transmission while attenuating the reflected signal (echo) 30 to 35 dB. In a TD-2 type radio station an isolator or circulator is located in the common receiving and transmitting waveguide runs at the head end of each bay lineup. The electrical characteristic and the location of the isolator or circulator and its termination in the transmitting waveguide run prevent marginal waveguide faults from causing echoes of sufficient amplitude to affect the envelope delay characteristic. However, should a serious waveguide fault exist, its effect on the envelope delay slope or ripple characteristic would be apparent. Whenever it is suspected that a waveguide fault is partially masked by the effects of the isolator or circulator in the transmitting waveguide run, the termination on the circulator should be replaced with a shorting plate or the isolator should be removed and a section of waveguide installed. This will permit the full effects of the suspected waveguide fault upon the envelope delay test signal to be seen on the test set. The TD-3D radio bays use circulators as part of the means for adding or dropping the transmitting or receiving signals. If only TD-3D type radio bays are in the bay lineup, the transmitting signal will travel through the bandpass filter and circulator (combining network) and then out towards the antenna. Should a waveguide fault exist, a portion of the signal would be reflected (echo) back towards the channel combining circulators, pass through them, and be absorbed by the termination at the end of the bay lineup. If the termination is removed and a shorting plate installed, the signal will then be reflected back toward the antenna. Whenever significant changes in the envelope delay ripple or slope characteristic of a single hop are observed when the termination on the common waveguide circulator is replaced with a short or the isolator is removed or the termination at the end of the bay lineup is removed and a shorting plate installed, this is a strong indication that a waveguide fault exists and the RF return-loss measurement should be made in accordance with Section 402-400-502.

10.06 Removing the isolator or shorting the common waveguide circulator in the receiving waveguide run is not a useful method of isolating a receiving waveguide fault. If the receiving waveguide is suspected of causing an envelope delay problem, the RF return-loss measurement should be made in accordance with Section 402-400-502.

10.07 When the envelope delay ripple limits are exceeded, the trouble should be isolated into either the IF or RF portion of the channel under test. Between the envelope delay test points specified in the section, there will be IF cabling of various lengths at the terminal stations and varying lengths of waveguide at all stations along the route. The following procedure is a method for isolating the trouble into or out of the IF cabling.

(a) At the receiving end, relocate the receiving envelope delay test set from the switching equipment location to the radio bay location and connect it directly to the output of the IF main amplifier. Observe the change in IF level from the previous test point, and adjust for the new IF test level accordingly. Clearing of the trouble condition indicates that the trouble is in the receiving IF cabling. No change in the ripple characteristic indicates that the ripple condition is still to be isolated.

(b) At the transmitting end of the switching section, relocate the transmitting envelope delay test set from the switching equipment location to the radio bay location and connect it directly to the input of the IF driver amplifier—transmitter modulator. Observe the change in IF level from the previous test point, and adjust for the new IF test level. Clearing of the trouble condition indicates that the trouble is in the transmitting IF cabling. No change in the ripple characteristic indicates that the ripple is still to be isolated.

(c) If auxiliary station switching or side-leg switching exists for the channel being tested at any of the repeater stations in the switching section, the IF cabling and switching equipment should be bypassed. This can be accomplished by patching from the output of the IF main amplifier through the proper attenuator pads to the input of the IF driver amplifier. The length of the patch cords should be kept to a minimum. If the ripple condition is now cleared, the trouble is in the IF cabling or switching equipment.

10.08 Whenever it becomes necessary to divide a switching section into smaller test sections in order to isolate a specific characteristic or problem, the craftperson should become acquainted with the basic envelope delay test procedures that apply to overall switch-section testing. When proper test precautions are followed, any point within the switch section can be used to produce useful data as to the individual channel performance or the condition to or from that specific test point. Figures 11, 12, and 13 are intended to give the trouble investigator basic guides that may be followed or further expanded upon to meet the needs of the particular circumstances or equipment configuration.

10.09 The most effective means of trouble isolation is to divide the switching section into two smaller sections. Figure 11 illustrates how a switching section of four radio hops can be divided into two separate 2-hop test sections. When such a test configuration is established, it is relatively easy to determine which test section is in trouble. Each of the two test sections must be considered as individual switching sections and the envelope delay limits applied accordingly. Before the trouble is found, it may be necessary to further divide a test section into smaller units in order to isolate the trouble into an individual radio hop. It is very important to always properly envelope delay equalize (parabolic and slope) the section being tested as if it were an overall switching section. Failure to properly equalize the section being tested before attempting to analyze the data will often result in false conclusions. Figure 12 illustrates the basic test configuration for making single-hop tests. It also illustrates other test sections that are available. In some instances, it may be desirable to perform some optional testing. If a trouble has been identified in test section 1, the results of sending from the transmitting terminal office and receiving at auxiliary station Beta (test section 2), should be supportive to the findings of test section 1. Likewise, when sending from auxiliary station Alpha and receiving at the receiving terminal station (test section 3), the test data should be supportive to the findings in test sections 1 and 2. If a gross discrepancy should exist in the test data between test sections 1, 2, and 3, further investigation would be warranted.

10.10 It may be difficult at times to accurately describe to another office the true envelope delay characteristic being received. Figure 13 illustrates how the envelope delay test sets, if equipped with the loop-around feature, can be used to transmit the received envelope delay test signal to a distant office or back to the transmitting end for display. Whenever there is any confusion concerning the exact envelope delay characteristic being received, the loop-around feature of the test sets should be used.

11. FLOWCHART FOR ENVELOPE DELAY TESTING SEQUENCE AND TROUBLE ISOLATION

11.01 The envelope delay distortion tests are summarized by a flowchart (Fig. 14) which outlines a normal testing sequence. It also provides trouble isolation guidelines that should be followed if the requirements given in Part 8 are not met.

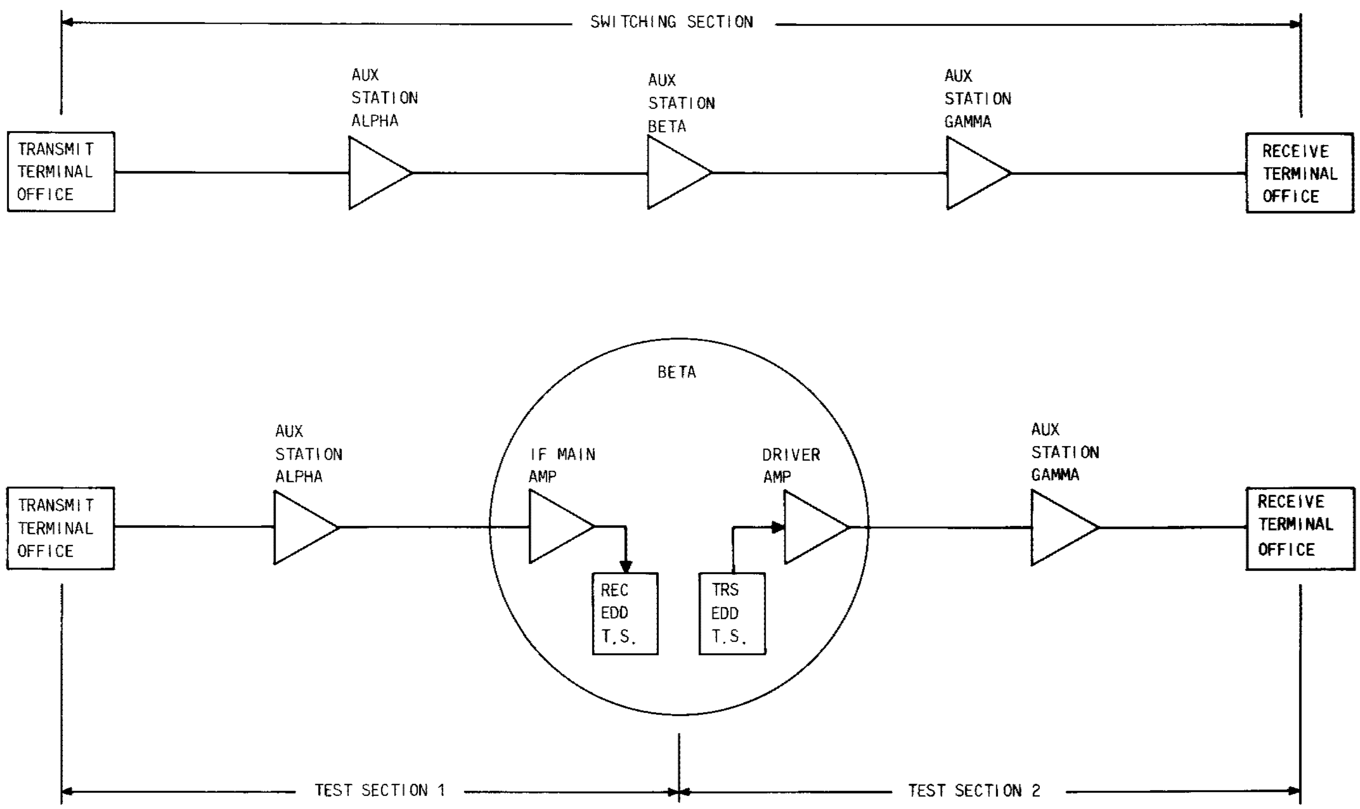


Fig. 11—Switching Section Divided Into Two Test Sections

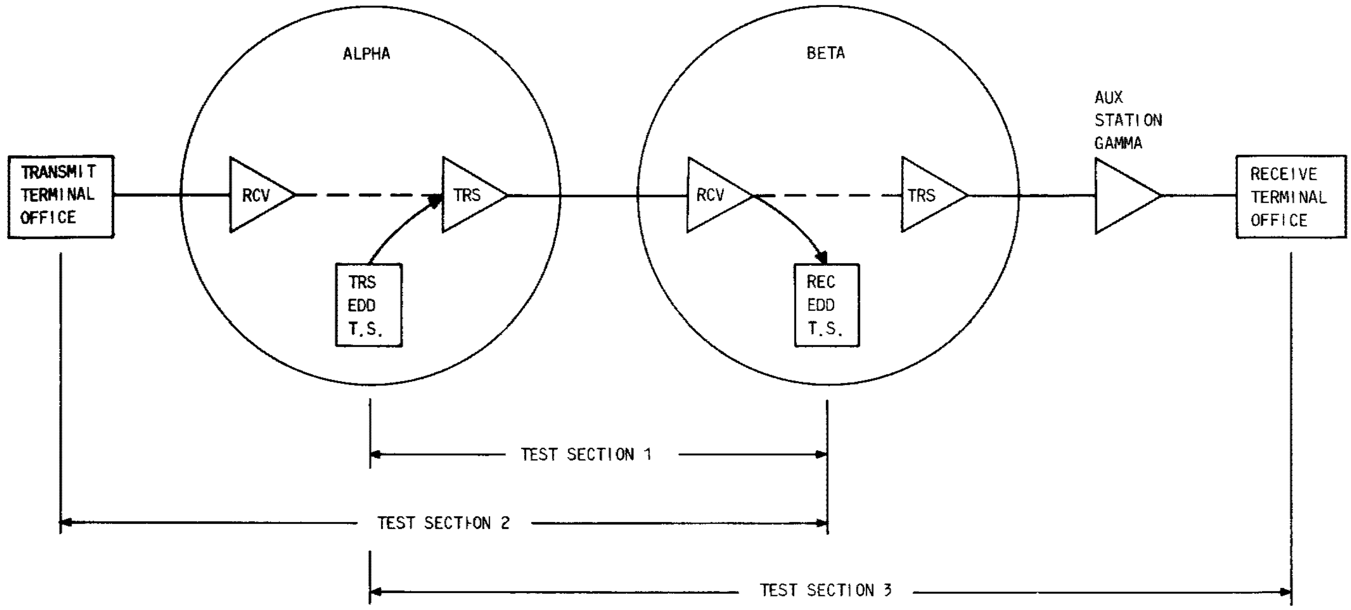


Fig. 12—Switching Section Divided Into Three Test Sections

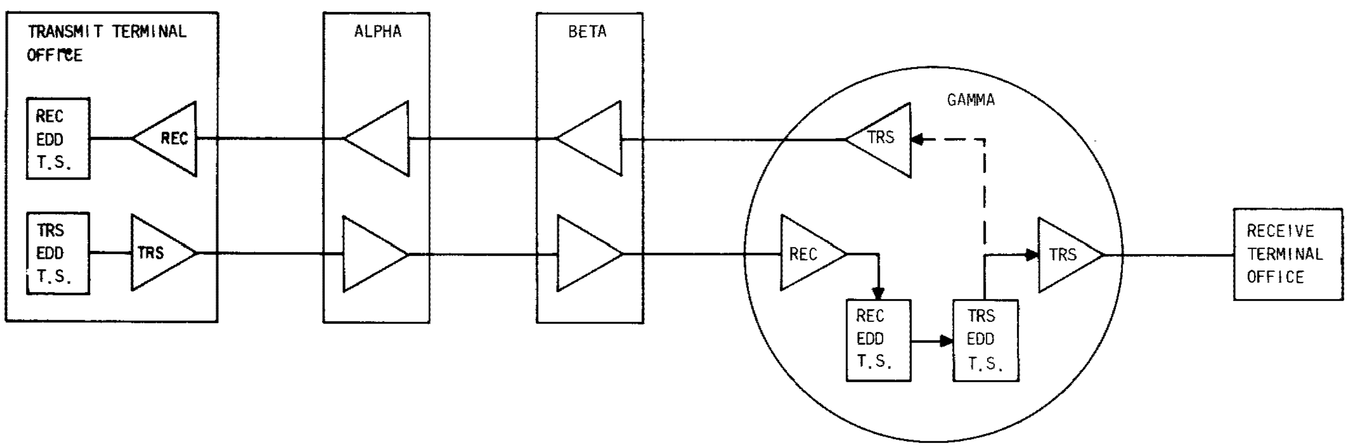


Fig. 13—Test Section Setup Using Test Set in Slave or Loop-Around Mode

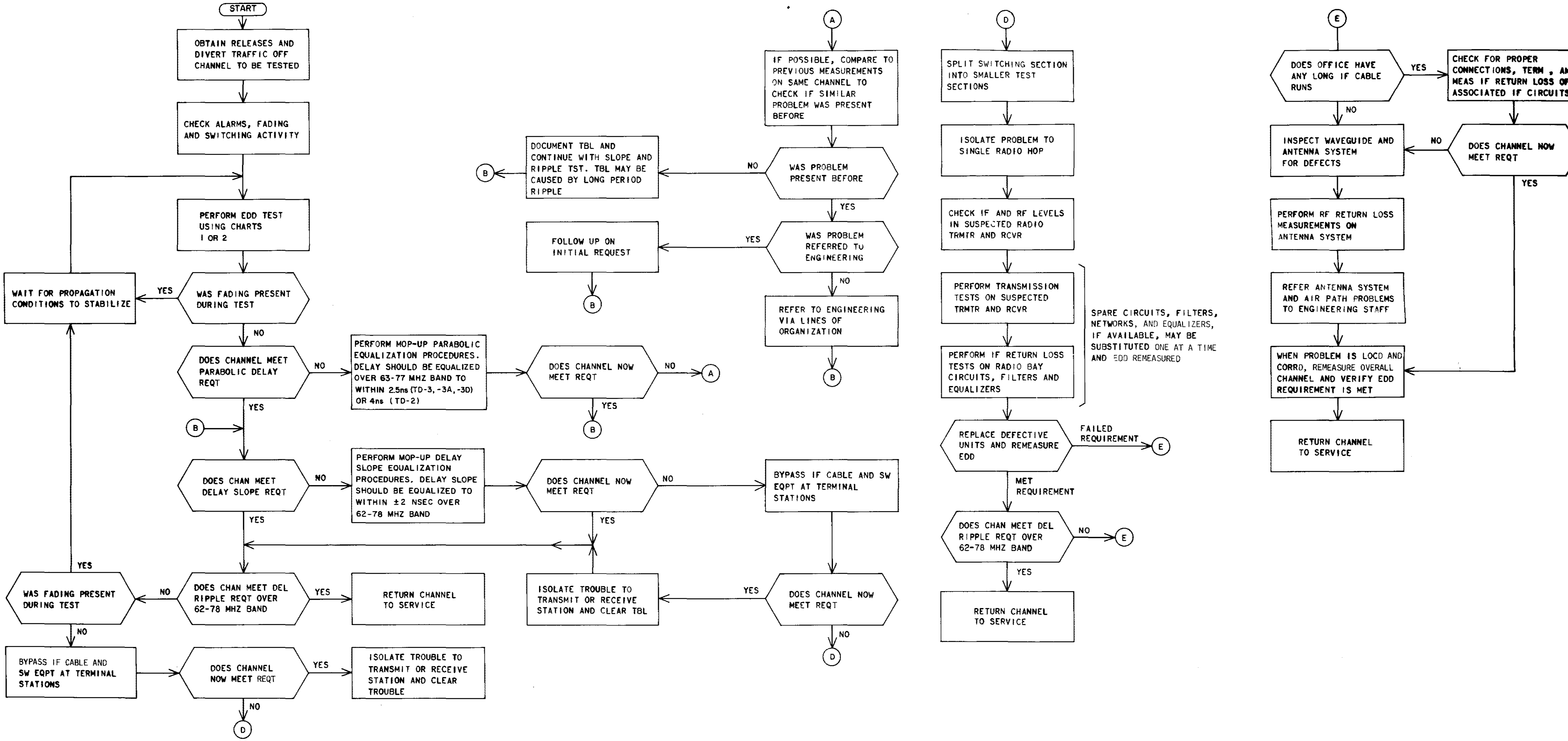


Fig. 14—Flowchart for Envelope Delay Distortion Tests