DISTORTION

AS RELATED TO TELETYPEWRITER OPERATION

CONTENTS Page

1.00 GENERAL

1.01 This section covers a discussion of the effect of distortion on the operation of start-stop teletypewriters. Methods of determining the internal distortion of a receiver are described and some of the more important considerations involved in the measurement and adjustment of start-stop receivers are discussed.

1.02 A properly designed start-stop telegraph receiver requires only a small portion of the time of each signal element to make a selection; i.e., to determine whether the signal element is marking or spacing. The remainder of the signal element gives an operating margin and serves as a reserve to take care of imperfections in the receiver or distortions which the telegraph signals may suffer in their passage over lines and through repeaters. The greater the signal distortion, the smaller will be the margin to overcome the effect of such factors as wear of parts, variation of adjustments or differences in speed between transmitter and receiver.

2.00 EFFECTS OF SIGNAL DISTORTION ON TELETYPEWRITER RECEPTION

2.01 General

(a) Each teletypewriter operation is initiated by a mark-to-space (M-S) transition at the beginning of the start element of the received character. The speed of the receiving machine should be such that it arrives at the stop position before the end of the stop interval. Since it is restarted by the succeeding M-S transition, any speed difference between the transmitting and receiving machines is prevented from cumulating for more than the duration of a single character.

(b) In start-stop systems it is not the duration of signal intervals that is of primary importance. It is the timing of the signal transitions relative to the start transition. Departures from perfect timing are known as start-stop displacements.

(c) The receiving machine starts anew at each start transition and the instants at which it samples the selective elements are spaced in time relative to the instant of starting, as shown in Fig. 1A. Therefore, the start transition acts as a basic reference point to which all other instants of time during the selective cycle are referred.

Four Types of Transition Displacements

2.02 The effect of signal distortion may cause **four types of transition displacements** from their normal times of occurrence relative to the start transition, as follows: (See Fig. 1B)

(a) S-M advance, which is the advance of a space-to-mark transition, called a marking beginning displacement (MB).

(b) S-M retard, which is the delay of a space-to-mark transition, called a spacing beginning displacement (SB).

(c) M-S advance, which is the advance of a mark-to-space transition, called a spacing end displacement (SE).

(d) M-S retard, which is the delay of a mark-to-space transition, called a marking end displacement (ME).

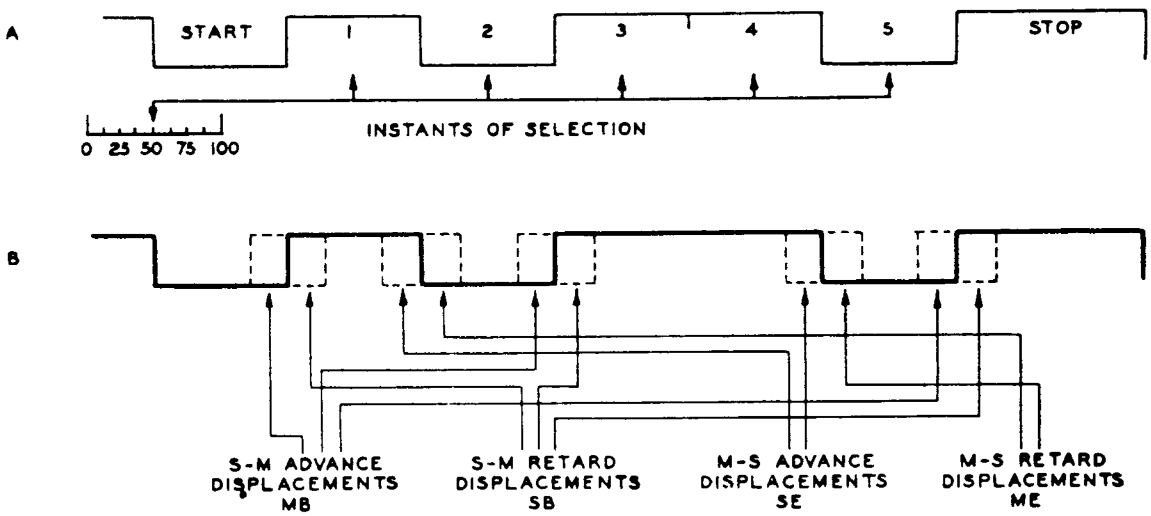


FIG. 1—FOUR POSSIBLE TYPES OF TRANSITION DISPLACEMENT

2.03 Bias and End Distortion

(a) The S-M displacements occur at the **beginning** of marking signals. The S-M advance increases the marking time of a signal element and is called an MB displacement. This may signify "marking beginning" or "marking bias" as marking bias will cause this type of displacement and no other type. Similarly, the S-M retard is called an SB displacement. The SB may signify "spacing beginning" or "spacing bias" as spacing bias will cause this type of displacement and no other type. The reasons for the effect of biased signals are discussed in 2.04.

TABLE 1

Start-Stop Displacements

		Displacement			Part of Signal Affected
Bias	Marking	S-M Advance	MB	Marking Beginning or Marking Bias	Marking Signal Beginnings
	Spacing	S-M Retard	SB	Spacing Beginning or Spacing Bias	
End Distortion	Spacing	M-S Advance	SE	Spacing End	Marking Signal Endings
	Marking	M-S Retard	ME	Marking End	

(b) The M-S displacements occur at the **end** of marking signals and this type of distortion is called "end distortion." An M-S advance increases the spacing time and is called an SE (spacing end) displacement. Similarly, an M-S retard displacement is called an ME (marking end) displacement.

(c) The general terms "bias" and "end distortion" are used to signify S-M and M-S displacements, respectively.

(d) The various terms for displacement are summarized in Table 1.

Effect of Bias on Displacement

2.04 The effect of bias appears on the S-M transitions only. Positive (marking) bias causes MB displacement and negative (spacing) bias causes SB displacement. This is illustrated in Fig. 2. Curve (2) shows a perfect received signal corresponding to the perfect transmitted signal at (1). In general, bias will affect both the beginnings and ends of received signal intervals. This is indicated in curve (3) which represents the same signal biased 25% to marking. However, for start-stop operation all time measurements must be related to the M-S start transition. Curve (4) has been drawn to represent the same wave as at (3) but with the M-S start transition lined up with the signal (2). Then comparing (4) with (2) shows that the marking bias has caused an advance displacement of the S-M transitions, by an amount equal to the per cent bias that is, MB displacement. Similarly, spacing bias causes a delay in the S-M transitions or SB displacement, as illustrated in curves (5) and (6).

(A) Effect of Characteristic Distortion on Displacement

2.05 General: Characteristics distortion does not affect all signal transitions alike because the effect on each transition depends on the signal combinations that have previously been sent over the circuit. Hence, the start transition and the other transitions of a character are, in general, shifted by varying amounts. It is convenient for purposes of description, since the start transition is made the point of reference for the remaining transitions of each character, to assume that any delay in the start transition is, in effect, the lag in the circuit for that character. Any shifts in the positions of subsequent transitions are then of interest only as they change the transition from its proper relationship to the start transition. Any of the four types of displacement shown in Fig. 1B may occur, depending on whether the transition is M-S or S-M and whether it has been delayed more or less than the start transition.

Effect on Character Length

2.06 Because characteristic distortion delays the start transition by different amounts from character to character, it causes the character length to vary during continuous automatic transmission. The maximum variation in character length is approximately as great as the maximum displacement affecting the selective transitions.

(B) Effect of Signal Distortion on Orientation Limits

Orientation Range

2.07 The total range through which the selective periods may be shifted relative to the start transition, without producing an incorrect selection, is known as the **orientation range** of the receiver. Its limits are read on a scale calibrated from 0 to 100 in per cent of a unit signal element.

2.08 Effect of Bias and End Distortion

(a) Fig. 3 shows by the solid lines a graph of teletypewriter orientation limits versus input-signal bias, for a receiver whose range is from 10 to 90 on unbiased signals. Diagrams of this type are called **"bias parallelograms."** The lines indicate the boundaries of the area of operation outside of which printing errors would occur. For instance, in the case of Fig. 3, a teletypewriter with its range indicator set at 60 would accept, without errors, signals with a marking bias of 30 per cent. With greater bias, errors would occur.

(b) The dashed lines of Fig. 3 show a graph of orientation limits versus input-signal end distortion. Diagrams of this type are called **"end distortion parallelograms."** It is generally useful to plot both of these diagrams on the same figure.

(C) Effect of Characteristic Distortion on Bias and End Distortion Parallelograms

2.09 In the usual start-stop system, which employs a stop interval longer than the unit element, characteristic distortion affects the upper and lower limits of orientation differently. This effect is due mainly to the longer stop interval. The fact that the start transition is always M-S determines which limit is affected most.

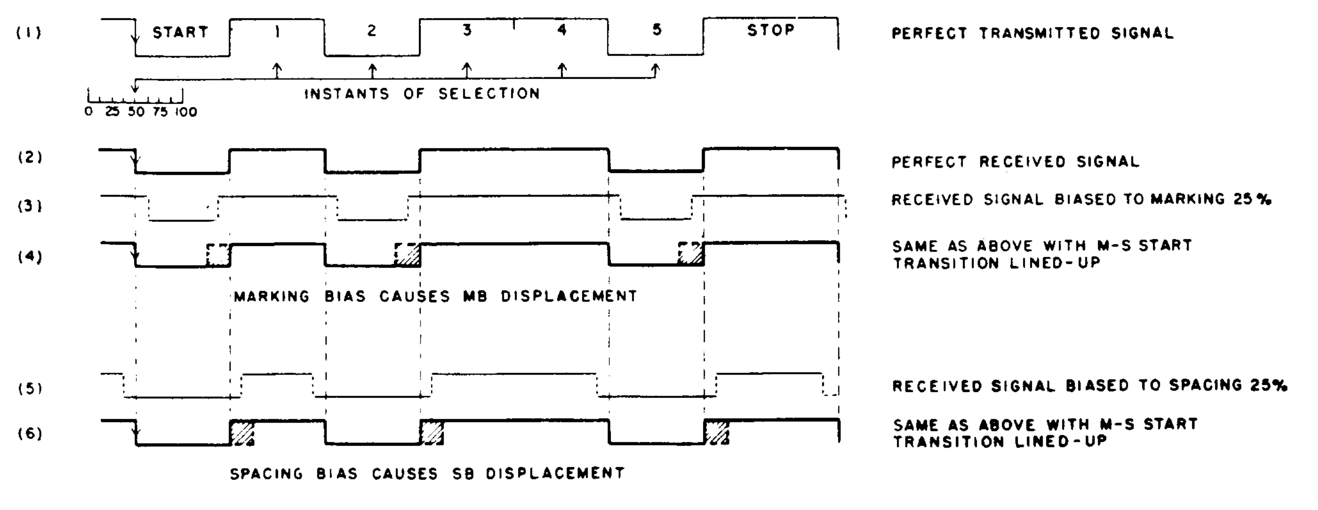


FIG. 2—EFFECT OF BIAS ON TRANSITION DISPLACEMENT

2.10 Negative characteristic distortion affects the upper limit of orientation more than it does the lower.

2.11 Conversely, positive characteristic distortion affects the lower limit of orientation more than it does the upper.

(D) Effect of Fortuitous Distortion on Displacement

General

2.12 Fortuitous distortion causes the start transition to be delayed more or less than normal, and has the same effect on the selective transitions. Since it is usually equally probable that the maximum fortuitous effects will occur on M-S or S-M transitions and will increase or decrease their delay, this type of distortion generally produces the four types of displacement.

Case Where Effect is Different on M-S and S-M Transitions

2.13 When the M-S and S-M transients give the wave different slopes at the point where the receiving device operates, the fortuitous effect is different on M-S and S-M transitions. If the effect is greater on the S-M transitions, the MB and SB displacements are greater than the SE and ME. If the opposite is true, the SE and ME displacements are greater. This effect produces what is known as "skew." See 3.05. In all cases, however, the orientation range is reduced equally at both ends.

Effect on Character Length

2.14 Fortuitous distortion also lengthens or shortens the character since it does not affect all transitions alike.

3.00 INTERNAL DISTORTION

General

3.01 Telegraph signal distortion may occur within a start-stop teletypewriter. It is convenient to define the components of internal distortion in terms of equivalent values of external distortion. Then from suitable measurements with distorted input signals it is possible to compute what the internal distortion is.

Effect of Distortion on Parallelograms

3.02 Fig. 4 shows by the families of dash-line curves how bias and end distortion parallelograms may be affected by internal fortuitous distortion which produces the four kinds of transition displacements in equal quantities.

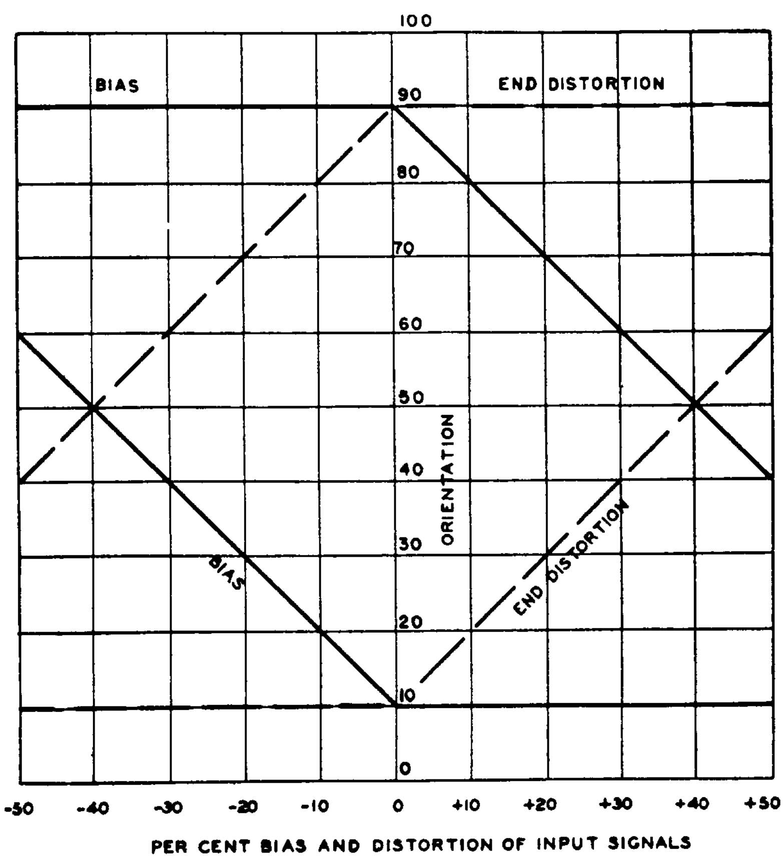


FIG. 3—BIAS AND END DISTORTION PARALLELOGRAMS

Use of Distorted Test Signals

3.03 As mentioned previously, the upper end of the orientation range is determined by whichever of the displacements MB or SE is the greater; and the lower end by whichever of the displacements SB or ME is the greater. To discover the magnitude of the smaller type of displacement it is necessary to reduce the larger displacement by distorting the transmitted signals.

For example, if a receiver has a large internal marking bias, the upper limit of orientation is determined by the MB displacement and hence the amount of SE displacement caused by internal distortion is concealed. However, by transmitting signals affected by SB displacement (in other words, signals biased to spacing) the total MB displacement may be decreased until it is less than the internal SE displacement, whose effect on margin can then be found. Thus the internal distortion may be determined by observing the effect of external distortion on the margins of operation.

3.04 Types of Internal Distortion

(a) It is convenient to regard any start-stop receiver as a theoretically perfect receiver affected by certain types of internal distortion. The internal distortion is usually considered to be composed of bias, skew (defined below) and fortuitous distortion. (The internal characteristic distortion is generally included in internal fortuitous distortion, since it is usually small, and a fairly elaborate testing procedure is required to separate its effects from those of internal fortuitous distortion.) The effects of internal bias and internal fortuitous distortion on the bias and end distortion parallelograms are indicated in Figs. 5, 6 and 7.

(b) In Fig. 5 the solid line of the received wave indicates the performance of a perfect receiver. Assume +20% internal bias and the resulting MB displacement is indicated by the heavy dashed lines. The scales below the received wave indicate the displacements that would occur as the test signals are biased over a range from +50% to −50%. The orientation range is then determined by assuming that the pointer moves from 0 to 100 over the orientation scale indicated at the top. Where any of the arrows showing instants of selection coincide with an M-S or S-M transition the scale reading shows the end of the range for that particular amount of test signal bias.

(c) The bias and end distortion parallelograms of Figs. 6 and 7 were plotted in a similar manner.

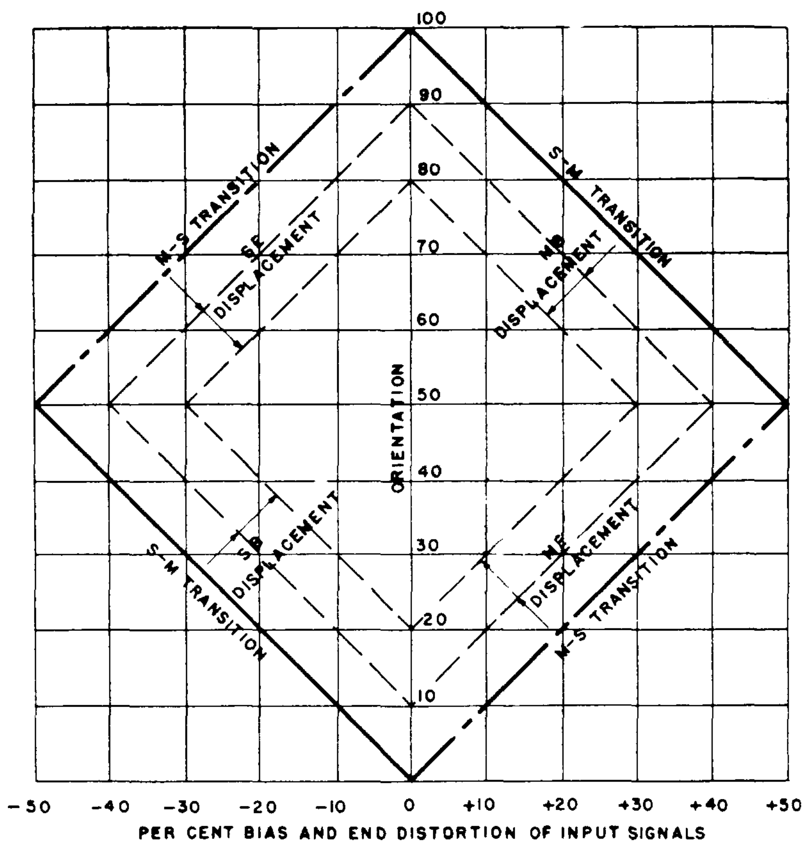


FIG. 4—BIAS AND END DISTORTION PARALLELOGRAMS SHOWING EFFECT OF EACH TYPE OF TRANSITION DISPLACEMENT

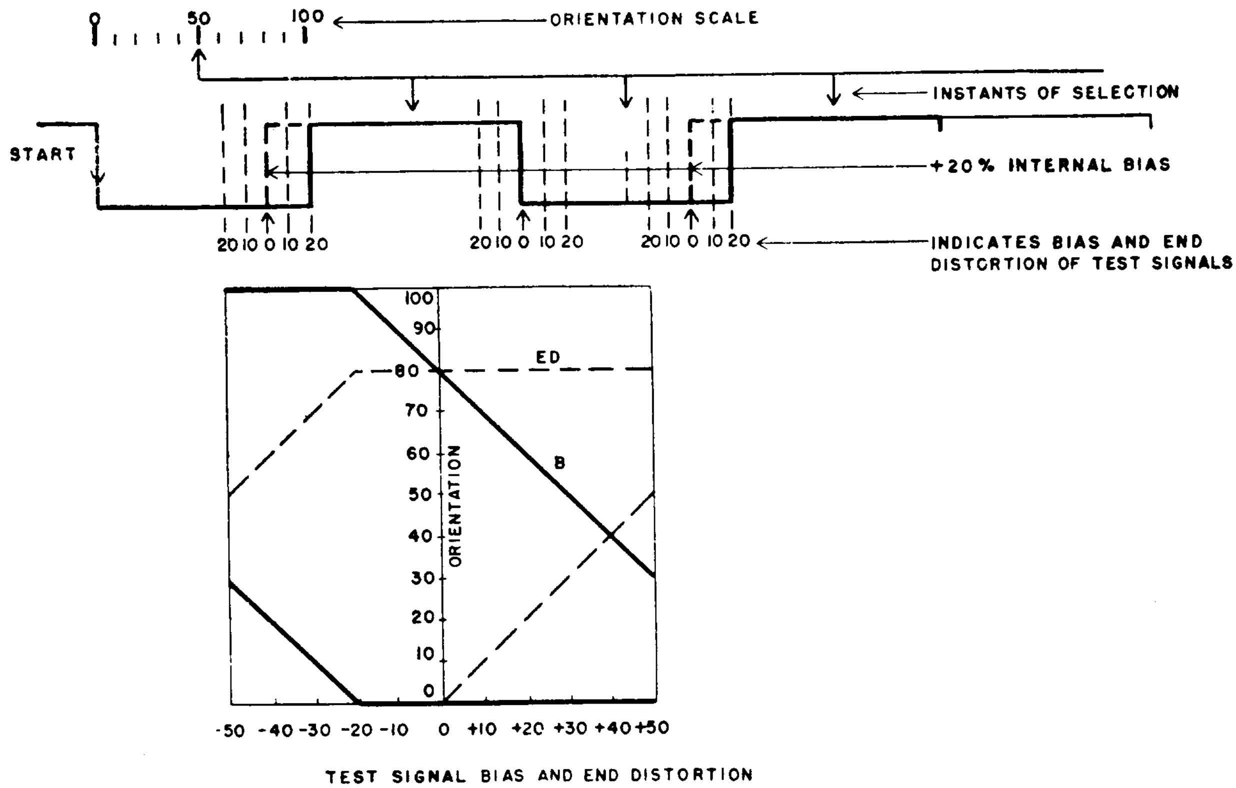


FIG. 5—BIAS AND END DISTORTION PARALLELOGRAMS +20% INTERNAL BIAS

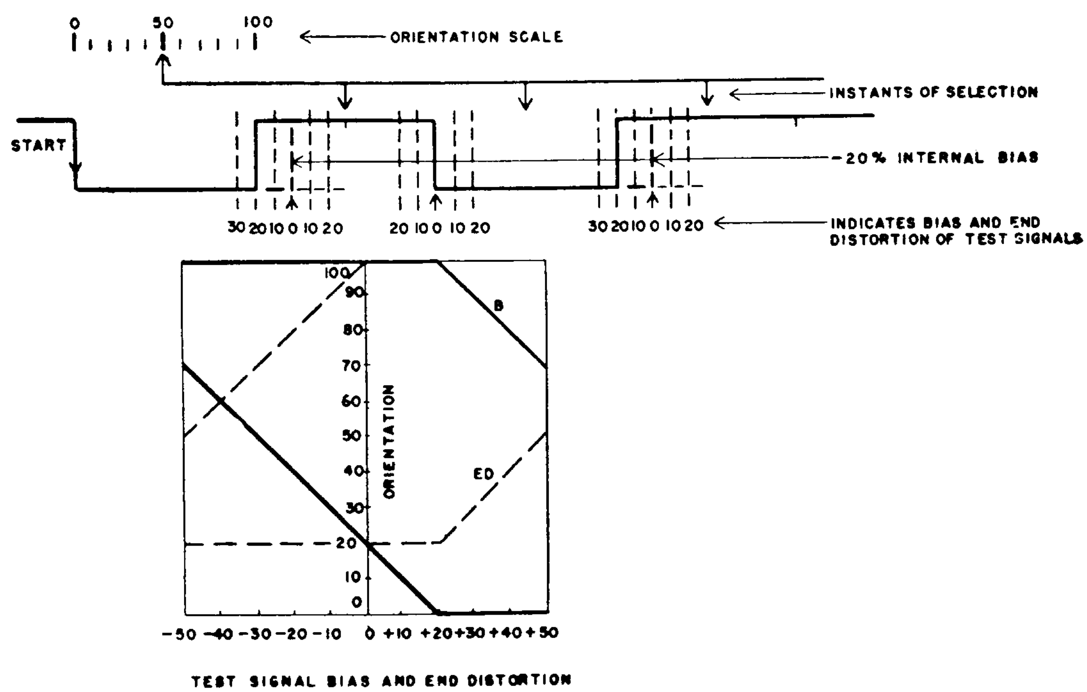


FIG. 6—BIAS AND END DISTORTION PARALLELOGRAMS —20% INTERNAL BIAS

Skew

3.05 Skew is said to occur when there exists distortion of the type mentioned in 2.13, in which the fortuitous effect on S-M transitions differs from that on M-S transitions. When the former is greater, the skew is said to be positive; when the latter, negative. Hence, in positive skew the MB and SB displacements are larger; in negative skew, the SE and ME displacements are larger. The amount of skew is defined as the difference between the magnitudes of the fortuitous effects on S-M and M-S transitions.

3.06 Cause of Skew

(a) In telegraph transmission systems skew may be caused by the effect of interference on a wave which has different slopes during M-S and S-M transitions. It may also result from an equivalent electromechanical effect in a start-stop receiver, as described in 3.12(e).

(b) Fig. 8 illustrates an asymmetrical wave in which the M-S transition is much steeper than the S-M transition. The dotted lines indicate the limits of an assumed random interference. The shaded area below shows how differently this interference affects the S-M and M-S transitions. In Fig. 8 the MB and SB displacements are larger than the SE and ME displacements; therefore the skew is positive. The value indicated is 15%. The effect of positive skew on the bias parallelogram is also indicated in Fig. 8.

(c) Fig. 9 shows the effect of negative skew. The skewing of the corners of the parallelograms shown in Figs. 8 and 9 led to the use of the term "skew" for this effect.

3.07 Internal Fortuitous Distortion

(a) It is usually considered, in measurements of miscellaneous signals, that the difference between the maximum distortion tolerance and 50% (the latter being the tolerance of a perfect receiver) is due to internal fortuitous effects, even though part of it may be due to the effects of internal characteristic distortion. Hence, the internal fortuitous distortion is usually defined as the difference between 50 and the tolerance to bias or end distortion, whichever of the latter may be the larger.

Internal Characteristic Distortion

3.08 In practice it is found that the relation between displacement and reduction of margin is sometimes not strictly linear. Especially at large values of displacement, the reduction in margin is often greater than the displacement causing it. This effect is due to internal negative characteristic distortion, which causes an increase in the distortion of shortened elements. Internal characteristic distortion, like any

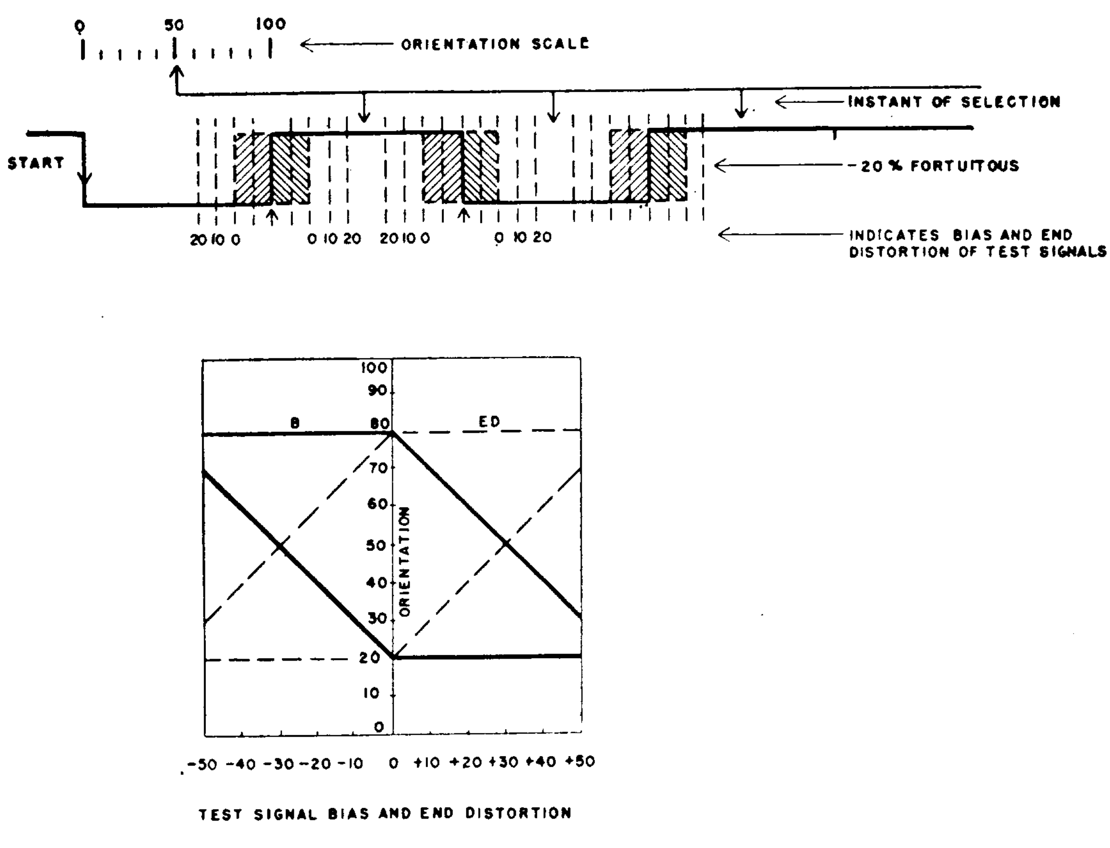


FIG. 7—BIAS AND END DISTORTION PARALLELOGRAMS 20% FORTUITOUS DISTORTION

form of characteristic distortion, is caused by the failure of some circuit or mechanical element to attain steady state before the occurrence of a succeeding transition. Fig. 10 shows an example of the bias and end distortion parallelogram of a receiver suffering from internal negative characteristic distortion.

3.09 Measurements of Receiver Distortion Tolerance

(a) In measuring the distortion tolerance of start-stop receivers, testing equipment is used which is arranged to transmit signals having any of the four types of displacement MB, SB, SE and ME. Positively biased signals are transmitted for MB displacement and negatively biased signals for SB displacement (Fig. 2). The test signals having SE or ME displacement differ from any signals experienced on transmission circuits in that only the M-S transitions of the selective elements are shifted relative to the start transition, being delayed for ME displacement and advanced for SE displacement. End distortion simulates the M-S displacements produced by characteristic and fortuitous distortion, and it has been found in practice that it yields results which enable a receiver's tolerance to these components of distortion to be predicted accurately.

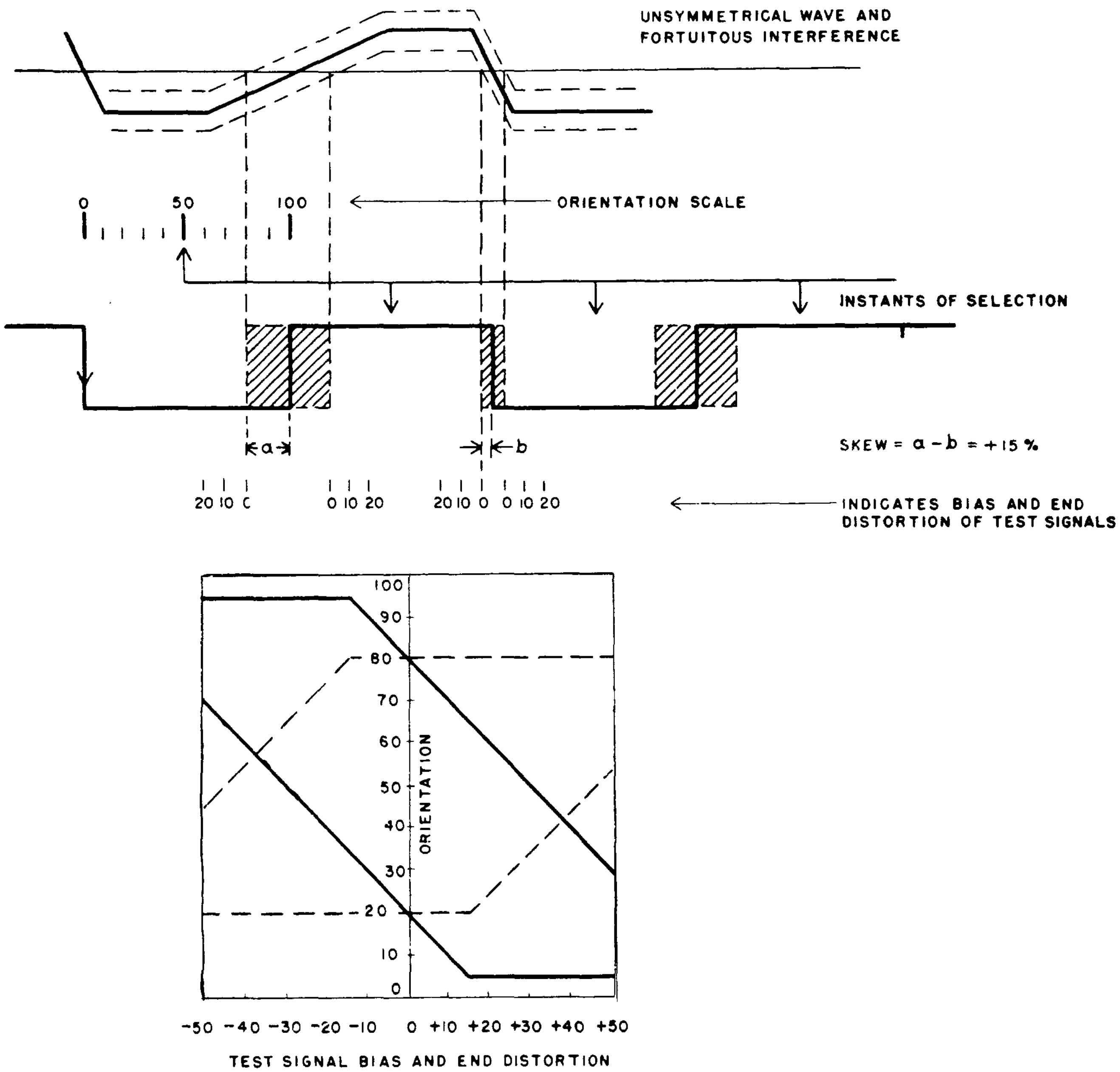


FIG. 8—BIAS AND END DISTORTION PARALLELOGRAMS AND 5% FORTUITOUS DISTORTION

(b) When fixed values of the four types of displacement are transmitted in turn, the limits of orientation for each are measured by means of the range scale of the receiver. Alternately, a distributor may be used in which the magnitude of displacement may be continuously varied and this enables measurements of internal distortion to be conducted with the orientation fixed or on receivers having no means or a limited means of varying the orientation.

3.10 Orientation Settings for Best Tolerance to Test Distortions

(a) The best orientation setting is that which permits the receiver to tolerate the greatest amount of any distortion which is expected. If all four types of displacement are considered equally likely, the orientation should be set at the point at which the minimum tolerance to any type of displacement is as large as possible. For example, consider a receiver which, with an orientation setting of 49, has the following tolerances to test displacements: (See Fig. 11.)

MB	44
SB	38
SE	42
ME	44

Let the orientation setting be raised 2% to 51. Then the tolerances are as follows:

MB	42
SB	40
SE	40
ME	46

The shift of orientation has increased the minimum tolerance to spacing bias from 38 to 40. Any further shift would make the tolerance to SE distortion less than the tolerance to spacing bias. This setting is called the "**center of fortuitous distortion toler-**

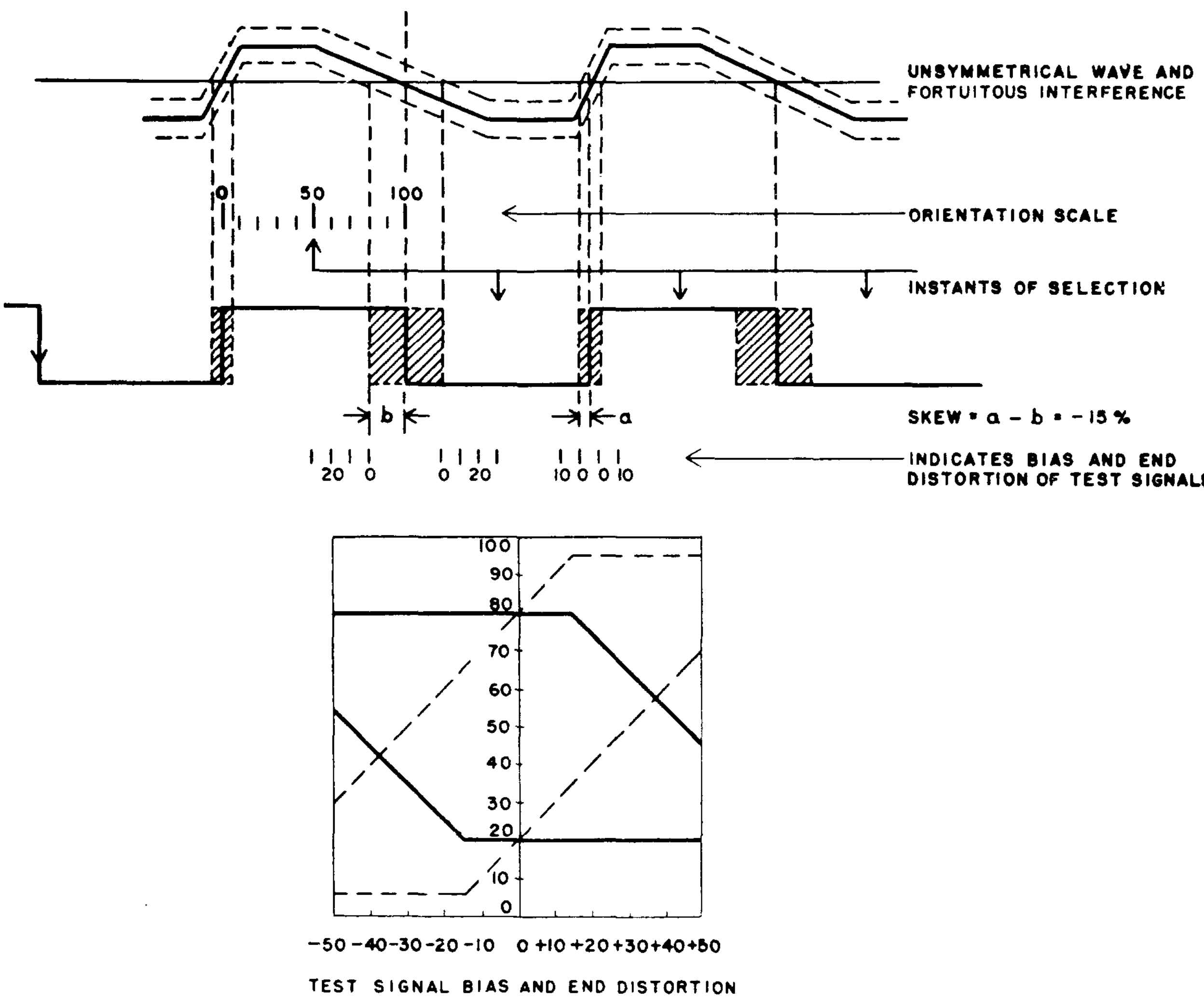


FIG. 9—BIAS AND END DISTORTION PARALLELOGRAMS — 15% SKEW AND 5% FORTUITOUS DISTORTION

ance" since the receiver will tolerate the maximum amount of fortuitous distortion.

(b) If, on the other hand, bias is considered more probable than distortions which produce "end distortion" effects, the orientation might be adjusted to the point at which the tolerances to marking and spacing bias are equal. For example, suppose the orientation setting of the receiver under consideration were raised 1% more to 52. The tolerances would then be:

MB	41
SB	41
SE	39
ME	47

This setting is called the **"center of bias tolerance"** since the receiver will tolerate the maximum amount of bias regardless of the sign of the bias.

(c) There is one more setting that is of interest. It is that at which the tolerances to marking and spacing "end distortion" are equal. Suppose

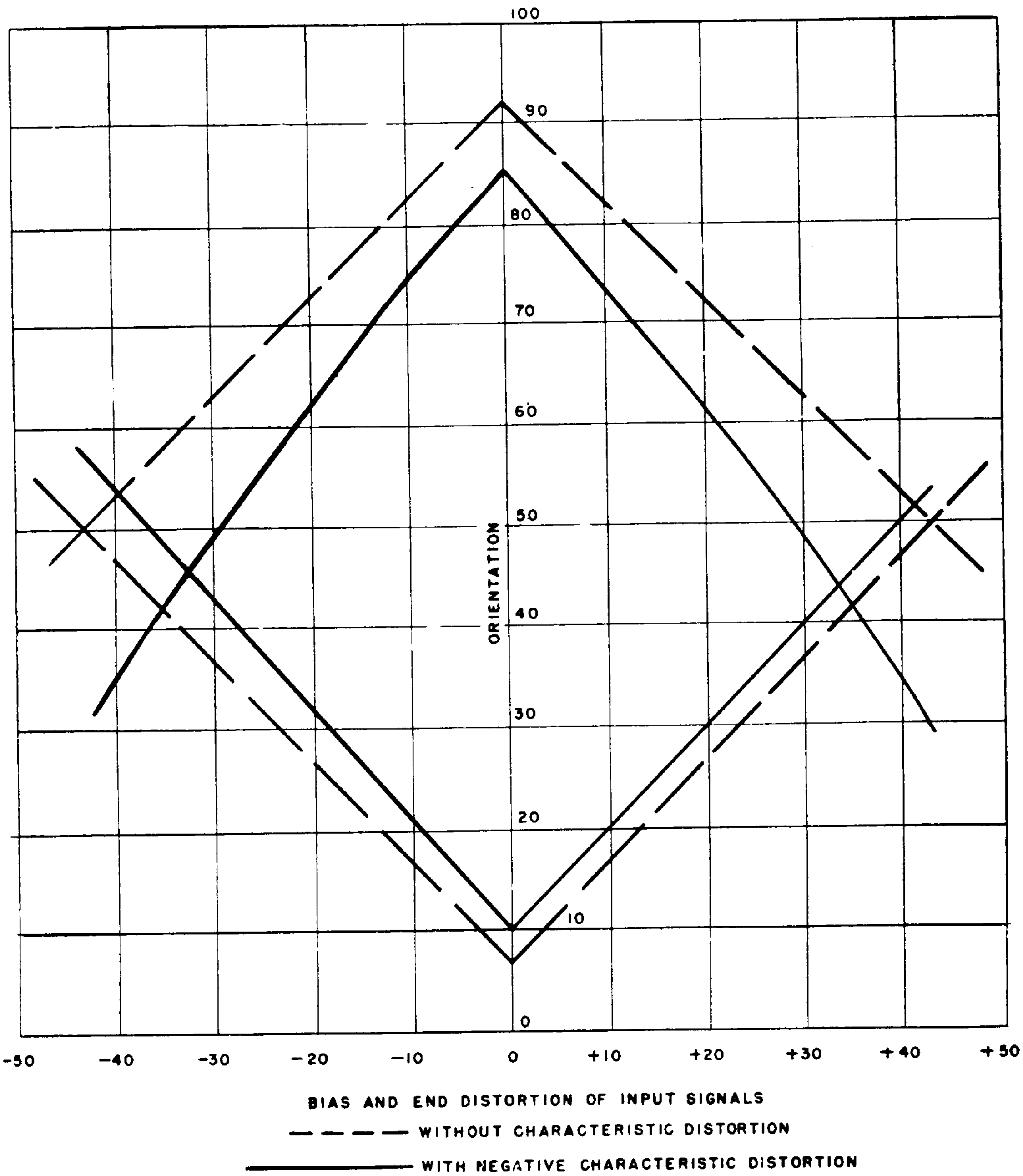


Fig. 10—Effect of Negative Characteristic Distortion on Bias and End Distortion Parallelograms

the orientation of the receiver were lowered 4% to 48. The tolerances would then be:

MB	45
SB	37
SE	43
ME	43

This setting is called the **"center of end distortion tolerance"** since the receiver will tolerate the maximum amount of **"end distortion"** regardless of its sign.

3.11 Calculation of Components of Internal Distortion

(a) Fig. 12 illustrates how the components of internal distortion are determined from measurements using distorted signals. Each diagram shows a portion of a teletypewriter character consisting of a start element, a marking selective element and a spacing selective element. The solid lines show an undistorted signal. The dashed lines show the displacement of a transition equivalent to

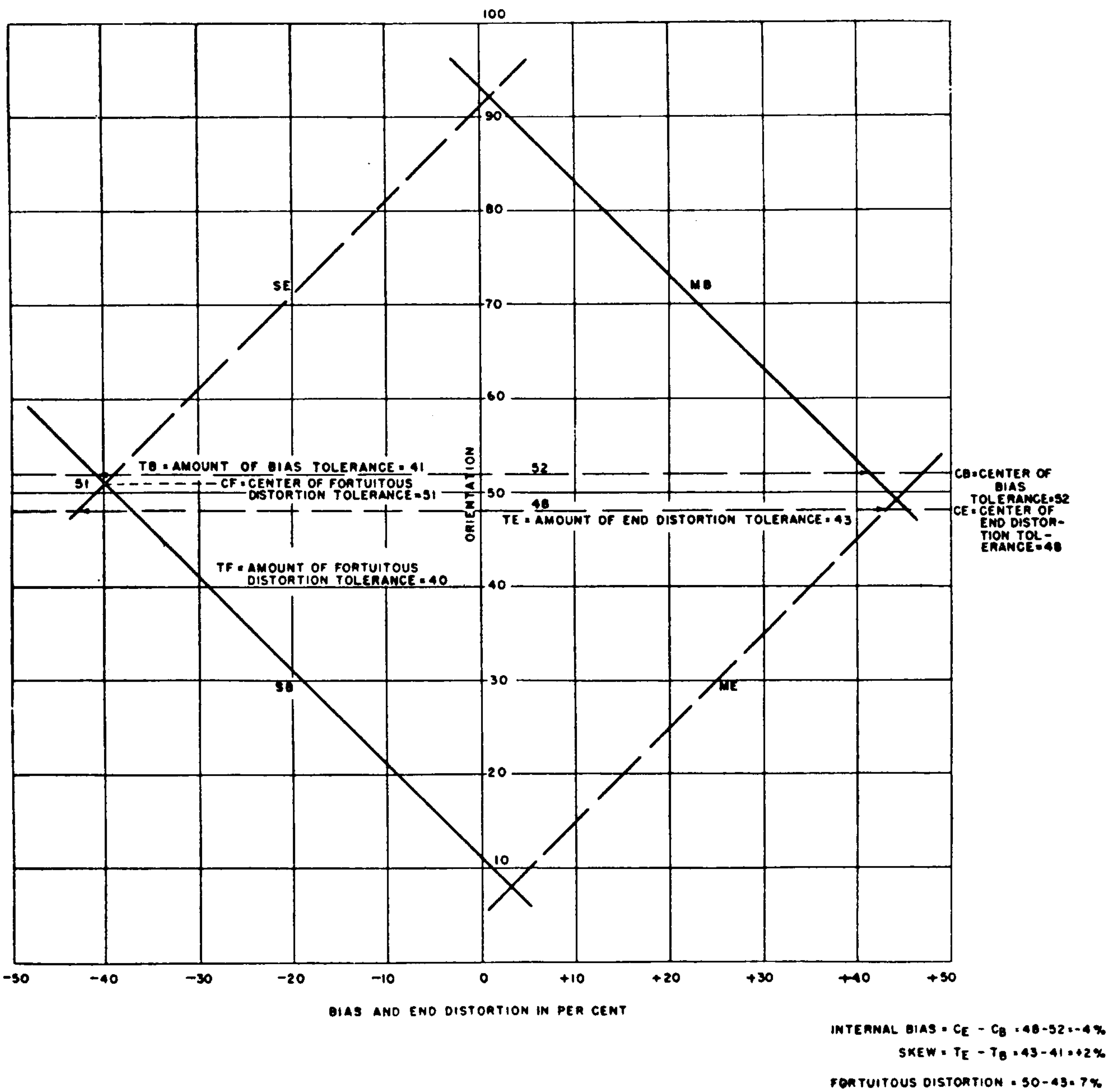


FIG. 11—PARALLELOGRAM FOR RECEIVER USED AS AN ILLUSTRATION OF DISTORTION TOLERANCES

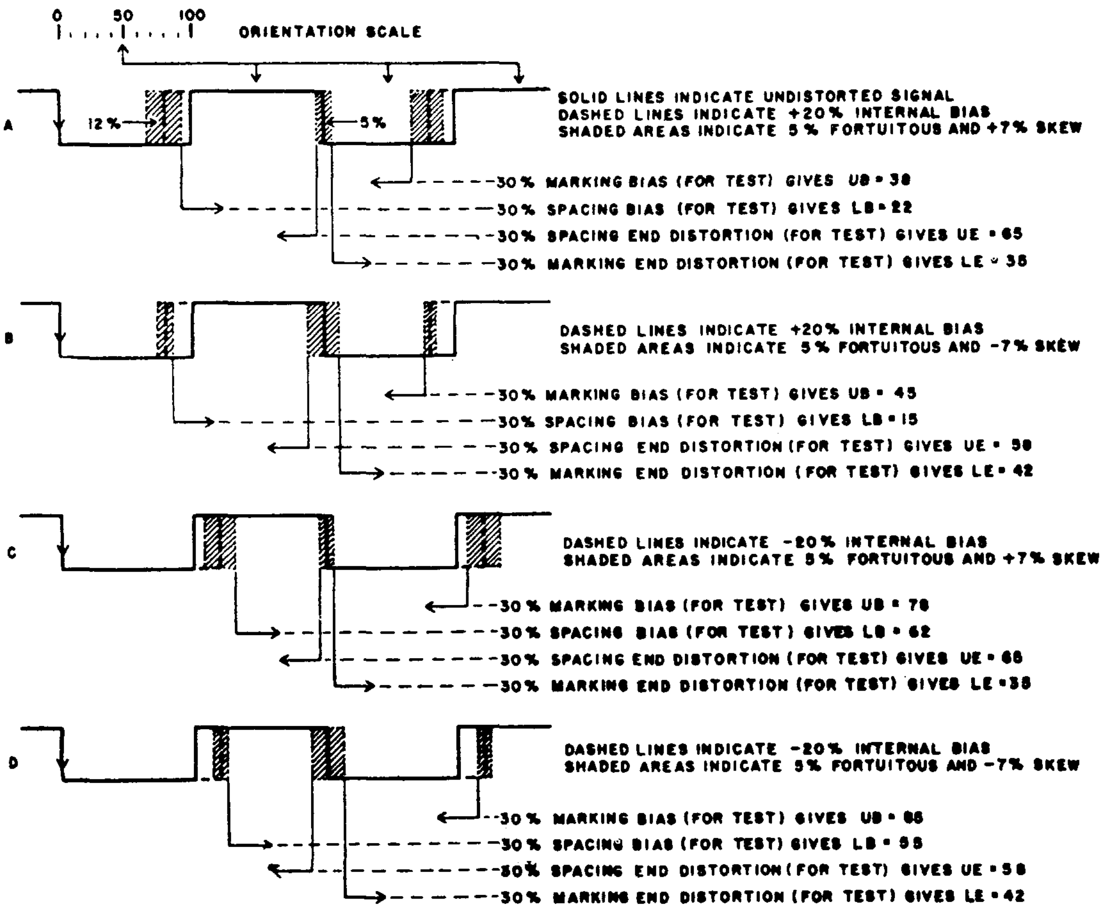


FIG. 12—USE OF DISTORTED TEST SIGNALS IN MEASURING INTERNAL DISTORTION

the effect of internal bias. Positive and negative 20% internal bias has been used in Fig. 12 for illustration. The shaded areas define the fortuitous effect; that is, the transition may fall anywhere within the shaded areas during repeated transmission of the signal. These shaded areas determine the internal fortuitous distortion and skew. Combinations of 5% fortuitous distortion with positive and negative 7% skew have been shown in Fig. 12 for illustration.

(b) Measurements are made with test signals containing the four types of displacement of equal magnitude as follows:

Displacement	Signal Contains	Orientation Range Limit Affected
MB	Marking bias, 30%	U_B
SB	Spacing bias, 30%	L_B
SE	Spacing end distortion, 30%	U_E
ME	Marking end distortion, 30%	L_E

Thirty per cent distortion for the test signals has been used as an illustration in Fig. 12 U_B and L_B are the upper and lower limits of orientation with, respectively, marking bias and spacing bias. U_E and L_E are the upper and lower limits of orientation with, respectively, spacing end distortion and marking end distortion.

The arrow points below the diagrams indicate the actual limits of orientation for the different test cases, as labeled.

(c) The following equations are listed for reference.

$$\text{Bias} = C_E - C_B$$

Where C_E = Center of tolerance to end distortion

C_B = Center of tolerance to bias

$$\text{Skew} = T_E - T_B$$

Where T_E = Amount of tolerance to end distortion

T_B = Amount of tolerance to bias

Fortuitous Distortion = 50 — Amount of Tolerance

Where amount of tolerance to bias or the amount of tolerance to end distortion is taken, whichever is the **larger**.

Fig. 13 shows the bias and end distortion parallelograms for the receiver having +20% internal bias, −7% skew and 5% fortuitous distortion used as an illustration in B of Fig. 12.

(d) By studying the above it can be seen that internal bias does not reduce the total bias tolerance of a receiver, but merely shifts the center of bias tolerance with respect to the center of end distortion tolerance. Hence, the effects of internal bias may be compensated for, as far as the bias tolerance of the receiver is concerned, by setting the orientation at the center of bias tolerance. However, internal bias does reduce the minimum end distortion tolerance of a receiver whose orientation is adjusted to the center of bias tolerance.

3.12 Some Causes of Internal Distortion

General

(a) The more obvious causes of internal distortion in teletypewriters are analogous to those which produce equivalent distortions in telegraph transmission circuits.

(b) **Bias** will result when an element (whether electrical, mechanical or electronic) of a receiver possesses asymmetry toward marking or spacing. For example, a mechanical element may travel more slowly from spacing to marking than from marking to spacing and thus cause spacing bias or its range of travel may be divided unequally into marking and spacing portions, thus producing an equivalent effect.

(c) **Characteristic distortion** will result when an element (whether electrical or mechanical) of a receiver fails to attain a steady state before being acted upon by a succeeding transition, or otherwise has its action dependent upon the previous history of the signal train.

(d) **Fortuitous distortion** will result when some mechanical element is irregular in its action, and if such action is more irregular on one type of transition than on the other, the result will appear as skew. For example, irregular action of the receiving clutch affects the selector alike on all selective transitions and appears as internal fortuitous distortion. Another source of internal fortuitous distortion is the period of indecision that occurs during

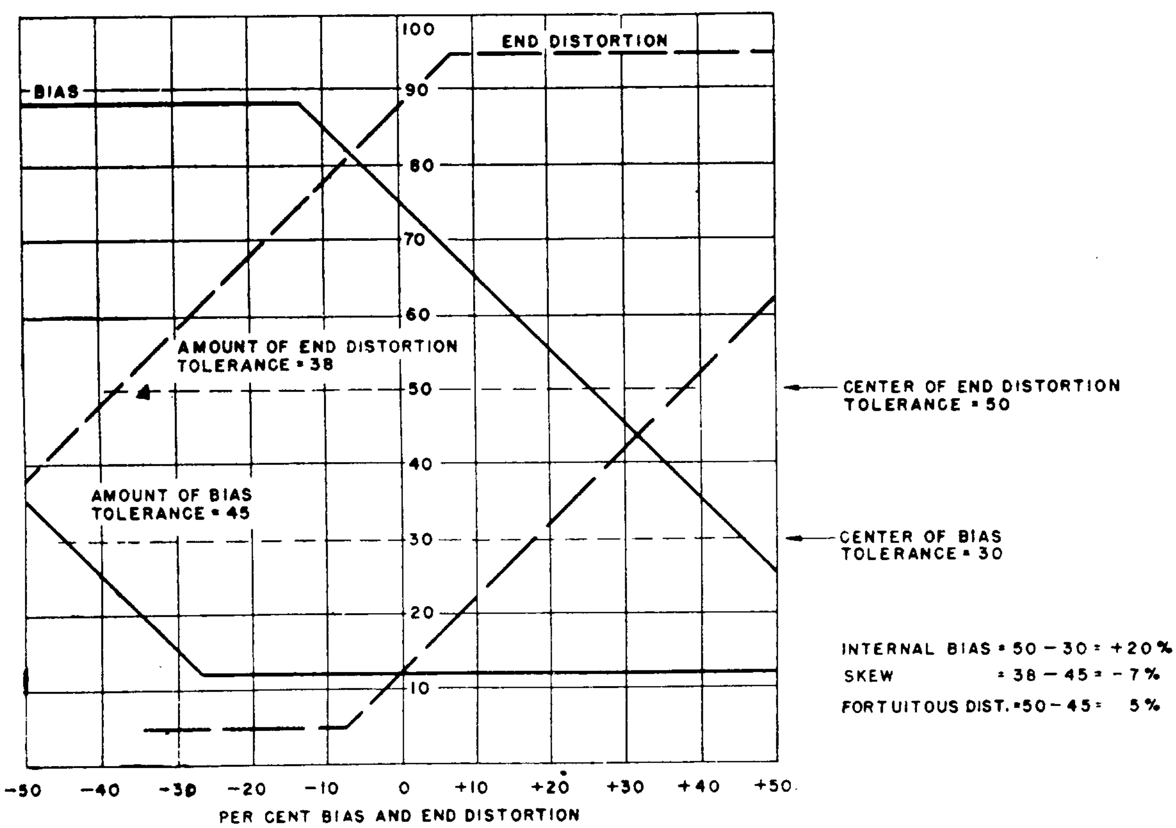


FIG. 13—BIAS AND END DISTORTION PARALLELOGRAMS FOR RECEIVER HAVING +20% INTERNAL BIAS, 5% FORTUITOUS DISTORTION AND −7% SKEW

the passage of a selective element past a locking member, at which time the choice between marking and spacing is largely fortuitous.

(e) A common cause of **skew** in teletypewriters may occur in the following manner: If the armature stops are so adjusted that, for example, the armature travel is greater on the marking side than on the spacing side of the armature lock, positive internal bias results. If, now, this bias is compensated by adjusting the armature air-gap and retractive spring tension so as to cause the receiving magnet to operate in a negatively biased manner (rather than by correcting the improper armature travel), the armature will be forced to operate in a region of the operating wave that is more sloping than the region in which it releases. Hence, it will operate more irregularly than it releases and thus it will be affected by positive skew.

3.13 Selector Action

(a) Over and above the sources of internal distortion, which are analogous in effect to sources of distortion encountered in telegraph transmission circuits, there is another whose action in causing internal distortion is not so obvious as those just described. This source of internal distortion may be termed "selector action," and it depends upon the relation between the operating time of a selector element and the period of time allowed for the element to act. For the purpose of explaining the effect of time relations within the selector on internal distortion, selector mechanisms may be classified as of three basic types; M, S, and P.

(b) An example of the **type M mechanism** is the early start-stop printer with an individual selector magnet for each element of the code and a separate receiving distributor. In this mechanism each selector armature is initially in the spacing condition. In response to a received signal element it either remains spacing or operates to marking, as called for by the signal. If it goes to marking it remains locked there for the rest of the character.

(c) An example of the **type S mechanism** is the holding-magnet selector of the present-day 14 and 15 teletypewriters. The operation is similar to that of the type M selector except that the marking and spacing operations are reversed. At the beginning of each signal element the selector armature and its associated selector arm are moved by the armature cam into the marking position. The armature then either remains in the marking position for the duration of the signal element, if the element is marking, or is released to go to spacing if the element is spacing. The selector arm is locked in the marking or spacing position and can not again change until the next signal element.

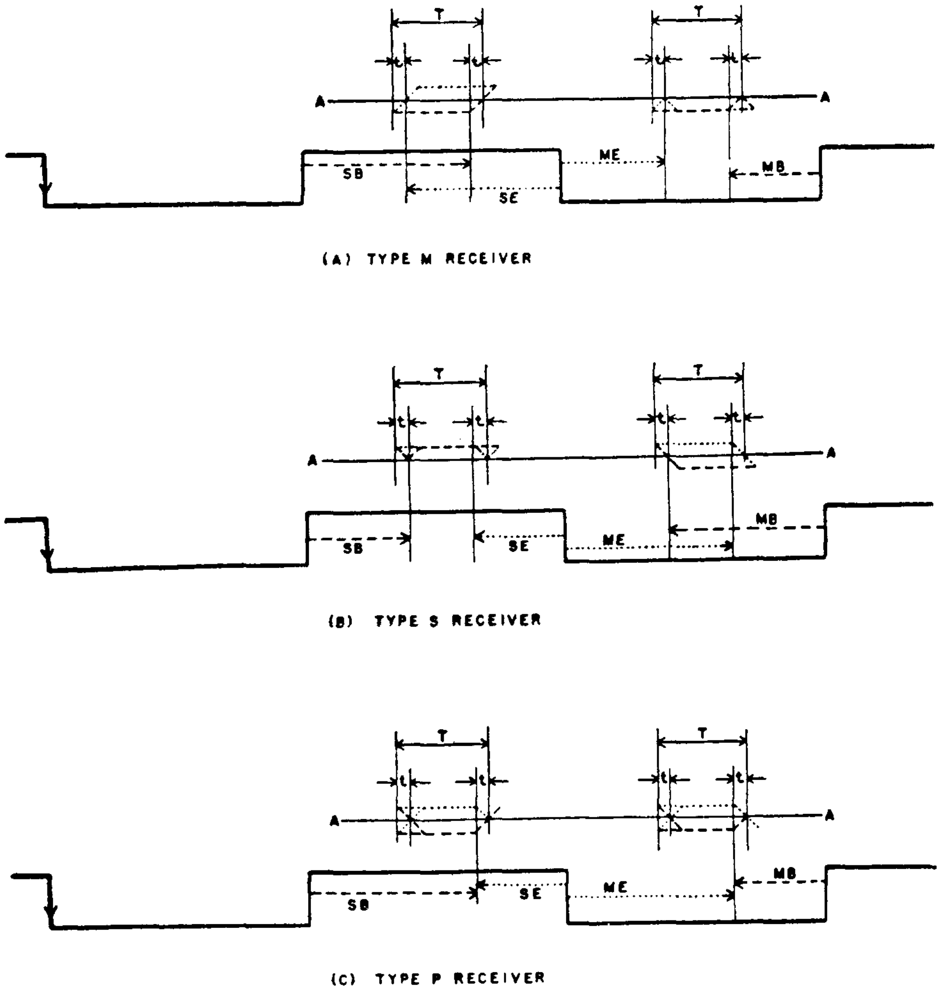
(d) An example of the **type P mechanism** is the pulling-magnet selector of the 14 and 15 teletypewriters. Here the selector armature may be initially in either the marking or the spacing position, depending upon the nature of the preceding signal element. It is locked at all times except during the selecting intervals. At the start of the next selecting interval it is unlocked and for the duration of the selecting interval it is free to follow the signal.

(e) Fig. 14A illustrates the action of a type M selector. A portion of a teletypewriter character is shown, consisting of the spacing start element, a marking first selective element and a spacing second selective element. The undistorted signal is shown in solid lines. Above the signal train is shown a schematic representation of the action of the selective system. The periods of time T are those during which the selector is subject to the action of the received signal, and t is the time that the selector must be subjected to the operative force in order to operate. The line A-A indicates the boundary between the marking and spacing regions of the selectors.

In this type of selector, as mentioned previously, when the selector crosses to the marking or upper side of line A-A it becomes locked and can not again go to spacing even though the signal should subsequently become spacing during the selective period T. The dashed line SB indicates the maximum amount of SB displacement that the receiver will tolerate. In other words, with the amount of SB displacement shown the selector will barely operate to marking during the marking signal element. Similarly, the dashed lines SE, ME, and MB indicate the maximum amounts of the corresponding displacements which the receiver will tolerate.

(f) It will be noted that the limits of end displacement tolerance occur at time t **after the beginning** of the selective interval. This instant is sometimes called the "instant of decision for end displacement." On the other hand, the limiting tolerances to bias are determined at a time T **before the end** of the selective interval, sometimes known as the "instant of decision for bias." If the selective periods were advanced relative to the start transition by lowering the orientation until the bias tolerances were equal, the instant of decision for bias would correspond with the center of bias tolerance. If then, the selective periods were delayed, by raising the orientation by an amount T-2t, the instant of decision for end displacement would correspond with the center of end displacement tolerance. Since the difference between the center of end displacement tolerance and the center of bias tolerance is equal to the internal bias of the receiver, the internal bias is also equal to the difference between the instant of decision for bias and the instant of decision for end displacement. In this type of receiver the internal bias is T-2t, and will be positive, zero or negative accordingly as 2t is less than, equal to, or greater than T.

(g) Fig. 14B shows the action of a type S selector. Here the instant of decision for bias occurs at time t before the end of the selective period and that for end displacement at time t after the begin-



(A) TYPE M RECEIVER

(B) TYPE S RECEIVER

(C) TYPE P RECEIVER

FIG. 14—EFFECT OF SELECTOR ACTION ON INTERNAL DISTORTION

ning of the selective period. Hence, the internal bias is equal to 2t-T.

(h) Fig. 14C shows the action of a type P selector. It is assumed in this figure that the selector operates toward marking at the same rate as toward spacing, since the effect of unequal rates of operation has been described in 3.12 (b). In a selector of this type, both instants of decision occur at time t before the end of the selective period and hence the internal bias is not dependent upon the relation of T and t. If, however, t is so long that the selector can not pass from one extreme of travel to the other, attain a steady state, and return to the center position within time T, a sort of characteristic distortion occurs, in which the instant of decision depends upon whether the selector began the selective period in the same or the opposite condition from that finally selected. In measurements of miscellaneous signals this appears similar to a fortuitous effect, since it decreases all tolerances equally. Hence, it is usually regarded as internal fortuitous distortion.

(i) Receivers equipped with holding magnet selectors are of type S, since the armature may be released but not operated, by the magnet. In this type of mechanism, the armature drives a subsidiary selective member, and the time T extends from the instant at which the armature is disengaged by its operating cam until the instant when the subsidiary selector becomes locked.

As this period is usually long compared to the magnet releasing time t1 and the subsidiary selector operating time t2, holding magnet selectors are subject to negative internal bias. In those mechanisms in which the subsidiary selector is flexibly coupled to the magnet armature, the former's operation is of type P. Therefore, it may be subject to a characteristic distortion effect similar to that mentioned in the description of type P operation, except that only the instant of decision for end displacement is affected. Consequently the result resembles negative skew rather than internal fortuitous distortion.

4.00 GENERATION OF DISTORTED SIGNALS

4.01 When bias is applied to teletypewriter signals and the sign of the bias is suddenly changed during the transmission of a character, all the succeeding transitions of that character are affected, not by bias, but by end distortion. This is shown in Fig. 15, which illustrates the action of a biasing current on a relay driven by a symmetrical wave.

(a) Shows the original unbiased signal.

(b) Shows the current wave, purposely rounded by elements of the electrical circuit in order to give a variable bias.

(c) Shows the unbiased signal which results from using the normal bias current (2).

(d) Shows the signals biased to marking by the use of biasing current of value (3), which is suddenly changed to value (1) at time (T). This changes the signal bias from marking to the same amount spacing.

(e) Shows the corresponding effect on the same signals when the bias is changed from negative to positive.

4.02 Signals such as these, in which the sign of the bias is changed at intervals, may be produced by the 119A Telegraph Signal Distorting Circuits, and have been referred to as "switched bias" signals. Since all four types of displacement are present in equal magnitude in the signals produced by this set, the effect on a start-stop receiver resembles that of fortuitous distortion. Thus the center of switched bias tolerance is the center of fortuitous distortion tolerance and the amount of switched bias tolerance is the amount of fortuitous distortion tolerance. This center is also the center of orientation in a receiver having no curvature or symmetrical curvature of the displacement vs. orientation-limit characteristic. The "switched bias" tolerance is one-half the orientation range in a receiver having no curvature of the characteristic.

4.03 The 119A signal distorting sets have the disadvantage that end distortion is produced only after the occurrence of the switch within a given char-

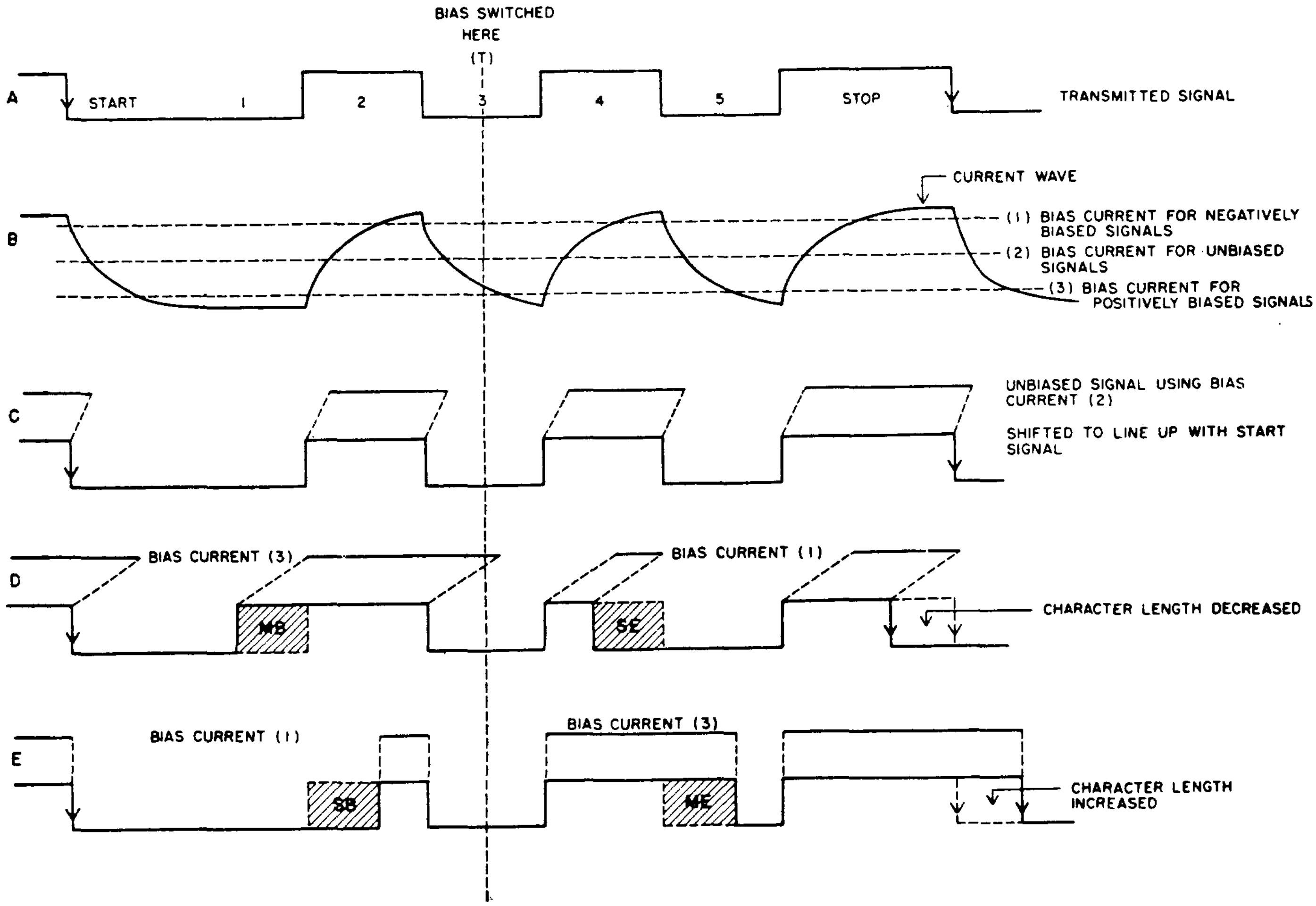


Fig. 15—"Switched Bias" Produced by Relay Causes Four Types of Displacement

acter. The switch is made under the control of a 60 IPM source and there may be a beating effect between this source and the 368 operations per minute of the teletypewriter. This means that during certain intervals there might be no switches made which will cause end distortion for testing.

4.04 These disadvantages have been overcome in a later design known as the 119C1 Telegraph Signal Distorting Circuit. In this design the M-S and S-M transitions are shifted electronically. Various types of distortions are generated as follows:

(a) **Steady marking bias** is produced by delaying all M-S transitions including the start transition, without delaying the S-M transitions.

(b) **Steady spacing bias** is produced by delaying all S-M transitions.

(c) **Switched marking and spacing bias** is produced by delaying M-S transitions during one character and then switching the effect during the stop interval so that S-M transitions will be delayed during the following character.

(d) **Switched marking and spacing end distortion** is produced by delaying the M-S transitions during one character and switching the effect to the S-M transitions during the following start element. In this way alternate start elements will either have both transitions delayed or neither transition delayed so that all start elements will be of correct length. During a character in which neither transition of the start element is delayed, the remaining elements will have their M-S transitions delayed; thus producing marking end distortion during that character. During the next character, in which both transitions of the start element are delayed, the remaining elements have their S-M transitions delayed so that spacing end distortion is produced. Succeeding characters alternate between marking and spacing end distortion.

(e) **A switched combination of all varieties of displacement** is produced in a manner similar to that just described except that the switching is done during the start element of every alternate character rather than every character. If the first character has been switched to produce marking end distortion, the next character, which is not preceded by any switching, will have marking bias. The third character will be switched during its start pulse to spacing end distortion and the fourth character of the cycle will have spacing bias.

4.05 In field practice, true switched bias signals (as obtained with the 119C1 set) and switched end distortion as well as switched combination distortion, applied at a central office, are used as a test of tolerance of the teletypewriter at a subscriber station in combination with the subscriber loop. Thus the teletypewriter and loop are tested as a unit. The loop may include characteristic distortion, the effect of which will be more severe on distorted than on undistorted signals. Therefore distorted signals provide a more accurate measure of transmission capabilities than an orientation range measurement with undistorted signals from the central office, since not only is the curvature of the distortion parallelogram taken into account, but the character length changes in much the same manner as in signals affected with characteristic or fortuitous distortion.

5.00 SOME CONSIDERATIONS INVOLVED IN THE MEASUREMENT AND ADJUSTMENT OF START-STOP RECEIVERS

5.01 Because of the effects of characteristic distortion, it cannot be assumed that the ultimate tolerance of a receiver is equal to the sum of the displacement of the received test signals and one-half the remaining orientation range, especially if the latter is large. To obtain accurate results, the ultimate tolerance must be measured with the orientation adjusted to the center of tolerance.

5.02 For the same reason (the curvature of the parallelogram caused by internal characteristic distortion) measurements of internal distortion on a receiver which is, itself, to be used to measure distortion should be made with displacements of approximately the same magnitude as the distortions which the receiver is to measure. In a receiver which is to be used to measure small distortions, the linear portions of the parallelograms are of particular interest. Hence, the receiver's internal bias and skew are measured using small amounts of displacement in the measuring signals. The internal fortuitous distortion may generally be neglected, since it does not affect the shape, but only the size, of the distortion vs. margin characteristic.

5.03 On the other hand, in a receiver which is to be used for receiving signals, the principal interest is not so much in the shape of the characteristic as in the ultimate tolerance to telegraph distortion at an optimum setting of the orientation mechanism. For this reason, a receiver destined for service use is best tested with signals containing fairly large displacements. Internal fortuitous distortion is deleterious in such a receiver, since it decreases the tolerance to displacement of all kinds. Skew, depending upon its sign, affects the tolerance to either S-M or M-S displacements.

5.04 It should be realized that the removal of skew does not necessarily improve a service receiver. In the case of bias or characteristic distortion the introduction of distortion of a given sign will remove or reduce internal distortion of the opposite sign, and thus improve the performance of the receiver. But, since skew is the difference between two fortuitous effects, it may be removed either by reducing the larger or increasing the smaller effect. The former procedure will increase the receiver's total tolerance to distortion, whereas the latter will reduce it.

5.05 In practice bias tolerance is generally considered to be more desirable than end distortion tolerance. The reason for this is that most transmission circuits suffer from some bias (of unpredictable sign and amount) which uses up some of the receiver's bias tolerance but none of its end distortion tolerance. This is why the orientation of a service receiver is generally adjusted to the center of bias tolerance, and small amounts of internal bias or negative skew are not considered objectionable, since they do not affect the tolerance to bias at the center of bias tolerance. Conversely, the presence of positive skew, which indicates a lowered bias tolerance, usually calls for a readjustment of the receiver to reduce the fortuitous effect on the S-M transitions. As explained above, removing the skew by introducing a fortuitous effect on the M-S transitions will not improve the bias tolerance.

5.06 It is gooa practice to specify a minimum bias tolerance about 5% greater than the minimum permissible end distortion tolerance, the orientation being adjusted to the center of bias tolerance for both measurements. Consequently, the sum of the external bias and positive skew must be kept reasonably small.