

Oct. 4, 1938.

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2,131,870

TELEGRAPH SYSTEM.

Filed Oct. 10, 1936

4 Sheets-Sheet 1

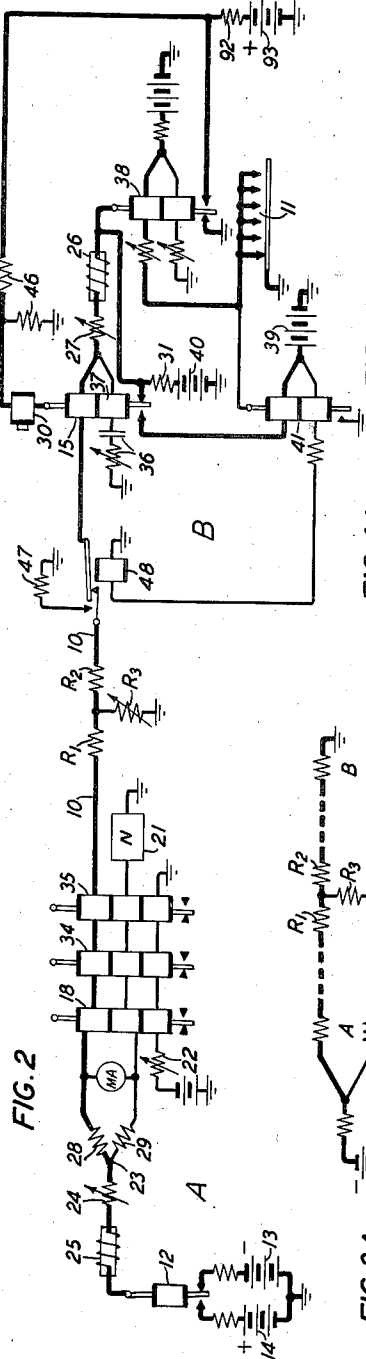
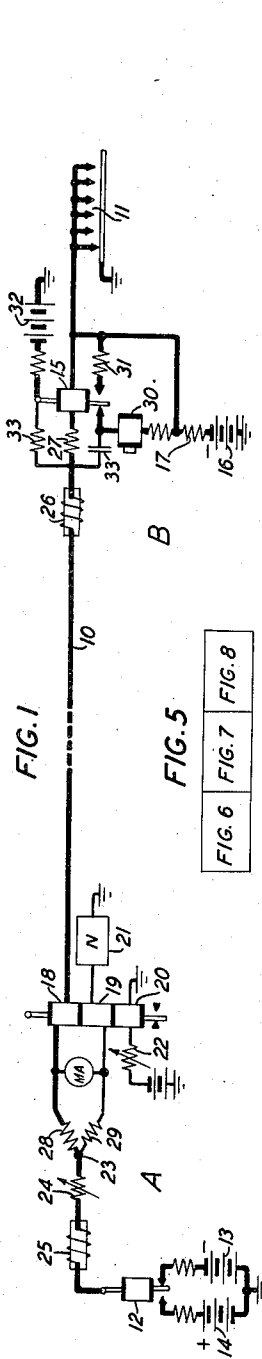


FIG. 4C

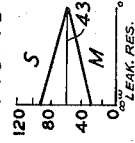


FIG. 4B

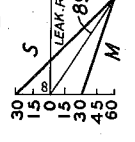


FIG. 4A

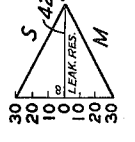


FIG. 4F

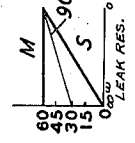


FIG. 4E

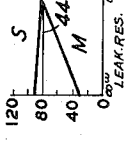
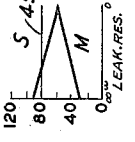


FIG. 4D



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TELEGRAPH SYSTEM

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4 Sheets-Sheet 2

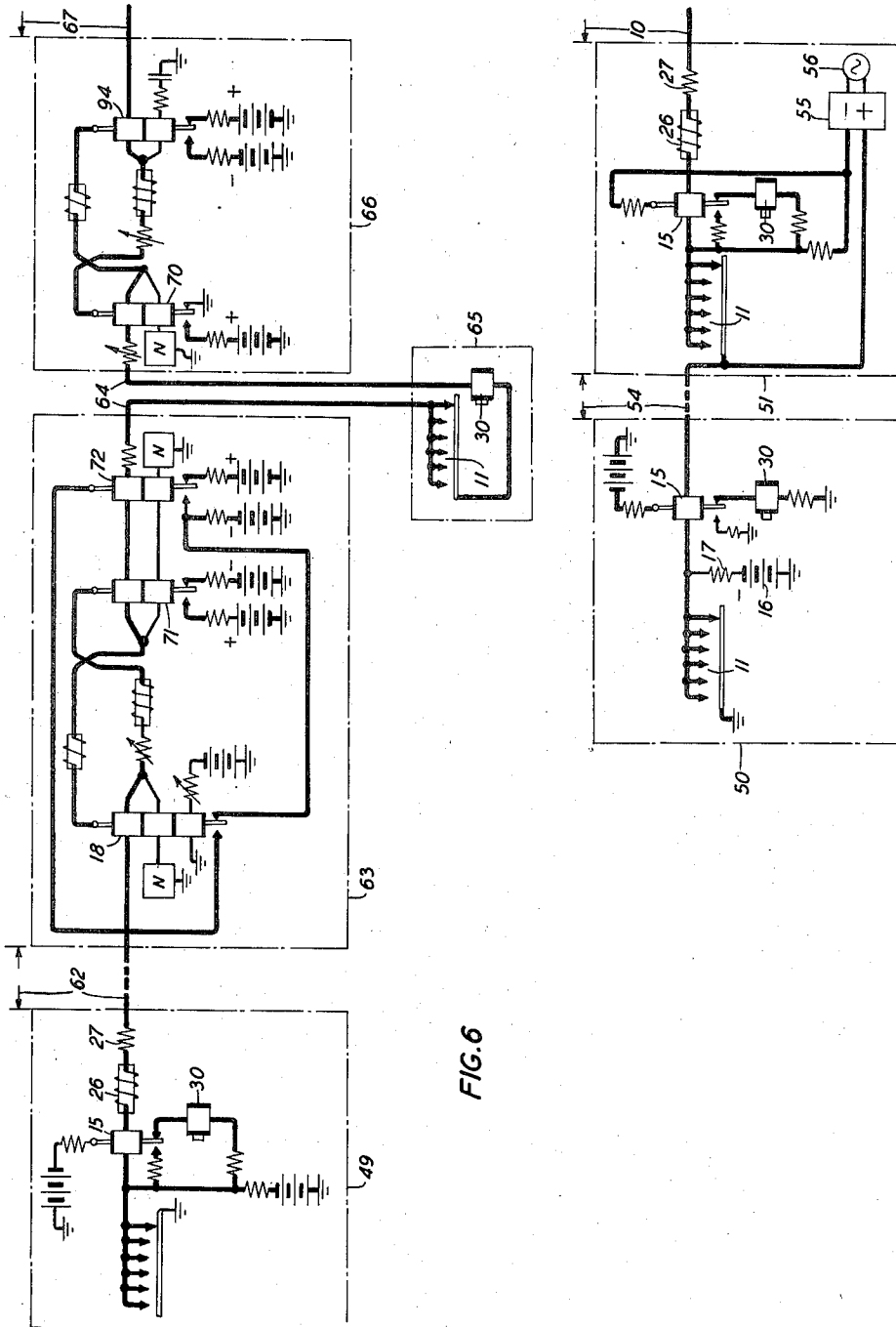


FIG. 6

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TELEGRAPH SYSTEM

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4 Sheets-Sheet 3

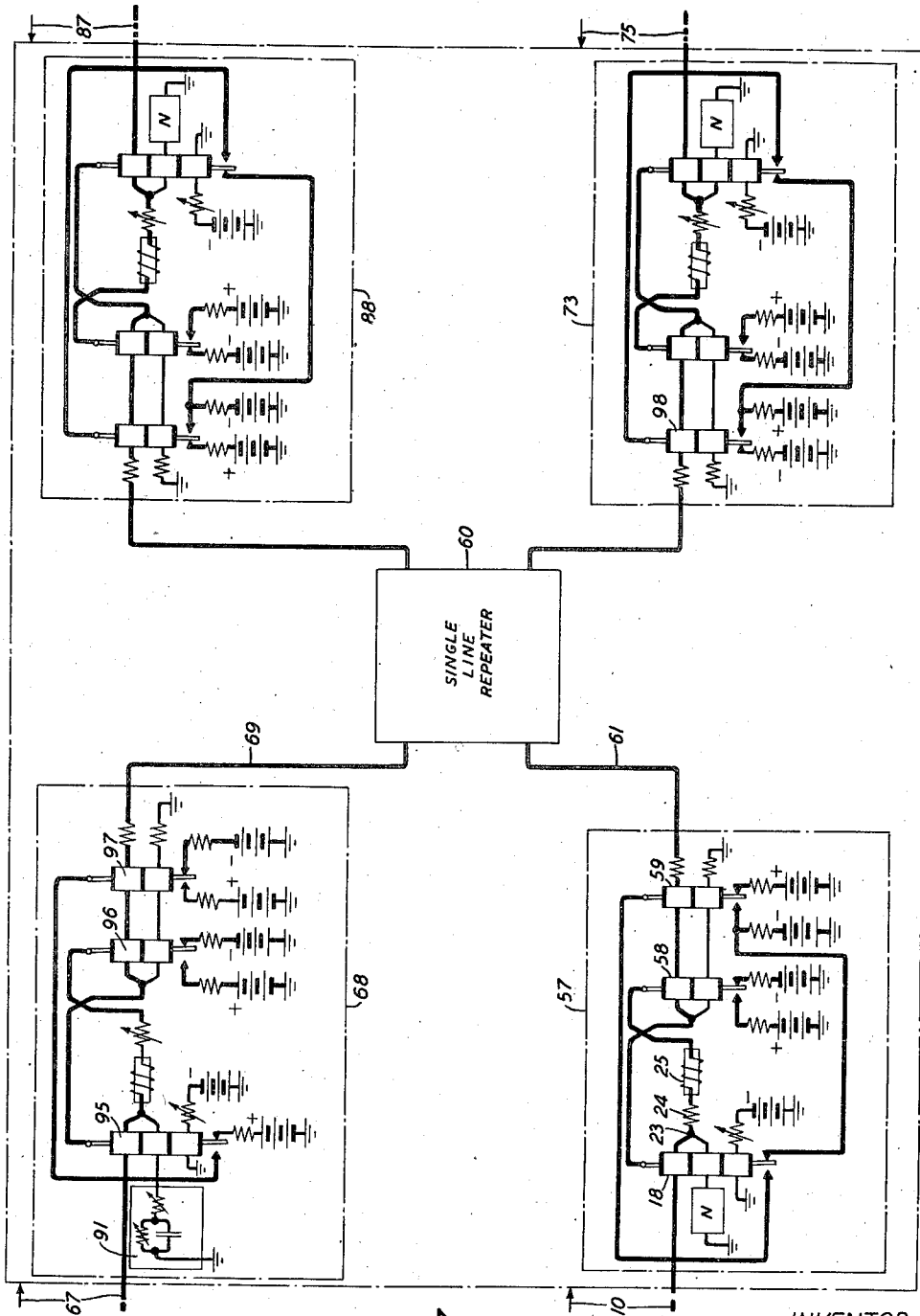


FIG. 7

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TELEGRAPH SYSTEM

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4 Sheets-Sheet 4

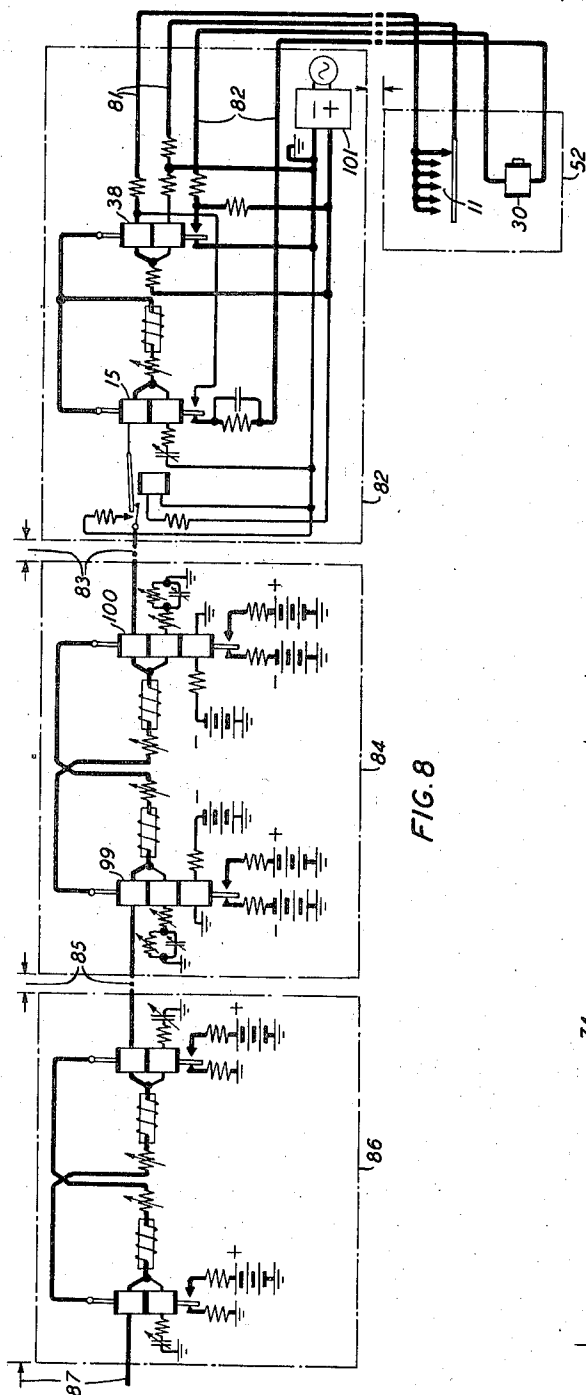
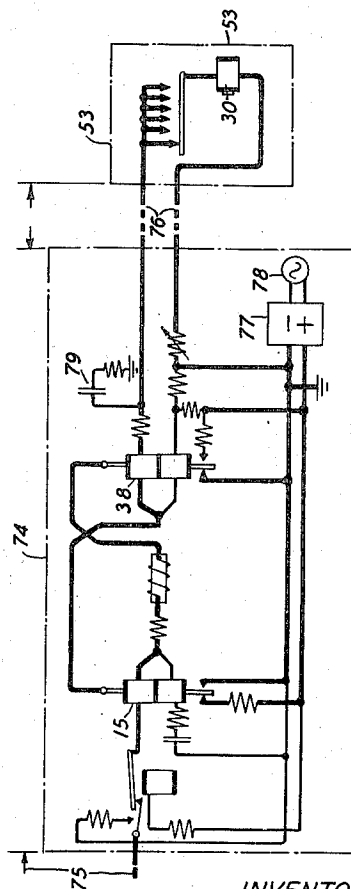


FIG. 8



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TELEGRAPH SYSTEM

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Application October 10, 1936, Serial No. 104,959

29 Claims. (Cl. 178—59)

This invention relates to telegraph systems and more particularly to improved arrangements for transmitting telegraph signal impulses over long open-wire telegraph lines and over the telegraph channels of long open-wire toll lines.

Long open-wire lines of these types are subjected to varying weather conditions. This causes a varying leakage resistance which varies over wide limits from a very high value under dry conditions to a relatively low value under wet weather conditions. Both the duplex and upset duplex telegraph transmitting and receiving arrangements usually employed at the ends of long lines of this type must be adjusted to compensate for this variation in the leakage current of the line in order to insure the correct reception of the telegraph signals. Variation of the leakage of the line tends to cause a variation in the bias of the received signals which must be compensated for by a variation of the biasing current of the receiving relays at each end of the line. This adjustment must be made in accordance with the variations in the leakage of the line so that it is necessary, at times, to adjust this bias current at the ends of the line at rather frequent intervals, thus causing a high cost of circuit maintenance. This is particularly true in the case of an outlying subscriber where it is very difficult to provide suitable maintenance of the telegraph circuit because the subscriber is so far removed from the telegraph station or repeater point, as is the usual case when transmitting telegraph signals over long circuits of this type.

It is an object of this invention to greatly reduce the amount of maintenance and adjustment required, first, at the outlying or subscriber's end of the line and, second, at both ends of the line without introducing any biasing or other distortion of the telegraph signals from any other source.

In accordance with one embodiment of this invention the outlying subscriber or telegraph station is arranged to be self-compensating or to require no balancing with changes in the leakage or leakage resistance of the line connecting that station to the central station. This arrangement, however, requires additional maintenance and adjustment of the biasing current and balance at the central station because the signals received at the central station vary more with leakage than do signals received from the usual duplex arrangements which require balancing at both ends of the line.

In accordance with another embodiment of this invention, however, after the central office

end has been adjusted to correctly receive the signal impulses, the adjustments at both ends of the line need not be altered with changes in leakage of the line because the signal impulses arriving thereat will cooperate with the receiving apparatus to produce signal impulses substantially unaffected by variations in the leakage of the line. In other words, the circuit is arranged to fully and automatically compensate for changes in the leakage resistance of the line.

It is also within the scope of this invention to combine line sections of the two above arrangements and to combine either one with existing types of line sections in suitable comprehensive telegraph communication networks. It is also within the scope of this invention to modify and adapt these arrangements to operate satisfactorily with various types of telegraph equipment and various types of telegraph circuits.

While the novel features of this invention are specifically set forth in the claims appended thereto, the foregoing and other objects and features of the invention may be more readily and more fully understood from the following description when read with reference to the attached drawings in which:

Fig. 1 illustrates an embodiment of this invention requiring adjustment at only one end of the line to compensate for changes or variations in the leakage of the line;

Fig. 2 shows an embodiment of the invention which requires no change in adjustment at either end of the line to compensate for variations in the leakage of the line;

Figs. 3—A to 3—C, inclusive, illustrate the various signaling conditions normally encountered in the system shown in Fig. 2;

Figs. 4—A to 4—F, inclusive, illustrate in diagrammatic form the manner in which the various currents received from the telegraph line vary with leakage under various conditions;

Fig. 5 shows the manner in which Figs. 6, 7 and 8 are arranged to form a typical comprehensive system to which this invention is applicable; and

Figs. 6, 7 and 8 when arranged as shown in Fig. 5 show a comprehensive telegraph system embodying features of the systems shown in Figs. 1 and 2 modified and adapted for use with different telegraph circuits.

Referring now to Fig. 1, A represents the first telegraph station and B the second telegraph station which are connected by telegraph line 10. Telegraph line 10 may be of any suitable direct current telegraph line or channel and may in-

clude or comprise a telegraph leg of a composited long distance toll line in which case it will include terminal composite sets as well as intermediate composite sets. In addition, various sections of the line may include entrance cable and open-wire lines. Various sections of the line may also be simplex lines and other sections may be straight direct current telegraph lines. The open-wire sections of said line 10 are subject to varying leakage due to changes in the weather conditions. During dry weather the leakage resistance of the line is very high and usually may be neglected. However, during wet weather the leakage resistance of the line falls to a relatively low value which seriously interferes with the transmission of telegraph signal impulses over the line unless compensating changes are made. However, in accordance with Fig. 1 the terminal equipment is so arranged that no compensation for changes in the leakage of the line need to be made at station B. At station B the line 10 is normally connected to ground through the sending contacts 11 of a suitable transmitting device such as for example the transmitting contacts of a teletypewriter shown in Fig. 1. At station A telegraph signal impulses are transmitted from the contacts of the sending relay 12. The marking and spacing contacts of relay 12 are connected to two substantially equal sources of potential or batteries 13 and 14 of negative and positive polarity, respectively. These signals are transmitted over line 10 and actuate the receiving relay 15 at station B. Any leakage of the line to ground will affect both the positive and negative signal impulses or currents equally. Consequently, on arriving at station B these currents will operate the receiving relay 15 equally fast in both directions and will not therefore affect the bias of relay 15. In other words, the algebraic sum of these currents is constant. Since relay 15 is a polar relay and receives equal positive and negative current, it may be given a zero bias. In other words, it will operate as well and as fast in one direction on positive current as it will operate in the opposite direction on negative current. Consequently, when this relay is so adjusted and receives positive and negative signal impulses from the contacts of relay 12, the response of relay 15 will be substantially independent of the leakage in line 10. This condition is further illustrated in Fig. 4—A which shows in diagrammatic form the current received by relay 15 as the leakage of the line decreases from infinity to zero. It is to be noted that the marking current received by relay 15 as shown by curve M of Fig. 4—A increases just as much as the spacing current received by relay 15 at station B decreases as the leakage resistance of the line decreases. It is to be understood that the curves in Fig. 4 are to illustrate this feature and that the scale of the leakage resistance has not been shown. Such a scale of leakage resistance is assumed as will make the curves M and S be straight lines. In actual practice if the scale of the leakage is linear, curves S and M will not be straight lines but curved lines which will approach the zero current condition asymptotically as the leakage resistance approaches zero. However, as shown in Fig. 4—A at any given value of leakage the marking current received by relay 15 has the same magnitude as the spacing current received by relay 15. Consequently, relay 15 will respond to both marking and spacing current without any addition of bias to the signal.

The term "bias" as applied to signals indicates

a lengthening of one signal impulse and a shortening of the other signal impulse. For example, marking bias means that the marking signal impulses are lengthened and the spacing impulses shortened, whereas spacing bias means that the spacing signals are lengthened and the marking signals are shortened. Thus the greater the bias of the signals the less satisfactory they are for operating telegraph apparatus or the poorer in quality they are, while the less the bias the better the quality of the signals.

A common cause for this lengthening and shortening of the various signals is that the marking and spacing currents are unequal, for example, for marking bias the marking current is greater than the spacing current whereas for spacing bias the spacing current is greater than the marking current. However, as pointed out above with the arrangement shown in Fig. 1, the receiving device 15 at station B receives equal marking and spacing current and consequently does not introduce any bias in the received signal and requires no biasing winding to compensate for any such bias.

The terms "marking" and "spacing" as used in this application differentiate the two line or signaling conditions transmitted between telegraph stations. The term "marking" is used to designate the line or signaling condition employed during the time no signal impulses are being transmitted but the system is energized and ready to transmit signal impulses. The term "spacing" designates other signal or line condition.

Referring again to Fig. 1, transmission from station B is effected by the opening and closing of the contacting device 11 in accordance with the signal impulses to be transmitted. During the open periods of these contacts battery 16 is connected through resistance 17 to the line 10. The potential of battery 16 is of the same polarity as the source of potential 13 normally connected to the telegraph line at station A. However, the source of potential 16 is of a greater magnitude than the source of potential 13 or the potential of point 23 so that it overpowers the potential source 13 and causes current to flow in the reverse direction over line 10. If, as in the preferred embodiment, source 16 is twice the magnitude of source 13, or rather the potential of point 23, then the two line currents will be of equal magnitude but opposite polarity. Under these conditions the receiving relay 18 would require no additional biasing or balancing winding. However, since a balancing winding 19 is provided, a biasing winding 20 must also be provided to compensate for the direct current flowing in winding 19 to insure proper operation of the receiving relay 18. The balancing winding 19 and balancing network 21 are required to prevent the operation of relay 18 during the transmission of signal impulses from the sending relay 12 over line 10 to station B. If there were no leakage on the line, current through the biasing winding 20 could be adjusted once by means of resistance 22 and thereafter remain constant. However, in case a variable lead due to varying weather conditions is encountered in line 10, it will be necessary to alter the adjustment of the biasing current by varying resistance 22 to compensate for variation in the leakage current. Fig. 4—B shows the manner in which the marking and spacing currents received at station A from station B vary with variations of the leakage resistance of line 10. In order to compensate for variations of the leakage resistance it is

necessary to adjust the bias of the receiving relay 18 along line 99 of Fig. 4—B.

It is also possible to control the potential of point 23 by varying the resistance 24 and thereby also effect the compensation for the variation of the leakage of the line. It should be noted that the values of both the positive and negative potentials applied to line 10 are varied by resistance 24, thus insuring that the bias of the signals received by the receiving relay 15 at station B will be unaffected by the value of the leakage resistance of the line.

Coils 25, 26 and elements 27, 28 and 29 are provided to reduce the noise in a telephone circuit due to the operation of the transmitting devices at the respective telegraph stations and also to properly adjust and control the magnitude of the line current flowing in line 10. It is to be understood that any suitable filter arrangement may be used in place of the coils 25 and 26 to reduce noise in the telephone circuit. In addition this noise reducing arrangement may be omitted in case the line is not composited and transmits only direct current telegraph signal impulses.

At station B printer magnet 30 is connected to the contacts of the receiving relay 15. A compensating resistance 31 is also connected to these contacts. The compensating resistance 31 is provided to maintain a load on source 16, which is the same as the source 32, so that substantially constant potential is applied to the printer magnet and line 10 during the operation of receiving relay 15. When the relay moves to its opposite or spacing contact it interrupts the circuit of magnet 30, thus decreasing the load on source 16. The potential of source 16 will then tend to increase. To prevent this resistance 31 is connected to the source 32 which is the same as 16 and provides a compensating load to maintain the voltage thereof substantially constant. In addition, when contacts 11 open during transmission of signal impulses, relay 15 moves to its opposite contact. This reduces the impedance between the line and the source of potential shown as 16 and 32. Resistance 31 serves, under this condition, to reduce this impedance and maintain it at a low value and thus tends to improve the transmission from station B. This resistance is more essential in case the load carrying capacity of this source of potential, which may be a rectifier or small motor generator, is just about adequate to supply the load.

Elements 33 provide contact protection for the contacts of receiving relay 15.

Sending relay 12 and receiving relay 18 may receive signals from and transmit signals to other relays of other types of suitable telegraph repeaters, as, for example, duplex telegraph repeaters, voice frequency carrier current telegraph repeaters, carrier current telegraph repeaters, etc., as well as from subscribers' lines. In addition sending contacts 11 may be replaced by sending relay contacts actuated by another subscriber's line. In this case the contacts of relay 15 would transmit to the subscriber's line.

In the embodiment of this invention shown in Fig. 2, the terminal circuits of line 10 are arranged to transmit and receive telegraph signal impulses so that the received signal impulses at both ends of the line will be substantially independent of variations in a leakage of the line.

For the purpose of illustration, it will be first assumed that the leakage resistance of the line is concentrated at a single point and is represent-

ed by leakage resistance R_3 in Fig. 2 connected to line 10. The resistance of line 10 is represented by resistance R_1 and R_2 , which also include the resistance of the terminal apparatus connected to the respective ends of line 10. As in Fig. 1, it is to be understood that line 10 may comprise any suitable direct current telegraph channel, including the telegraph channel of a composite toll line, in which case the line may include both terminal and intermediate composite sets. In addition, line 10 may include portions of cable circuits including entrance cables commonly employed in open-wire lines, where these lines pass through cities and towns. As in Fig. 1, the line at station B is normally connected to ground through the contacts of a sending relay 38. Signals are transmitted from station A to station B by means of sending relay 12 which may be actuated by signal impulses received from any suitable source, including various types of telegraph repeaters. Relay 12 transmits the corresponding signal impulses or currents by connecting the positive and negative sources of potentials 14 and 13, respectively, to the telegraph line 10. These sources of potential are of substantially equal magnitude so that substantially equal currents of opposite polarity will be transmitted over line 10 in accordance with the operation of relay 12. These currents will be equally attenuated by the line and the leakage resistance and will have substantially the same value when received by relay 15 at station B. Receiving relay 15 at station B is provided with substantially no or zero bias so that receiving relay 15 will respond equally well to both of the signaling currents received thereby and will, consequently, introduce no bias distortion as described in connection with Fig. 1 and shown in Fig. 4—A.

In order to more readily understand the operation of the transmission of the signals in the reverse direction from station B to station A, reference will be made to Figs. 3—A to 3—C, inclusive, which illustrate the various signaling conditions.

Fig. 3—A illustrates the connections to line 10 when both stations are normal or transmitting marking signal impulses.

Fig. 3—B shows the conditions when station A is transmitting a spacing impulse to station B. As may be readily seen from these figures, the positive current transmitted to station B under these conditions will be attenuated substantially the same amount as the negative current from station A under marking conditions. Consequently, the algebraic sum of these two currents, as received at station B, will be independent of the leakage resistance R_3 of line 10 because the sum will always be zero.

Fig. 3—C shows the circuit connections during the time a spacing impulse is being transmitted from station B to station A and if the receiving device at station A is to respond to this spacing impulse as readily as it does to the marking impulse, when the line 10 is connected to ground as shown in Fig. 3—A, it will be necessary for the algebraic sum of the currents received at station A to be independent of the leakage resistance R_3 of the line. It will be also necessary to adjust the magnitude of the bias of the receiving relay 18 at station A to the average of these two currents to insure proper operation which is independent of variations of the line leakage resistance R_3 . The magnetic effect of the bias current should oppose the magnetic effect of the average of the two received currents. The cur-

rent i_1 received at station A during the transmission of marking impulses from station B, as illustrated in Fig. 3—A, is as follows:

$$i_1 = \frac{E_1}{R_1 + \frac{R_2 R_3}{R_2 + R_3}}$$

and the current i_2 received at station A during the time the spacing impulse is being transmitted from station B is as follows:

$$i_2 = \frac{E_1 + \frac{E_2 R_3}{R_2 + R_3}}{R_1 + \frac{R_2 R_3}{R_2 + R_3}}$$

The sum S of these currents i_1 and i_2 is

$$i_1 + i_2 = S = \frac{2E_1 + \frac{E_2 R_3}{R_2 + R_3}}{R_1 + \frac{R_2 R_3}{R_2 + R_3}}$$

As pointed out above, if the signals received from station B are to be substantially independent of the line leakage resistance R_3 , it is essential that the sum of these two currents shall be independent of the value of the leakage resistance R_3 or

$$\frac{dS}{dR_3} = 0$$

Differentiating the sum S with respect to R_3 , equating it to zero, and simplifying, the condition required for the sum S to be independent of the value of R_3 is as follows:

$$\frac{R_1}{R_2} = \frac{2E_1}{E_2}$$

Thus we see that by controlling the relative magnitude of the potentials at each end of the line with respect to the location of the leakage resistance along the line, it is possible to maintain the algebraic sum of the marking and spacing currents as received at station A substantially independent of the value of the line leakage resistance.

In the above example, it was assumed that the line leakage resistance R_3 was concentrated at a definite point along line 10. In practice, however, this leakage resistance is usually distributed along the line or along some portion of the line. If the exposed portion of the line which experiences the variation of line leakage is somewhere near the center of the line, the line leakage may be replaced by a concentrated effective line leakage resistance which is at the center of the exposed line and the potentials at the ends of the line adjusted in accordance with the position of this concentrated effective leakage resistance R_3 . In case the line is substantially all open-wire line and all, therefore, subjected to varying distributed leakage throughout its length, the concentrated effective resistance may not be at the center of the line. It has been discovered that if the terminal impedance of the receiving and transmitting devices connected to the line is very low, the distributed leakage of the line 10 may be replaced by a concentrated effective leakage resistance which is located approximately 0.4 of the resistance of the line from station A. If the terminal resistance of the line is relatively high, then the distributed leakage of the line should be replaced by an effective resistance which is substantially at the center of the line between stations A and B. In practice, the position of the equivalent concentrated resistance is usually be-

tween about 0.45 and 0.5 of the resistance of the line from station A.

The action of the circuit during the transmission of signal impulses from station B to station A may be also explained by reference to Fig. 4—C. In this figure the line marked M represents the variation in the marking current received at station A during the time a marking impulse is transmitted from station B by sending relay 38 connecting ground to line 10 over an obvious circuit. Similarly, curve S illustrates the manner in which the current received at station A varies with the leakage resistance of the line during the times spacing impulses are transmitted from station B by relay 38 connecting the source of positive potential 93 to line 10. It is to be noted that as the marking current increases the spacing current decreases a corresponding amount so that the sum of the currents is substantially constant. By providing a biasing current for the receiving relay at station A which is equal in magnitude but opposite in direction to the average of these two currents represented by line 43 of Fig. 4—C, the resultant magnetic effect of these two currents upon the received relay 13 will be substantially equal under all conditions of line leakage. Thus, the response to the receiving relay at station A is also independent of the line leakage resistance R_3 .

It should be noted that during spacing signal impulses transmitted from station B to station A of Fig. 2, the line current is increased because the source of potential 93 at station B aids the source of potential 13 connected to the line at station A. This is just the opposite from the arrangement shown in Fig. 1 in which the source of potential 16 connected to the line at station B opposes the potential 13 normally connected to the line at station A. In the usual telegraphic circuit, resistances R_1 and R_2 are approximately equal so that the magnitude of the source of potential 16 should be approximately twice the magnitude of the source of potential 13. Under these conditions the line current is increased to about three times its normal value when a spacing signal is transmitted from station B to station A. When resistances R_1 and R_2 are approximately equal, substantially equal powers or currents are received by the receiving relays at both ends of the line. This means that the relays at each end of the line should be of the same sensitivity and that the length of the line is not limited by the apparatus or relays at one end more than by the equipment at the other end of the line.

In order to readily adjust the effective values of these potentials, a variable resistance 24 is connected between the armature of the sending relay 12 and line 10, as shown in Fig. 2. This variable resistance permits the potential of point 23, which is the effective potential applied to line 10, to be varied because resistance 24, in combination with resistance 29, the resistance of the balancing windings of relays 18, 34, 35, and the resistance of balancing network 21, form a potentiometer. Thus, by varying the resistance 24, it is possible to vary the potential of point 23 and thus adjust the effective value of the potential applied to line 10 at station A. It should be noted that with this arrangement, the values of both the positive and negative potentials applied to line 10 are simultaneously varied, so that they are both of substantially the same magnitude and thus transmit currents of substantially the same magnitude to station B independently of the value of resistance 24, thus insuring that the bias of

receiving relay 15 at station B will be unaffected by variations of the leakage resistance of the line.

As shown in Fig. 2, the particular system is adapted for use in a telegraphic system in which the repeater station A is provided with a receiving relay 18, a break relay 34, and vibrating relay 35. Three windings of these relays 18, 34 and 35 are shown in Fig. 2, the top winding being the line winding, the middle winding being a balancing winding and the lower winding being a biasing winding to adjust the bias of these relays to an average of the two line conditions received from station B. It is to be understood that these relays may be provided with additional windings, as, for example, by the usual vibrator windings connected in the usual vibrator circuit and controlled by the vibrating relay 35. It is to be understood that a similar arrangement may also be provided at station A of Fig. 1. However, under certain conditions, as, for example, with relatively short lines, the vibrating relay may not be required.

Since no bias or zero bias is required for the receiving relay 15 at station B, the balancing network 36, connected to the balancing winding 37 of relay 15, is provided to balance only the alternating-current components of the telegraph signals transmitted over line 10. With this arrangement the auxiliary bias windings shown on the relays at station A are eliminated. It is to be understood that a similar arrangement of the receiving relay may be employed at station B in the arrangement shown in Fig. 1. The arrangement shown in Fig. 2 has a further advantage in that the received telegraph signal impulses and particularly the higher frequency alternating-current components of these received signal impulses do not need to pass through the high inductance of element 26 of the transmitting noise filter.

The printing magnet or relay 30 of Fig. 2 is arranged to receive polar signal impulses from receiving relay 15. One terminal of the winding of relay 30 is connected to the armature of relay 15, while the other terminal of the winding of relay 30 is connected to about the mid-point of potentiometer comprising resistances 46 so that this mid-point is substantially at half the potential of source 93. The marking and spacing contacts of relay 15 are connected to ground through marking contacts of the sending relay 38 and to battery 39 through the upper winding of the break relay 41, respectively. Thus when receiving relay 15 is on one contact, current flows from the mid-point of potentiometer comprising resistances 46 through the winding of relay or magnet 30 to ground and when relay 15 is on its other contact, current flows in the opposite direction through the winding of relay or magnet 15 from battery through the contacts of relay 15 to the mid-point of potentiometer 46.

Break relay 41 is provided to insure the interruption of the home copy of the teletypewriter machine at station B during the reception of a break signal over line 10. This relay is only required for teletypewriters which are not provided with a "break lock". In addition, relay 48 is provided to normally connect the line 10 to ground through resistance 47 during the time the apparatus at station B is shut down and the power supply disconnected.

It is to be understood that additional teletypewriter apparatus may be connected in series with the teletypewriter apparatus shown at station B. For example, additional transmitting contacts 11 may be connected in series with the transmit-

ting contacts 11 shown in Fig. 2. In addition, additional receiving relays or magnets 30 may be connected in series with the magnet 30 shown in Fig. 2, providing additional local telegraph transmitting and receiving stations, any one of which may transmit messages to all of the others and over line 10, as well as receive messages from line 10. Furthermore, the transmitting and receiving apparatus connected to both ends of the line may be part of repeaters connected to any type of telegraph lines and apparatus such as to subscribers' lines, composited toll lines, carrier current lines, etc.

A compensating load 31 is connected to the contacts of the receiving relay 15 and the source of potential 40 to provide a more constant load and thus a more constant source of potential, thus insuring more uniform operation of the circuit arrangement during the transmission of signal impulses by relay 38. This compensating resistance 31 is particularly desirable when the sources of potential 16, 39 and 40 are provided by a rectifier or motor generator of small power capacity.

In adjusting the circuit arrangement shown in Fig. 2, it is usually desirable to provide a source of potential 93 about twice as great as the sources of potential 13 and 14, and to make minor adjustments of the effective potential transmitted to line 10 from station A by varying the value of resistance 24. This arrangement has the further advantage that all the adjustments may be made at one end of the line, preferably at the central, interconnecting or branch point or station shown as station A in Fig. 2.

Inasmuch as the power received by the receiving relays at each of the stations is less during wet weather or times of low leakage resistance, it is usually desirable to adjust resistance 24 and also the resistance 22 of the biasing circuits of the receiving relays at station A at this time so as to insure proper operation of these relays. Then when the leakage resistance R_3 increases during the dry weather, the power available to operate the relays increases and the adjustments are not so critical. However, the magnitudes of both the marking and spacing currents increase equally so that no distortion is introduced by these relays at this time.

With this arrangement it is possible to add a small amount of bias to the signals as received by the receiving relays which also automatically varies to some extent with variations of the leakage resistance R_3 , thus tending to maintain or improve the quality of the received signals.

The usual method of adding or adjusting the bias of receiving relays is to adjust the biasing current flowing through the biasing windings, as for example, by adjusting the values of resistance 22 at station A of Fig. 2. This has the effect of raising or lowering the bias line shown in Figs. 4-A to 4-F. In Fig. 4-D, this condition is illustrated where the bias line 45 is shown raised. Under these conditions, it should be noted that the spacing current crosses the bias line in some position along the line, depending upon the amount the bias is varied. This means that as the leakage current varies, the biasing current through the relays must also be varied to provide the same amount of bias to the signals received thereby and transmitted from its contacts. However, by also varying the resistance 24 at station A it is possible to raise or lower the apparent intersection of the marking and spacing curves, as shown in Fig. 4-E, so that they will intersect on

the new bias line 44 as shown in Fig. 4—E. When this is done, the amount of bias added to the signals by the biasing current flowing through the biasing windings is more nearly independent of the value of the leakage resistance R_3 and consequently will require much less adjustment as the leakage resistance of the line varies.

As pointed out above, the curves shown in Figs. 4—A to 4—F are shown as intersecting straight lines merely to illustrate the relative manner in which these two currents vary, it being understood that the leakage scale is not linear but is so proportioned that the marking and spacing curves M and S are straight lines. If the leakage scale were linear, then the lines M and S would be curved and approach the bias lines as asymptotes.

It is to be noted that the transmitting impedance of transmitting apparatus at both ends of line 10 in both Figs. 1 and 2 is substantially the same during the transmission of both signaling conditions. Thus the cable capacity will be charged and discharged equally under both signaling conditions when either of the two stations is transmitting. Consequently, no distortion will be introduced from this source in the arrangements shown in Figs. 1 and 2. In Fig. 2 the marking contact of relay 38 is connected directly to ground while the spacing contact is connected to a source of positive potential 93 through a protective resistance 92. Resistance 92 is usually so small, however, that the impedance as seen from the line is substantially the same when relay 15 is on either contact. Likewise contacts 11 of Fig. 35 1 are connected directly to ground, while line 10 is connected to sources 16 and 32 through additional resistances when these contacts are open. These additional impedances or resistances should be as small as possible without placing too great a load on the power supply. In practice the impedance to ground is substantially constant under both signaling conditions so that it is only necessary to make very slight bias adjustments at the other end of line 10 (station A) to compensate for these different impedances.

While only single line sections have been shown in Figs. 1 and 2, it is to be understood that these embodiments of the invention may be modified and adapted to fit into comprehensive telegraph systems connecting a number of stations over both single section and multisection lines. A typical system of this type is illustrated in Figs. 6, 7 and 8 when arranged in accordance with Fig. 5. The system shown in these figures is designed to provide communication between the outlying subscribers' or telegraph stations 49, 50, 51, 52 and 53 by means of line sections in accordance with this invention. Fig. 7 shows a more or less central connecting or branch station or point. The apparatus shown in Fig. 7 will usually be located in one central office or interconnecting station. However, it is to be understood that this need not necessarily be so because each one of the repeaters shown in this figure may be located at a different point and still be connected together by telegraph lines to provide satisfactory communication between the various outlying telegraph stations.

The subscribers' or outlying telegraph stations 49, 50 and 51 are connected to the central point by means of circuit arrangements in accordance with Fig. 1. However, in the case of stations 50 and 51 an additional outlying station close to the other station is shown connected to the same line to the central station. In this case, instead of

connecting ground to the common terminal of the transmitting device 11 located at station 51, a line is extended from this common connection of the contact device 11 at station 51 over a short local telegraph line 54 to a second station 50. The circuit arrangement at station 50 is somewhat modified from that shown at station 51 of Fig. 6 and at B in Fig. 1 in that the printing magnet of a printing telegraph machine or other receiving device 30 is shown connected directly to the contacts of the receiving relay 15 and is not connected in the circuit of source of potential 16 and resistance 17. Either arrangement works equally well. However, the arrangement shown at 50 requires slightly more power than the arrangement shown at station 51 of Fig. 6 and station B of Fig. 1. It should also be noted that the source of power at station 51 is shown to be a rectifier and it is to be understood that the power supplied at any of these stations which are illustrated by either batteries or rectifiers in the various figures of the drawings, may be rectifiers, batteries, motor generator sets, or other suitable sources of direct current power. In addition, it is essential in the case of the rectifier 55 shown at station 51 that the direct current side be ungrounded and insulated conductively from the alternating-current power supply 56 connected to the rectifier.

As in Fig. 1 the line from the receiving relay 15 passes through elements 26 and 27 to reduce the noise of the telegraph signals in telephone circuits in case the line passes over a composited telephone and telegraph line. In addition, the line 10 extends to the repeater 57 at a distant point. The line side of the repeater 57 is similar to the arrangement shown at station A of Fig. 1. The receiving relay is provided with a line winding, balancing winding and a biasing winding. In addition, the sending relay 58 connects negative and positive battery to the line through the noise filters or filtering element 25 and resistance 24. The telegraph line at the subscriber's station is normally connected to ground so that the positive and negative signal impulses transmitted from repeater 57 to both telegraph stations 51 and 52 are equally attenuated. Consequently, receiving relays 15 at these stations when adjusted to have zero bias respond equally well to both types of signal impulses independent of the leakage resistance of the line 10. The spacing signal impulses transmitted from stations 50 and 51 to the repeater 57, however, connect the source of potential 55 or battery 16 to line 10. The sources of potential 55 and battery 16 are about twice the magnitude of the sources of potential 13 and 14 of repeater 57 shown in Fig. 7. This causes the line current to reverse during spacing impulses transmitted from stations 50 and 51 to repeater 57. However, as pointed out above in case of line leakage, variations in the bias of the receiving relay 18 of repeater 57 shown in Fig. 7 must be adjusted to compensate for the different line leakage resistances as shown in Fig. 4—B. The local side of the repeater 57 is provided with a sending relay 58 and a break relay 59 which are in turn connected through a single line repeater 60 to other repeaters as shown on Fig. 7. Repeater 60 may be located at the same point as repeater 57 or may be connected thereto by means of a short telegraph line or conductor 61. It is to be understood, however, that the length of this line 61, also the length of line 54, is short in comparison with the length of line 10.

Single line repeaters 60 may be of any suitable

type, as for example, the repeaters described in the following patents: 1,601,799, Herman, October 5, 1926; 1,752,436, Kinead, April 1, 1930; 1,479,430, Fell, January 1, 1924. The repeaters described in these patents are hereby made a part of this specification as if fully included herein.

The outlying station 49 of Fig. 6 is similar to station B of Fig. 1 and is connected by means of line 62 to a repeater at some intermediate station by means of line 62. Line 62 is a long telegraph line or a long direct current telegraph channel of a composited telephone and telegraph line and may include open-wire lines. The line side of repeater 63 connected to line 62 of Fig. 6 is similar to the portion of the repeater shown at station A of Fig. 1 and is arranged to transmit signal impulses to station 49 so that no balance or biasing adjustment is required by the receiving relay 15 of station 49 to compensate for variations in the leakage resistance of line 62. However, the receiving relay 18 at repeater 53 must be provided with an adjustable biasing circuit to compensate for changes in the leakage resistance in line 62 as described above.

Repeater 63 is connected by means of line 64 to a second repeater 66 at some other intermediate point. As shown in Fig. 6 the line 64 is arranged for so-called upset duplex operation, that is, duplex operation in which current normally flows in line 64. This permits an additional station 65 to be inserted in line 64 at some intermediate point. It is understood that line 64 may comprise a long telegraph line or a telegraph channel of a long composited telephone and telegraph circuit.

It should be noted that the relays 70, 71 and 72 connected to the ends of line 64 must be adjusted to compensate for variations in the leakage resistance of line 64. This is usually and most conveniently accomplished by varying the direct current resistance of network N connected to the windings of relays 70 and 72 which varies the direct current in the balancing windings of these relays and thus provides a very simple means for altering the bias adjustment of these relays. The curves M and S of Fig. 4—F show how the marking and spacing currents as received at both ends of line 64 vary with variations of the leakage current. Line 90 shows how the bias of the receiving relays at both ends of the line must vary to compensate for variations of the leakage resistance of line 64. In case line 64 is a long telegraph line or channel of a composited toll line, repeaters 63 and 66 are through repeaters and noise killing chokes or filters are provided between the transmitting contacts and each of the lines extending from these repeaters.

Line 64, however, need not be a long toll line but may be merely a short local line extending to some local station 65 and repeaters 63 and 65 may be terminal repeaters with their local sides connected together. In this case the noise filters or impedances need only be connected between the transmitting contacts and the telegraph channels of the long composited toll line.

Repeater 66 is connected to repeater 68 located at or near the interconnecting station shown in Fig. 7 by means of a long line 67 which is similar to lines 64, 62 and 19 of Figs. 6, 7, 1 and 2. The portions of repeaters 66 and 68 which are connected to line 67 operate in accordance with the embodiment of this invention shown and described with reference to Fig. 2, in which the receiving relays at both ends of the line do not

require any adjustment whatever to compensate for variations in the leakage resistance of line 67. The resistances and condenser in box 91 of repeater 68 show a typical balancing network for balancing the line.

Thus the telegraph channel which connects station 49 with the central interconnecting station comprises a section of telegraph line in accordance with Fig. 1, a section of telegraph line operated in accordance with the usual upset duplex arrangement and a section of line operated in accordance with Fig. 2 which is self-compensating and does not require any change in the adjustment of relays at either end of the system to compensate for variations in the leakage resistance of the line between them.

Outlying station 53 shown in Fig. 8 is connected to the central exchange station shown in Fig. 7 over a telegraph line 75 which operates in accordance with the embodiment of this invention described with reference to Fig. 2. However, station 53 comprising the transmitting contacts 11 and the receiving or recording magnet 30 may be located a short distance away from the main terminal repeater 74 or apparatus of line 75 and connected thereto by means of a short line 76. It should be noted that the terminal apparatus 74 is arranged to transmit and receive signal impulses to the teletypewriter or receiving apparatus 53 as well as received from said station 53 over the line 76. This enables the transmitting device and receiving magnet to be connected directly in series with this line as is the usual practice with teletypewriter transmitting and receiving apparatus. It is also obvious that additional local teletypewriter stations similar to station 53 with the transmitting and receiving apparatus connected in series may be connected in series with line 76. These stations may intercommunicate between each other as well as transmit and receive signal impulses to and from line 75 connected to the extended telegraph system shown in Figs. 6, 7 and 8.

The power supply for the terminal apparatus 74 is shown in Fig. 8 as a rectifier 77 which is connected to some source of alternating-current power 78. The rectifier 77, however, may be replaced by any suitable source of direct current and the source of alternating-current power when required comprises any suitable commercial power line or generator capable of supplying the required amount of power.

The network 79 is usually connected across line 76 adjacent the terminal apparatus 74 of line 76 to enable relay 38 to be operated satisfactorily over short lengths of cable included in line 76 without altering the adjustment of the relay 38.

The telegraph station 52 comprising transmitting contacts 11 and the printer magnet 30 is connected to the central interconnecting point or station shown in Fig. 7 over an extended telegraph channel. Lines 83, 85 and 87 of this channel may be similar to the lines 75, 62, 64, 67 and 19 of Figs. 6, 7, 8, 1 and 2 and may include any or all of the various elements of these lines. The terminal apparatus connected to line 83 in repeaters 80 and 84 are arranged in accordance with the embodiment of this invention described and shown with reference to Fig. 2. As shown in Fig. 8, the teletypewriter or station 52 is connected to the terminal apparatus 80 of line 83 by means of two separate loops or lines 81 and 82. These lines or loops may include several miles of cable. They may also include additional telegraph transmitting and receiving apparatus similar to the appa-

ratus shown at station 52. However, the source of power associated with terminal apparatus 88 is usually insufficient to permit loops of several miles between the terminal apparatus 80 and the tele-

5 typewriter 52.
The terminal apparatus of repeaters 86 and 84 connected to line 85 is also arranged in accordance with the embodiment of this invention shown in Fig. 2, which is self-compensating and requires
10 no adjustment in the apparatus at either of these repeaters and repeater stations to compensate for variations in the leakage resistance of line 85. It is to be understood that the repeaters or repeater stations 82, 84, 86 and 88 are all located
15 along the telegraph line or channel between the interconnecting station shown in Fig. 7 and the outlying station 52 shown in Fig. 8. However, it is to be noted that the equipment connected to the ends of line 85 has been reversed. In other words,
20 the end of line 85 towards the interconnecting station shown in Fig. 7 is connected to ground and positive battery by repeater 86 instead of to positive and negative battery, while the end of line 85 more remote from the interconnecting
25 station of Fig. 7 is connected to positive and negative sources of potential by the equipment in repeater 84. It is thus obvious that the equipment at the ends of the long telegraph lines or composited telegraph channels may be inter-
30 changed to that shown and described in and with reference to Fig. 2. This also applies with respect to the embodiment of this invention shown in Fig. 1, it being obvious that the transmitting and receiving apparatus shown at station A might be
35 equally well located at station B if the apparatus at station B were located at station A. It is also possible to arrange either or both the systems shown in Figs. 1 and 2 in long lines with either end of any of the sections toward the central
40 office and the other end away from the central office. Thus, it is possible to have a repeater comprising two terminal equipments similar to that shown at station B connected together or two similar to the equipment shown at station A in
45 Figs. 1 and 2 connected together, or it is possible to have equipment shown at station B connected to equipment similar to that shown at station A of either Fig. 1 or 2 and either of these embodiments connected to the line extending towards
50 the central office and the other equipment connected to a long toll line extending away from the central office or interconnecting point.

As shown in Fig. 2 variable resistance 24 is provided to control the potential of point 23 and thus
55 make all the controls for insuring that both ends of the line will be self-compensating at the central office end rather than at the outlying end. In case, however, the apparatus at two ends of the line are interchanged, in other words, the appa-
60 ratus at station B is located at the central or interconnecting point, a potentiometer may be provided between the contacts of the sending relay 38 and line 10. This will permit the adjust-
65 ment of the potential applied to this end of the line so that all the adjustments still can be made at the central point and none at the outlying subscribers' telegraph stations.

The repeaters connected to line 87 are similar to those connected to line 85 excepting as pointed
70 out before. The equipment located at the interconnecting station shown in Fig. 7 connects sources of positive and negative potential to line 87 whereas the repeater equipment of repeater 86 connected to line 87 connects positive potential
75 and ground to the line. In other words, the

equipment at the two ends of the line is reversed from that of line 85.

It is to be noted that the system shown in Figs. 1 and 2 will not operate as a full duplex telegraph system. That is, signal impulses cannot be trans-
5 mitted over the line connecting the stations A and B in both directions at the same time and independently of each other. It is only possible to transmit these signals over the system in one
10 direction at a time. This is due to the fact that when the source of potential is connected to the line at station B by the transmitting devices at this station, the receiving relays at both stations
15 A and B are positioned independently of the transmitting device 12 at station A. In Fig. 1 the receiving relays 15 and 18 at stations B and A, respectively, are positioned to their spacing con-
20 tacts or positions when the transmitting contacts 11 are open, so that sources of potential 16 and 32 are connected to line 10. The armatures of these relays remain on their spacing contacts so long as
25 the contacts 11, or any break contacts in series with them, remain open independently of the position of transmitting relay 12 at station A. In Fig. 2 the armature of relay 15 at station B is
30 positioned to the marking contact while the receiving relay 18, break relay 34 and vibrating relay 35 at station A assume their spacing positions when sending relay 38 connects the source
35 of potential 93 to the line. These relays assume these positions and maintain them during the time the sending relay 38 is connecting battery to the line independently of the position of the send-
40 ing relay 12 at station A. It is thus evident that during the time potential is connected to the line at station B it is impossible to transmit signals from station A to station B. Consequently, it is
45 impossible to operate these systems on a full duplex basis.

The arrangements shown in Figs. 1 and 2, how-
50 ever, have the advantage, when operated in the so-called half duplex manner of operation in which signaling impulses are transmitted in only one direction at a time, that the usual number
55 of break relays are not required. This can be more fully understood by reference to the more comprehensive system shown in Figs. 6, 7 and 8.

As described above, stations 50 and 51 are connected to a central interconnecting point or station by means of the telegraph system shown
60 in Fig. 1.

When it is desired to send a break signal from stations 50 and 51 during the time they are
65 receiving signal impulses from the interconnecting stations shown in Fig. 7, the transmitting device 11 at either of these stations, or a break contact connected directly in series with them,
70 is open. This connects either source of potential 16 or 55, as the case may be, to line 10. As pointed out above, under this condition, the receiving relays 15 at stations 50 and 51 as well as the re-
75 ceiving relay 18 of repeater 57 at the central interconnecting station shown in Fig. 7 assume their spacing positions and maintain these spacing positions independently of the position of the sending relay 58 of repeater 57. This insures the breaking of the signals received at stations 50 and 51 and also the transmission of a break signal through repeater 57 by the receiving relay 18 over line 61 to the other repeaters and stations
of the system shown in Figs. 6, 7 and 8.

When it is desired to transmit a break signal from some other station of the system to either stations 50 or 51 during the time they are trans-
mitting telegraph signal impulses to the other

stations, a break signal will be transmitted from the station desiring to send the break signal. Assume that the break signal is transmitted through the single line repeater 60 of Fig. 7 over the line 61 to repeater 57 and thence over line 10 to stations 51 and 50. Under this condition, the line 61 is opened by the single line repeater 60 so that the lower windings of the sending relay 58 and the break relay 59 control these relays. Since these windings are connected to the receiving relay 18, these relays will follow the receiving relay 18. Now, the receiving relay 18 of the repeater 57 will follow the signals transmitted from the transmitting device 11 at stations 50 or 51 independently of the position of the sending relay 58 of repeater 57 so that relay 18 may continue to follow the signal impulses transmitted from stations 50 and 51. However, under these conditions the break relay 59 connects the same potential to both contacts of the receiving relay 18 so it will not cause relays 58 and 59 to follow the operation of relay 18, thus insuring that the sending relay 58 remains on its spacing contact and transmits a spacing signal to stations 50 and 51. This spacing signal will interrupt the recording of the "home copy" at these stations and thus indicate to the attendant that another station wishes to break in and transmit a message over this system.

It is thus evident that a break relay is required at only one end of the line 10, namely, the end at which signals are transmitted by connecting potentials of opposite polarity to the line.

As pointed out above, signal impulses are transmitted from station 49 over line 62 to repeater 63 by means of the system shown in Fig. 1. Since the other line 64 connected to repeater 63 is provided with an intermediate station 65 which may open the line 64 to transmit break signals to station 49, it is necessary that repeater 63 be also provided with a break relay 72 which operates in a manner similar to that described with reference to the break relay 59 of repeater 57. In case line 64 does not include an intermediate telegraph station, then the break relay 72 will not be required because the line 64 would never become open-circuited. Consequently, both the windings of relays 71 and 72 would be at all times effective so that the position of the armatures of these relays would be independent of the position of the armature of the receiving relay 18. Under these conditions no break relay would be required because the sending relay 71 would move to its spacing contact on break signals received from line 64 and remain there so long as the break signal is received by this relay. It will, therefore, transmit this break signal to station 49 during the time station 49 is transmitting the signal impulses and indicate to the operator there that another station of the system may wish to break in and transmit a message.

Signal impulses are transmitted over the line 67 between repeaters 66 and 68 in accordance with the telegraph system shown in Fig. 2. When it is desired to transmit a break signal from station 49 or station 65 which is connected to repeater 66 by means of line 64 during the time the signal impulses are being received at these stations from another station connected to the telegraph system shown in Figs. 6, 7 and 8, line 64 may be open at station 65. This causes the sending relay 70 of repeater 67 to move to its spacing contacts during the next marking signal impulse received by receiving relay 94 from line 67. This will maintain relay 94 in its marking

position and operate relay 95 of repeater 68 to its spacing contact and maintain this relay on its spacing contact so long as line 64 is open at station 65, thus transmitting a break signal to the transmitting station indicating to the transmitting operator or attendant that station 65 wishes to interrupt the transmission of signals and transmit to the other stations of the system.

In case it is desired to transmit a break signal from some other station of the system to station 65 during the time station 65 is transmitting signal impulses, the break signal will be transmitted from these stations through repeater 68. Assume that the break signal is transmitted through single line repeater 60 which will open line 69 to transmit a break signal to repeater 68. This interrupts the circuit of the upper or line windings of the sending relay 96 and the break relay 97 of repeater 68. This means that these relays will be operated by their lower windings from the received relay 95 which will follow the signal impulses transmitted from station 65. To prevent sending relay 96 from following these signals and interfering with the break signal it (relay 96) should be transmitting to station 65 through repeater 66, the break relay 97 connects the same potential to both contacts of the receiving relay 95 during the first marking signal received over line 67 after the break signal is received over line 69. This insures that both the send and break relays 96 and 97 thereafter remain on their spacing contacts and transmit a spacing or break signal to station 65 through repeater 66. It is thus evident that in the arrangement shown in Fig. 2 as in the system shown in Fig. 1, a break relay is required only at the end of the line that positive and negative sources of potential are used to transmit the signal impulses over the line.

The same break arrangement is also shown in the repeaters 73 and 74 connected to the ends of line 75. Repeater 73 connects sources of both positive and negative potential to line 75 to transmit signal impulses to repeater 74. Consequently a break relay 98 is required at this repeater. Repeater 74, however, transmits impulses of one polarity and ground over line 75. Consequently, no break relay is required and none is provided.

As pointed out above with reference to line 64, no break relays are provided for repeater 84 of Fig. 8 because repeater 84 of Fig. 8 is a through repeater and the line 85 connected thereto does not come to an intermediate station, so that this line is never open. Thus, both the line and balancing windings of relay 99 to repeater 84 are always effective to control this relay. Consequently, the position of the armature of this relay is independent of the position of the receiving relay 100 of this repeater, so that break signals will be transmitted through repeater 84 in both directions without the use of break relays.

The telegraph station 52 is connected to repeater 82 by means of two loops, one loop being used to transmit signal impulses and the other loop being used to receive signal impulses at station 52. In this case due to the divided loop between station 52 and repeater 82, it is necessary to make some provisions in repeater 82 to insure the proper transmission of break signals to and from station 52. The transmission of break signals from station 52 during the reception of signal impulses thereby is similar to the transmission of break signals from station 53 in that the receiving relay 38 of repeater 82 is operated to

its spacing position. This connects a source of potential 101 to the line 83 which causes receiving relay 15 to be maintained in its marking position, thus insuring the transmission of the break signal independently of the reception of signals from line 83.

However, in case it is desired to transmit a break signal to station 52 during the time signal impulses are being transmitted from station 52, some means must be provided to prevent the sending relay 38 of repeater 82 from operating the receiving relay to its marking position during the time the receiving relay 15 is in its spacing position. If such additional means are not provided, the operation of relays 38 and 15 as described will interfere with the transmission of the spacing or break signal from relay 15 to station 52. As shown in repeater 82 the spacing contact of relay 15 is connected to the upper or line winding of the receiving relay 38. This causes relay 38 to lock in its marking position when relay 15 has been operated to its spacing position by the reception of the break signal as soon as relay 38 is operated by a marking signal transmitted from station 52. This insures the proper transmission of the break signal received over line 83 to station 52 because relay 38 is locked operated so relay 15 will be maintained in its spacing position so long as the break signal is received over line 83 and will transmit the signal to this station 52 independently of the operation of the transmitting device 11 at station 52.

In case the received signal impulses are transmitted over the receiving loop of the split or divided loop by means of polar signals, that is, the signal impulses of positive and negative polarity, both contacts of the receiving relay 15 are required to transmit these signal impulses. Consequently, the spacing contact is not available to lock the transmitting relay 38 in its operated position during the time the break signal is received and thus insure the proper transmission of the break signal to the telegraph station or apparatus. In this case, as shown in Fig. 2, an additional break relay 41 is required. This relay is connected in series with the spacing contact of the receiving relay and connects ground in parallel with the transmitting contacts or device 11 at station B, thus insuring the proper transmission of a break signal from receiving relay 15 to the receiving apparatus at the station during the time signal impulses are being transmitted by the transmitting device 11 because the operation of transmitting device 11 at this time cannot cause relay 38 to repeat the signal impulses transmitted thereby.

It should be noted that the receiving relay 15 at station B of Fig. 1 correctly responds to both the signal impulses received from station A and to the signal impulses transmitted from station B so that the receiving magnet of the printing or recording device 30, when connected directly to the contacts of this receiving relay 15, will record both signal impulses received from station A and the impulses from station B, which is usually called the "home copy".

However, the receiving relay 15 of station B of the system shown in Fig. 2 responds only to the signal impulses transmitted to station B from station A but does not respond to the signal impulses transmitted from station B. Consequently other provisions must be made for the recording of the "home copy" at station B. As shown in Fig. 2, the circuit of the printing magnet 30 of the receiving or recording device at this

station is connected in series with the transmitting contacts of relay 38, so that it will also receive the signal impulses transmitted by the transmitting relay 38 from station B.

This is also true of the circuit of magnet 30 at station 52 which is connected to the transmitting contacts of the sending relay 38 so that it will receive the same impulses as are transmitted from station 52 and thus provide a "home copy" of the messages transmitted from station 52. In the case of station 53 the receiving magnet is connected directly in series with the transmitting contacts 11 so that it will follow all the signal impulses transmitted by these contacts. In this arrangement no special provision is, therefore, necessary.

The term "source of potential" as used in this specification and, in particular, in the appended claims includes sources of zero potential, i. e., ground potential, as well as sources of both positive and negative potentials.

What is claimed is:

1. A telegraph communication system comprising a first station, a second station, a direct current telegraph line connecting said stations, terminal composite circuits included in said line, intermediate composite sets included in said line, an open-wire portion subject to varying leakage conditions included in said line, receiving means at each of said stations, transmitting means at each of said stations connected to the ends of said line for transmitting two signaling conditions to the other of said stations the values of which are so related to each other and to said line that the algebraic sum of the currents of said signaling conditions at the other of said stations is substantially independent of variations of the leakage resistance of said telegraph line, said transmitting means being arranged to have substantially the same impedance when transmitting both of said conditions to the opposite station, and variable biasing means at one of said telegraph stations for adjusting the receiving means thereat to respond equally to said two conditions transmitted thereto from the other of said stations.

2. A telegraph system comprising a first station, a second station, a direct current telegraph signaling channel connected between said stations, transmitting means at said first station for connecting sources of potential of substantially equal magnitude but opposite polarities to said telegraph channel, transmitting means at said second station for normally connecting ground to said telegraph channel and for connecting a source of potential to said channel in accordance with signal impulses to be transmitted thereby which is so related to said other sources of potential and to said channel that the algebraic sum of the currents received at said first station is independent of variations of the leakage resistance of said telegraph channel, receiving apparatus at said second station for responding to the sources of potential of opposite polarities connected to said channel at said first station whereby the algebraic sum of the signaling conditions received at said second station is independent of variations of leakage of said telegraph channel, receiving apparatus connected at said first station, variable biasing means connected to said receiving apparatus at said first station for biasing said receiving apparatus to respond equally to both signaling conditions connected to said channel at said second station.

3. A telegraph system comprising a first sta-

tion, a second station, a direct current telegraph communication channel connecting said stations, receiving apparatus connected to said channel at each of said stations, transmitting apparatus at said first station for normally connecting a source of potential to said channel and transmitting apparatus at said second station for normally connecting ground to said channel, additional means connected to said transmitter at said first station for connecting to said transmission channel in accordance with the signals to be transmitted a source of substantially equal magnitude, but of opposite polarity to the source of potential normally connected to said transmission channel at said first station, and additional means at said second station for connecting a source of potential to said transmission channel in accordance with the signals to be transmitted of such a value that the current normally flowing over said line is increased, said sources of potential being so related to each other and said transmission line that the algebraic sum of the signaling currents received at each of said stations from the other of said stations is substantially independent of the leakage of said line.

4. A telegraph system comprising a first station, a second station, a direct current telegraph channel connecting said stations, said channel including terminal and intermediate composite sets and a portion of open-wire line subject to varying leakage, means for transmitting and receiving two different signal conditions to and from each of said stations, resistance means connected in said line cooperating with the transmitting means at each of said stations for rendering the algebraic sum of the signaling currents received at each of said stations substantially independent of said varying leakage, and biasing means associated with said receiving means at each of said stations for producing a biasing effect upon said receiving means which is substantially one-half the effect of the algebraic average of said received signaling currents but opposite in direction thereto.

5. A telegraph system in which the receiving apparatus responds equally well to all signaling impulses for any given value of leakage resistance comprising, a telegraph line subject to varying weather conditions, means for normally transmitting current over said line, means for transmitting signal impulses of opposite polarities over said line connected to one end of said line, means for transmitting signal impulses of current substantially three times the magnitude of said normal current from the other end of said line, and receiving apparatus connected to each end of said line which is responsive to the signal impulses transmitted from the other end of said line.

6. A telegraph line subject to leakage, a source of potential normally connected to one end of said line, a receiving device connected to said end of said line, means for normally connecting the other end of said line to ground, and means for connecting a source of potential of opposite polarity to said other end of said line in accordance with signals to be transmitted thereover and means for adjusting the magnitude of said sources of potential so that the ratio of substantially twice said first potential to said second potential, is equal to the ratio of the resistance of said line measured from said first end to the point where an equivalent concentrated leakage resistance would be connected to

the line to the remainder of the resistance of said line.

7. A telegraph system comprising a telegraph line, transmitting and receiving apparatus connected to each end of said line, sources of positive and negative potential connected to the transmitting apparatus at one end of said line, ground and a source of one potential connected to the transmitting apparatus at the other end of said line and potentiometer means connected between the transmitting apparatus at the first end of said line and said line for so adjusting the relative potentials connected to the ends of said line that the sum of the currents received at each end of the line is substantially constant and independent of the leakage resistance of the line.

8. A two-way self-compensating telegraph system comprising a first station, a second station, a telegraph line connected between said stations, means for normally connecting a source of potential to one end of said line and for connecting ground to the other end of said line, means for transmitting signal impulses of opposite polarity connected to the first end of said line, and means for transmitting signal impulses of increased magnitude from the other end of said line, receiving means connected to each end of said line for receiving impulses transmitted from the opposite end of said line, and variable bias means connected to the receiving apparatus at said first end of said line, and means connected to said line for controlling the relative magnitudes of said impulses so that the algebraic sum of impulses of different character is substantially constant and independent of the leakage resistance of the line.

9. A telegraph system in accordance with claim 8 characterized in this that a potentiometer is connected between the transmitting means at said first end of said line and said line for adjusting the relative magnitudes of said impulses of different character, whereby all of the adjustments of the relative magnitudes of said impulses by which the algebraic sum of the received impulses is made independent of the leakage of said line, may be made at said first end of said line.

10. A self-compensating telegraph system comprising a first telegraph station, a second telegraph station, means for normally transmitting a current over said line, means for transmitting signal impulses of opposite polarity in one direction over said line and signal impulses of increased magnitude in opposite direction over said line, the receiving means connected to each end of said line for receiving the impulses transmitted from the opposite end of said line, and means for adjusting said receiving apparatus and the magnitude of said impulses so that the bias of the received impulses is substantially independent of the leakage of said line.

11. A two-way telegraph system comprising a first station, a second station, a direct current telegraph channel connected between said stations, means for transmitting two signal conditions of opposite polarity from said first station to said second station, means for transmitting two signaling conditions of different magnitude from said second station to said first station, receiving apparatus at each of said stations connected to said line for receiving the signal conditions transmitted from the other of said stations, and means for adjusting said receiving apparatus and the relative magnitudes of all said signaling conditions so that one of said signaling

conditions at each of said stations increases as much as the other of said signaling conditions decreases with a change of the leakage of said line.

12. In a two-way telegraph system, a first station, a second station, means for transmitting signal impulses from each of said stations to the other of said stations, means at each of said stations for receiving impulses transmitted to it from the other of said stations, means for so adjusting the bias of said receiving apparatus and means for so adjusting the magnitude of the signaling impulses that the effective bias of said receiving apparatus is automatically varied with changes of the leakage of said line to maintain the quality of the received signals substantially constant.

13. A telegraph system comprising a line, a portion of which is subjected to variable leakage resistance, receiving apparatus connected to each end of said line, apparatus for transmitting two different signaling currents from each end of said line the sum of which as received at the opposite end of the line is substantially constant and independent of said line leakage resistance and biasing means connected to said receiving apparatus which produces an effect opposite to and substantially equal to one-half the magnetic effect of the sum of the signaling currents received by said receiving apparatus.

14. A method of operating a telegraph system in which two signaling currents are transmitted in each direction thereover which comprises adjusting the magnitude of the two currents received at each end of the line so that their sum is substantially constant and independent of the leakage resistance of said system and adjusting the bias of the receiving apparatus at each end of the system so that its magnetic effect is opposite to and equal in magnitude to substantially one-half the magnetic effect of the sum of the two signaling currents received thereby.

15. A signaling system comprising a line, a portion of which is subjected to a variable leakage resistance, transmitting apparatus connected to each end of said line for transmitting two signaling conditions thereover the sum of the currents of which, as received at the opposite end, is substantially constant and independent of the value of said variable leakage resistance, receiving apparatus connected to each end of said line, and biasing means connected to said receiving apparatus which produces a magnetic effect thereupon opposite to substantially one-half the magnetic effect of the sum of said currents received thereby.

16. The method of operating a telegraph system in which two signaling conditions are transmitted over a telegraph line in each direction which comprises adjusting transmitting potentials at both ends of the line so that the sum of the currents received at each end of the line for both signaling conditions remains substantially independent of the value of the leakage resistance of the line and adjusting the receiving apparatus at each end of the line to respond equally to both signaling conditions received thereby.

17. The method of operating a telegraph system a portion of which is subjected to a variable leakage resistance and in which two signaling conditions are transmitted in each direction thereover which comprises adjusting the transmitting potentials at each end of the system so that substantially the same magnitude of current

leaks off through the leakage resistance for each of the signaling conditions transmitted over the system in each direction and adjusting the receiving apparatus connected to the system to respond equally to the two signaling conditions received thereby.

18. The method of operating a telegraph system a portion of which is subjected to a variable leakage resistance in which two signaling conditions are transmitted in each direction thereover which comprises adjusting the transmitting potentials at each end of the line so that potentials of substantially the same magnitude appear across the effective leakage resistance for both the signaling conditions transmitted in each direction over the system and adjusting the receiving apparatus to respond equally to the signaling conditions transmitted from the opposite end of the system.

19. The method of operating a telegraph line a portion of which is subjected to a variable leakage resistance which comprises applying three signaling conditions thereto, adjusting the potentials for causing said signaling conditions so that the potential across the effective leakage resistance of said line is of substantially the same magnitude for all of said signaling conditions.

20. An impulse transmitting system comprising a line, impulse receiving apparatus connected to each end of said line, impulse transmitting apparatus connected to each end of said line having two positions, means effective when said transmitting apparatus connected to one end of said line is in either of said positions for connecting to said line sources of potential which are so related to each other and to the electrical characteristics of said line that the bias of the impulses transmitted in one direction over said line is substantially constant and independent of the leakage resistance of said line, means effective when said transmitting apparatus connected to the other end of said line is in either of said positions for connecting to said line sources of potential which are so related to each other and to the electrical characteristics of said line that the bias of the impulses transmitted in the other direction over said line is substantially constant and independent of the leakage resistance of said line.

21. An impulse transmitting system comprising a line, impulse receiving apparatus connected to each end of said line, impulse transmitting apparatus connected to each end of said line having two positions, means for connecting sources of potential to said line when said transmitting apparatus are in their respective positions for causing impulse currents to flow thereover, which potentials are so related to each other and to the electrical characteristics of said line that the algebraic sum of the impulse currents received at either station from the other station is substantially constant and independent of the leakage resistance of said line.

22. An impulse transmitting system comprising a line, impulse receiving apparatus connected to each end of said line, impulse transmitting apparatus connected to each end of said line having two positions, means for connecting sources of potential to said line when said transmitting apparatus are in their various positions, which sources of potential are so related to each other and to the electrical characteristics of said line that the magnitude of the potential across any given value of leakage resistance under both

signaling conditions transmitted from either end of said line is the same.

23. An impulse transmitting system comprising a line, impulse receiving apparatus connected to each end of said line, impulse transmitting apparatus connected to one end of said line for transmitting two different impulse currents over said line, means for so establishing the polarities and magnitudes of said currents with respect to each other and the electrical characteristics of said line that their sum as received at the opposite end of said line is substantially constant and independent of the leakage resistance of said line, impulse transmitting apparatus connected to the other end of said line for transmitting two different impulse currents over said line, means for so establishing the polarities and magnitudes of said currents with respect to each other and the electrical characteristics of said line that their sum as received at the opposite end of said line is substantially constant and independent of the leakage resistance of said line.

24. An impulse transmitting system comprising a line, impulse receiving apparatus connected to each end of said line, impulse transmitting apparatus connected to each end of said line for transmitting two different impulse currents over said line, means for so establishing the polarities and magnitudes of said currents with respect to each other and to the electrical characteristics of said line that the bias of said impulses as received at the opposite end of the line is substantially constant and independent of the leakage resistance of said line.

25. An impulse transmitting system comprising a line, impulse receiving apparatus connected to each end of said line, impulse transmitting apparatus connected to each end of said line for transmitting two different impulse currents over said line, means for so establishing the polarities and magnitudes of said currents with respect to each other and to the electrical characteristics of said line that said impulses as received at either end of said line differ by the same amount from an average value for any given value of leakage resistance of said line.

26. An impulse transmitting system comprising a first station, a second station, an impulse transmitting channel connected between said stations, impulse transmitting apparatus connected to said channel at one of said stations for transmitting impulses of two different magnitudes over said channel, the magnitudes of which are so related to each other and to the electrical characteristics

of said channel that their sum remains substantially constant and independent of the leakage resistance of said channel and receiving apparatus connected to said channel at said second station for responding to said impulses.

27. An impulse transmitting system comprising a first station, a second station, an impulse transmitting channel connected between said stations, impulse transmitting apparatus having two positions connected to said channel at one of said stations for transmitting impulses of two different magnitudes over said channel, impulse receiving means connected to said channel, means for connecting a source of potential to said channel at said second station and means for connecting sources of potential to said channel when said transmitting apparatus is in either of said positions, which potentials are so related to each other and to the electrical characteristics of said channel that the sum of the currents received at said second station is substantially constant and independent of the leakage resistance of said channel.

28. A telegraph system comprising a telegraph line, means at each end of said line for impressing upon the line two signaling conditions, a biased receiving instrumentality at each end of the line to respond to said two signaling conditions transmitted from the other end, means effective with any leakage current between zero and a large value whereby one of said signaling conditions transmitted at either distant end of said line adds an effect of a certain magnitude to the biased condition of said receiving apparatus, and means effective with the same line leakage current whereby the other condition subtracts an effect of equal magnitude therefrom.

29. A telegraph system comprising a telegraph channel of a composite toll line subjected to variable leakage resistance conditions, receiving apparatus connected to each end of said line, means for applying two signaling conditions to each end of said line, potential means connected to said transmitting apparatus so related to each other and to the distribution of the line resistance and leakage resistance that the magnitude of potential across the equivalent concentrated leakage resistance of any given value is substantially the same for all the signaling conditions but of opposite polarity for the two signaling conditions transmitted from either end of the line.

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