Oct. 18, 1938. R. W. DEARDORFF 2,133,380

COMMUNICATION SYSTEM

Filed March 27, 1937

FIG. 1

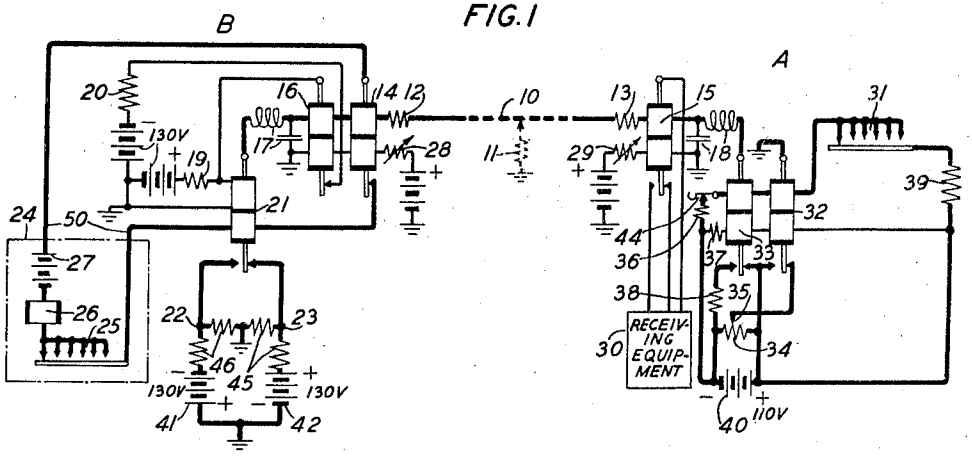


FIG. 2A

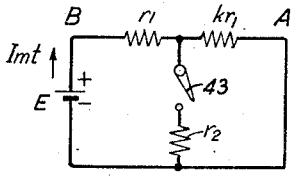


FIG. 2B

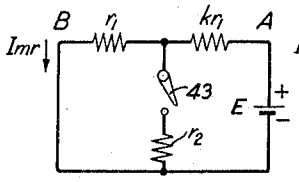


FIG. 2C

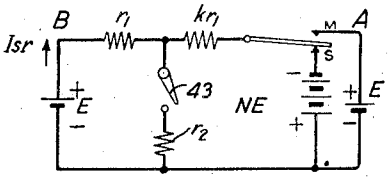
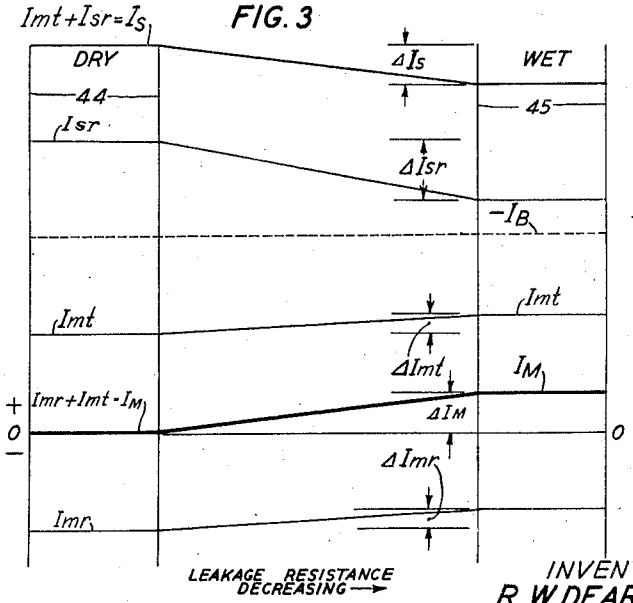


FIG. 3



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COMMUNICATION SYSTEM

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12 Claims. (Cl. 178—2)

This invention relates to a communication system and more particularly to improved arrangements for transmitting telegraph or other signal impulses over long open wire communication lines and over the telegraph channels of long open wire composite toll lines.

Long open wire lines of these types are subjected to varying weather conditions. This causes a varying leakage resistance of the open wire sections which varies over wide limits from a very high value under dry weather conditions to a relatively low value under wet weather conditions. Both the duplex and upset duplex telegraph transmitting and receiving apparatus and circuits 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 a correct reception of the telegraph signals. Variation of the leakage resistance 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 of the leakage resistance of the line so that it is necessary at times to adjust this biasing 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 and apparatus because the subscriber is so far removed from the central telegraph station or repeater point, as is usually the 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 at both ends of the line without introducing any bias or other distortion of the telegraph signals from any other source.

It is a further object of this invention to provide a telegraph system in which the apparatus at each end of the line applies similar signaling conditions to the line to indicate or transmit similar conditions or impulses.

Still another object of this invention is to provide telegraph line circuit between two telegraph stations either or both of which may be a central station or an outlying station the operation of which is substantially independent of the leakage resistance of the line.

In accordance with a specific embodiment of this invention two telegraph stations are connected together by a telegraph line or channel a portion of which includes an open wire line subjected to varying weather conditions and thus to a varying leakage resistance. Similar receiving relays are connected to this line at each of the stations for responding to the signaling conditions transmitted from the opposite end of the line. Means are provided at each station for normally connecting substantially the same potential to both ends of said line in accordance with the signaling impulses to be transmitted thereover. In order for the receiving relays at said stations to respond substantially equally well to all signaling conditions transmitted over the line from the opposite station independently of changes of the line leakage, the potentials applied to the ends of said line are determined by the distribution of resistance of said line circuit and the distribution of the leakage resistance of the line. Thus the receiving relays respond to the signal conditions transmitted to it without bias due to variations in the leakage resistance of the line.

The term bias as employed in this specification and applied to signals or signal impulses indicates a lengthening of one signaling condition or impulse and a shortening of another signaling condition or impulse. For example, marking bias means that the marking signal impulses are lengthened and that the spacing signal impulses are shortened, whereas spacing bias means that the spacing impulses are lengthened and the marking impulses are shortened. Signal impulses of greater bias are poorer in quality and less satisfactory for operating telegraph apparatus, while telegraph signal impulses of less bias are better in quality and more suitable for operating telegraph apparatus.

A common cause of this lengthening and shortening of the various signaling conditions or impulses is that the marking and spacing currents are of unequal magnitude. For example, for marking bias the marking current is greater than the spacing current while for spacing bias the spacing current is greater than the marking current. This is also true if one of the signaling currents differs from a fixed biasing current by a greater amount than the other signaling condition differs from the same biasing current in the opposite direction. The unequal currents cause the receiving relay to respond differently to the two signaling conditions. This adds a bias to the received signal impulses. However, in accordance with this invention the two signaling conditions always differ substantially the same amount from an established zero flux condition of the relay which is effected by a suitable biasing flux or current, independently of the leakage resistance of the line. Consequently, the leakage resistance or changes of the leakage resistance of the line does not add any bias to the received signals.

The terms marking and spacing as used in this application differentiate two line or signaling conditions transmitted between the telegraph

stations. The term marking is used to designate the line or signaling condition employed during the time no signaling or intelligence impulses are being transmitted but the system is energized and ready to transmit signaling or intelligence code combinations of impulses. The term spacing designates the other signal or line condition.

While the novel features of this invention are specifically set forth in the claims appended hereto, 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 drawing in which:

Figure 1 illustrates an embodiment of this invention applied to a typical telegraph system; and

Figs. 2A, 2B, 2C and 3 show simplfied diagrams illustrating the operation of this invention.

In order that the operation of this system may be more fully understood the simplified sketches shown in Figs. 2A, 2B and 2C will be described first. Fig. 2A represents a T-network or circuit which is approximately equivalent to the line or telegraph circuit. r_1 and Kr_1 represent the resistance of the line between stations A and B and r_2 represents the leakage resistance of the line. Switch **43** is provided to indicate that the leakage resistance r_2 of the line may or may not be connected to the line. Under dry weather conditions switch **43** is open so that resistance r_2 is not connected while under wet weather conditions switch **43** will be closed so that resistance r_2 will be connected to the line. In this manner Fig. 2A may simulate both wet and dry weather conditions. E represents the magnitude of the potential normally applied to the line at station B. I_{mt} represents the current flowing in the line at station B due to the source of potential E normally connected to the line at station B. In considering this current the line at station A is shortcircuited so that current from other sources of potential will not flow in the circuit.

Assume that marking and spacing impulses are transmitted from station A to station B and that the transmitting relay at station B remains on its marking contact. Under these conditions the voltage and current relations under the dry and wet weather conditions at station B are as follows:

(1) $I_{mt}(\text{dry})=\dfrac{E}{r_1(1+K)}$ — Marking current from home battery dry weather

(2) $I_{mt}(\text{wet})=\dfrac{E}{r_1+\dfrac{Kr_1r_2}{Kr_1+r_2}}=$

$\dfrac{E}{r_1}\cdot\dfrac{Kr_1+r_2}{Kr_1+(K+1)r_2}$ — Marking current from home battery wet weather

Fig. 2B illustrates the circuit used to determine the current I_{mr} flowing in the line at station B received from station A during marking conditions due to the potential E applied to the line at station A. The other designations represent the same elements as in Fig. 2A. It is assumed that the voltage E at station A is the same as the voltage E at station B in order to simplify the explanation. It is of course not essential that these two voltages be the same and if they are different, it is only necessary to introduce an additional constant in these equations by which one voltage is multiplied to obtain the other voltage. Fig. 2B also illustrates the circuit used to determine the current I_{sr} flowing in the line at station B due to the spacing potential NE applying to the line at station A to transmit spacing impulses. The voltage and current relations under dry and wet weather conditions due to the potential applied to the line at station A are as follows: For reasons later apparent the same voltage polarity is used for marking conditions at each end of the line. This means that the home and distant battery components are in opposite directions.

(3) $I_{mr}(\text{dry})=-E\dfrac{1}{r_1(1+K)}$ — Marking current from distant end battery (dry)

(4) $I_{mr}(\text{wet})=\dfrac{-E}{r_1}\cdot\dfrac{r_2}{Kr_1+(K+1)r_2}$ — Marking current from distant end battery (wet)

(5) $I_{sr}(\text{dry})=NE\dfrac{1}{r_1(1+K)}=$ Spacing current from distant end battery (dry)

(6) $I_{sr}(\text{wet})=\dfrac{NE}{r_1}\cdot\dfrac{r_2}{Kr_1+(K+1)r_2}$ — Spacing current from distant end battery (wet)

In considering these networks as a part of a signaling or telegraph system with voltages at each end of the line the superposition principle is used, which means that the current in any part of the line is obtained by adding all the current components together algebraically. There is a component current for each source of potential in the circuit and each component is computed on the assumption that its source of potential is the only one effective in the circuit. This, of course, requires that the circuit be closed at the points where voltages are removed. Fig. 2C represents a simplified circuit under these conditions in which the circuits shown in 2A and 2B are combined to form a representative telegraph system for transmitting impulses from station A to station B. The total current I_M and I_S in the line at station B under the marking and spacing conditions of the transmitting apparatus at station A, respectively, is as follows:

(7) $I_M(\text{dry})=(I_{mt}+I_{mr})(\text{dry})=0$

(8) $I_S(\text{dry})=(I_{mt}+I_{sr})(\text{dry})=\dfrac{(N+1)E}{r_1(1+K)}$

When a polar receiving relay is employed at station A, it should be biased by a current I_B flowing in a biasing winding which produces a magnetic effect on the relay which is equivalent in magnitude but opposite in direction to the magnetic effect of one-half the sum of the total marking and spacing currents, or

(9) $I_B(\text{dry})=-\dfrac{I_M+I_S}{2}=-\dfrac{(N+1)E}{2r_1(1+K)}$

The corresponding values of the marking, spacing and biasing currents under wet weather conditions are as follows:

(10) $I_M(\text{wet})=(I_{mt}+I_{mr})(\text{wet})=\dfrac{E}{r_1}\cdot\dfrac{Kr_1}{Kr_1+(K+1)r_2}$

(11) $I_S(\text{wet})=\dfrac{E(Kr_1+r_2+Nr_2)}{r_1(Kr_1+Kr_2+r_2)}=\dfrac{E}{r_1}\cdot\dfrac{Kr_1+(N+1)r_2}{Kr_1+(K+1)r_2}$

(12) $I_B(\text{wet})=-\dfrac{(I_S+I_M)}{2}=-\dfrac{E}{2r_1}\cdot\dfrac{2Kr_1+(N+1)r_2}{Kr_1+(K+1)r_2}$

If the system is to be compensated so that the bias does not require adjustment for changes in the line leakage resistance, the two biasing cur-

rents under dry and wet weather conditions should be the equal, or

$$(13)\quad I_B(\text{dry}) = I_B(\text{wet}) = -\frac{(N+1)E}{2r_1(1+K)} =$$

$$-\frac{E}{2r_1}\cdot\frac{2Kr_1+(N+1)r_2}{Kr_1+(K+1)r_2} \text{ or } N=2K+1$$

Thus when this relationship that $N=2K+1$ is fulfilled, the marking and spacing currents received at station A both differ from the biasing current by the same amount so that the polar receiving relay at this station will respond equally to these two currents and thus will add no bias to the received impulses.

It is to be understood that an equivalent mechanical bias could be employed if it is so desired and the operation of the system would still be substantially independent of the leakage resistance of the line under normal conditions.

It is to be noted that if the expressions for the biasing current remain substantially constant and independent of the leakage resistance of the line, the algebraic sum of the marking and spacing currents received from the line also remains constant and substantially independent of the leakage resistance because the biasing current is equal in magnitude to one-half the algebraic sum of the marking and spacing currents received from the line.

The variations of the different component currents due to changes in the leakage resistance are illustrated in Fig. 3 in which the horizontal lines between vertical lines **44** represent the various currents indicated under dry weather conditions and between lines **45** under wet weather conditions. The sloping lines between the dry and wet weather conditions indicate the manner in which the currents vary as the leakage resistance of the line changes. As shown in Fig. 3 the leakage resistance of the line decreases from left to right. The scale of the leakage resistance is so chosen that these lines are straight. The change in the various component currents indicated may be determined as follows:

$$(14)\quad \Delta I_{mt} = I_{mt}(\text{wet}) - I_{mt}(\text{dry})$$

$$= E\frac{Kr_1+r_2}{r_1(Kr_1+Kr_2+r_2)} - E\frac{1}{r_1(1+K)}$$

$$= E\frac{(1+K)(Kr_1+r_2)-(Kr_1+Kr_2+r_2)}{r_1(Kr_1+Kr_2+r_2)(1+K)}$$

$$\Delta I_{mt} = E\frac{K^2}{(Kr_1+Kr_2+r_2)(1+K)}$$

$$(15)\quad \Delta I_{mr} = I_{mr}(\text{wet}) - I_{mr}(\text{dry})$$

$$= E\left[\frac{-r_2}{r_1(Kr_1+Kr_2+r_2)} + \frac{1}{r_1(1+K)}\right]$$

$$\Delta I_{mr} = +E\frac{K}{(Kr_1+Kr_2+r_2)(1+K)} = +\frac{1}{K}\Delta I_{mt}$$

$$\Delta I_{sr} = -NE\frac{E}{(Kr_1+Kr_2+r_2)(1+K)} = -\frac{N}{K}\Delta I_{mt}$$

In the above calculations, the current in the line at one station was considered under the different transmission conditions at the other station. So far as the transmission from that station to the other station is concerned it is to be understood that either of the two conditions could be marking and the other spacing. However, when conditions are as assumed and the arrangements are the same at both ends of the line the transmission in the opposite direction will also be independent of the leakage resistance of the line because the same equations and relations also apply to the transmission in this direction.

In obtaining the relative values of the various currents as shown in Fig. 3, it is assumed that the normal or marking potentials connected to both ends of the line are the same and that the equivalent concentrated leakage resistance is located at the center of the line. Under this condition $K=1$ and $N=3$. The line designated I_{mr} represents the current flowing in the line at station B due to the marking potential connected to the line at station A. It is to be noted that as the leakage resistance decreases the current received at station B decreases, or as shown on Fig. 3, ΔI_{mr} is positive. The line designated I_{mt} represents current flowing in the line at station B due to the marking potential connected to the line at station B. In this case the current flowing in the line at station B increases as the leakage resistance decreases so that as shown on Fig. 3 ΔI_{mt} is positive. Under the assumed conditions when K is equal to 1 and the marking potentials connected to both ends of the line are substantially the same, it follows from Equation 15 that ΔI_{mt} is equal to ΔI_{mr}. It is to be noted that if it is assumed that I_{mt} is positive, I_{mr} will be negative since these two currents flow in opposite directions. The total marking current flowing in the line at station B will be the sum of these two currents. This is designated on Fig. 3 as

$$I_{mr}+I_{mt}=I_M.$$

In this case ΔI_m will be twice either ΔI_{mt} or ΔI_{mr} because I_M is the sum of I_{mt} and I_{mr}, so ΔI_m will be the sum of ΔI_{mt} and ΔI_{mt} and ΔI_{mr} and both ΔI_{mr} and ΔI_{mt} are positive.

When spacing impulses are transmitted from station A the current received at station B due to the spacing potential applied to the line at station A is represented in Fig. 3 by the line designated I_{sr}. This current I_{sr} under dry conditions will be three times the current I_{mr} because the spacing potential at station A is three times as great as the marking potential, since N is 3 as pointed out above. It also follows from Equation 15 that ΔI_{sr} is three times as large as ΔI_{mt} and is in the opposite direction to ΔI_{mt}. The total spacing current Is flowing in the line at station B is the sum of I_{sr} and I_{mt}. This current is represented in Fig. 3 by the line designated

$$I_S=I_{mt}+I_{sr}.$$

ΔI_s is the algebraic sum of $\Delta I_{sr}+\Delta I_{mt}$. Since these changes in current are in an opposite direction ΔI_s will be equal to twice the change the current ΔI_{mt} and will be in the opposite direction. In other words, ΔI_s is of the same magnitude as ΔI_M but in the opposite direction. Thus as the leakage resistance decreases the average of I_M and Is remains constant. In accordance with this invention the bias of the receiving relays at the respective stations is adjusted to be equal in magnitude to this average value but opposite in effect thereto so that the relays will respond equally well to both the marking and spacing signaling conditions. Assuming that the line winding and biasing windings have the same number of turns, the line designated $-I_B$ represents in Fig. 3 the magnitude of the current flowing through the biasing winding of the receiving relays **14** and **16** at station B but is of an opposite polarity. In other words the actual biasing current tends to maintain the relay on its marking contact while the spacing current tends to maintain the relay on its spacing contact.

It is further evident that for every value of leakage resistance the marking and spacing currents differ from the minus biasing current by the same amount but in opposite directions so the optimum biasing current is independent of the leakage resistance of the line.

The above relations have been derived upon the assumption that the leakage resistance is concentrated at the center of the line. Actual leakage resistance is usually distributed more or less evenly along the exposed portion of the line. The actual line may be replaced by an equivalent line in which the leakage resistance is concentrated at the center. In this case, however, the impedance of the line varies somewhat with variations of the leakage resistance so that in practice it is found that the effect of the distributed leakage appears to be a shifting of the equivalent concentrated resistance towards one end of the line. This merely means that the constant K will assume a somewhat different value and for this value the system will be substantially self-compensating for variations in the distributed leakage resistance. The difference between the concentrated values and the distributed lines is in practice found to be small so that variations or adjustments directed to these effects are of a second order.

Referring now to Fig. 1 which illustrates the invention applied to a typical telegraph system, station A is assumed to be an outlying subscriber's station while station B is a central station. The telegraph line or channel **10** connects these two stations together and may include both intermediate terminal composite sets as well as other apparatus usually associated with telegraph lines or composite toll lines. The resistance **11** indicates the variable leakage to which a portion of the line is subjected. As illustrated in Fig. 1 the leakage resistance **11** is assumed to be substantially in the middle of line **10**. This is near the position at which it would normally be in the usual telegraph system. With this resistance in the middle of the line the K in the above equations becomes 1 and N equals 3. Consequently, the spacing potentials connected to both ends of the line should be substantially three times the normal marking potentials and opposite in polarity to these marking potentials.

At station A the receiving polar relay **15** is provided with two windings. The upper winding is connected in series with the line **10** while the lower winding is connected in a biasing circuit provided with a variable resistance **29** for adjusting the bias. As pointed out above a mechanical bias may be employed instead of the electrical bias if desired. A noise suppression network **18** is provided to prevent the telegraph signal impulses from disturbing the telephone circuit of the composite toll line. The telegraph line is then connected through the armature of relay **33**, the contacts of relay **32** and source of potential **40**, contacts and armature of relay **32** to ground.

Relay **15** controls receiving equipment **30** through its armature and contacts. Receiving equipment **30** may be of any suitable type, as for example, a telegraph sounder or printing telegraph equipment which operates in its normal manner and thus need not be described in detail here. Relays **32** and **33** are controlled through transmitting contacts **31**. These transmitting contacts may be of any suitable type, as for example, a tape transmitter or contacts of a teletypewriter keyboard. Relays **32** and **33** are both provided with two windings, the lower winding serving as a bias winding and tending to maintain the relays on their spacing contacts. The current flowing through the upper windings is in such a direction as to move the armatures of these relays to their marking position. The circuit of these upper windings includes brake-key **44** and transmitting contacts **31**. Thus when the circuit of this upper winding is opened either at the brake-key **44** or the transmitting contacts **31** the current flowing through the lower winding causes the relay armatures to move to their spacing positions and make contact with the spacing contacts. When the upper circuit is closed current flowing through the upper windings produces an effect sufficiently greater in magnitude upon the armatures to overcome the magnetic effect of the lower windings to cause the armatures to move to their marking positions and make contact with their marking contacts. Resistances **36**, **37** and **39** are provided to control the current flowing through the respective windings of these relays so they operate in the manner just described to repeat the signal impulses to line **10**. Source of potential **40** which is illustrated as being 110 volts is connected to the contacts of these relays through resistance networks comprising resistances **34** and **38**. Tap **35** is located so that its potential is 36.6 volts negative with respect to the positive terminal of source **40**. These resistances are connected to the contacts of relays **32** and **33** in such a manner that when these relays are held on their marking contacts a potential of 36.6 volts positive is introduced between line **10** and ground and when these relays are on their spacing contacts a voltage of 110 volts negative is introduced between line **10** and ground. Thus the potential applied to line **10** during spacing impulses is of opposite polarity and is substantially three times the potential applied to line **10** when these relays are on their marking contacts. It is to be understood that any other suitable sources of potential may be employed to transmit the signal pulses.

Under normal conditions with relay **21** at station B on its marking contact relay **15** at station A will not follow the signal impulses transmitted from station A. Consequently the receiving equipment **30** will not record a home copy of the messages transmitted. If it is desired to secure a home copy of the transmitted messages at the transmitting station either additional receiving equipment may be provided at station A, which is operated from transmitting contacts **31**, or additional circuit arrangements provided for controlling the receiving equipment **30** both from receiving relay **15** and transmitting contacts **31**.

At station B the telegraph line **10** is connected through the upper windings of polar receiving relays **14** and **16**, noise suppression unit **17**, armature and contacts of transmitting relay **21**, two sources of potential **41** and **42** through networks comprising resistances **45** and **46**. The resistances of network **45** are so related that point **23** is at a potential of +36.6 volts with respect to ground. The resistances of network **46** are so related that the potential of point **22** is at a potential of −110 volts with respect to ground. Here again the voltage connected to the spacing contact is three times the voltage connected to the marking contact and is of the opposite polarity so substantially the same transmitting potentials are applied to both ends of the line for the transmission of signal impulses. Under these conditions, the transmission in both directions is

self-compensating for changes in the leakage resistance of the line. As shown in Fig. 1 the circuit arrangement at station B is provided with local telegraph apparatus 24 which includes transmitting contacts 25, a recording magnet 26 and a source of potential 27. It is to be understood, however, that any type of transmitting and receiving apparatus may be connected in the circuit and at station B including repeating relay windings and contacts of any suitable type of telegraph repeater including both cord circuit and carrier current repeaters. Relays 14 and 16 are provided with a biasing winding which is connected in a biasing circuit including variable resistance 28 which is used to adjust the biasing current to the proper value as explained hereinbefore. Relays 14 and 16 respond to the signals transmitted from station A. Relay 14 repeats the signals to the apparatus 24 connected to the local line or loop 50 of station B while relay 16 controls the biasing current through the transmitting relay 21 in such a manner that relay 21 does not follow the signal impulses received from station A but is instead maintained on its marking contact during this time. However, when signals are transmitted from the telegraph apparatus 24, relay 21 will follow these signal impulses and repeat them to line 10. They then cause relay 15 at station A to repeat the same impulses to the receiving equipment 30 at station A.

Thus, when no signals are being transmitted, substantially no current, except leakage current, flows in line 10 because substantially the same potential is normally applied to both ends of the line. When spacing impulses are transmitted from one station, current flows in one direction in the line and when the other station transmits spacing impulses, current flows in the opposite direction in the line 10.

It should be noted that this arrangement does not provide a full duplex circuit between the two stations because the receiving relays at both stations are moved to their marking contacts when the transmitting apparatus at both stations are on their spacing contacts. Consequently it is possible to transmit signal impulses over line 10 in only one direction at a time. It is to be noted that resistances 12 and 13 connected in line 10 are provided to limit the current flowing over the line and are related to each other in such a manner that the effective leakage resistance 11 is substantially in the center of the line. If it is impossible to so adjust these resistances then the relative potentials applied to the ends of the line under marking and spacing conditions are adjusted as pointed out above, so that the response of the receiving relays at both stations to both signaling conditions transmitted from a distant station is substantially the same and independent of the leakage resistance of the line.

It is to be understood that this invention may be used in a comprehensive telegraph network for transmission to outlying subscriber or telegraph stations over long open wires as well as between central switching stations.

The invention has been described with specific reference to the telegraph system shown in Fig. 1. However, it is to be understood that the invention is equally applicable to transmitting telephone or other signaling and switching impulses over long lines subjected to varying leakage resistance.

What is claimed is:

1. A two-way non-duplex impulse transmitting system comprising a line circuit, open wire lines subjected to a variable leakage resistance comprising a portion of said line circuit, similar impulse transmitting and receiving apparatus at both ends of said line, means connected to said transmitting apparatus for so adjusting the transmitting potentials applied to the ends of said line that the response of the receiving device at the opposite end of said line is substantially the same to all received signaling conditions independent of changes of the magnitude of the leakage resistance of said line.

2. A communication system comprising a line, a portion of which is subjected to variable leakage resistance, similar receiving relays connected to each of the ends of said line, apparatus for transmitting two different signaling currents from each end of said line and means for controlling the transmitting potentials applied by said transmitting apparatus whereby the sum of the two signaling currents received at the opposite end of said line is substantially constant and independent of said line leakage and bias means connected to the receiving relays which produces a magnetic effect substantially opposite to half the magnetic effect of the sum of said signaling currents.

3. A telegraph system comprising a direct current telegraph channel, a polar receiving relay connected to each end of said telegraph channel, means for normally connecting potentials of the same polarity to both ends of said channel and means for applying potentials of opposite polarity to either end of said channel in accordance with the telegraph signal impulses to be transmitted thereover and means for so adjusting the values of said potentials with respect to the line resistance and the leakage resistance that the receiving relays respond to both potentials applied to the opposite end of said channel substantially the same and independent of any change leakage resistance of said line.

4. In a two-way signaling system a first station, a second station, a transmitting channel connected between said stations, similar apparatus for receiving impulses at each of said stations and similar apparatus for transmitting impulses at each of said stations, said transmitting apparatus normally applying the same polarity of potential to both ends of said transmitting channel and means for applying the opposite polarity in accordance with the impulses to be transmitted, means for so regulating said potentials in accordance with the distribution of resistance of said means for transmitting signal impulses that the algebraic sum of the currents received at either station from the other station is substantially constant and independent of the leakage resistance of said transmitting channel.

5. A two-way telegraph system comprising a first station, a second station, a telegraph transmission line connecting said stations subjected to varying leakage resistance, a similar receiving relay at each of said stations connected to said line, transmitting apparatus at each of said stations also connected to said line comprising a marking condition and a spacing condition, means for applying substantially the same potentials to said line at both stations in marking positions of said apparatus whereby substantially no current flows in said line under this condition, and means for applying other potentials to said line when said transmitting apparatus is in its spacing condition whereby cur-

rent flows in said line in one direction when signals are transmitted in one direction and current flows in said line in the other direction when signals are transmitted in the other direction, and means for so adjusting the potentials applied to said transmitting apparatus that the response of the receiving apparatus at the opposite station is substantially the same for both potentials applied at the transmitting station.

6. A signaling system comprising a line circuit subjected to varying leakage resistance, receiving apparatus connected to each end of said line, transmitting apparatus connected to each end of said line comprising a marking contact and a spacing contact, means for connecting substantially the same potential to the marking contacts of both of said transmitting devices, means for connecting other potentials to the spacing contacts of said transmitting apparatus and means for so adjusting the said potentials in accordance with the distribution of resistance and leakage of said line that the algebraic sum of the currents received at either station from the other station remains substantially constant and independent of the leakage resistance of the line.

7. In combination a line circuit, a polar receiving relay connected to each end of said line, transmitting apparatus connected to each end of said line having a marking contact and a spacing contact, means for connecting substantially the same potential to each of said marking contacts, means for connecting substantially the same potential to each of said spacing contacts, said potential connected to said spacing contacts being of opposite polarity and substantially three times the magnitude of the potential connected to said marking contacts whereby the receiving apparatus at either station responds substantially the same to both said marking and spacing potentials transmitted from the other end of said line independent of variations of the leakage resistance of said line.

8. A telegraph system comprising a first station, a second station, a telegraph line connected between said stations, a portion of which is subjected to varying leakage resistance, similar receiving apparatus connected to said line at each of said stations, similar transmitting apparatus connected to said line at each of said stations having a marking contact and a spacing contact, means for connecting substantially the same potential to the marking contacts of said transmitting apparatus at each of said stations, means for connecting substantially the same spacing potential to the spacing contacts of said transmitting apparatus at each of said stations which is so related to the potential connected to both of said marking contacts and to the distribution of leakage resistance and line resistance of said telegraph line that the sum of the currents received at either of said stations from the other of said stations is substantially constant and independent of the leakage resistance of said line, and bias means cooperating with said receiving apparatus which produces an effect equal in magnitude to one-half the algebraic sum of the currents received at each of said stations but opposite in direction thereto.

9. In combination, a communication line, receiving apparatus connected to each end of said line, transmitting apparatus connected to each end of said line having a marking and a spacing position, means for connecting substantially the same potential to said line when said transmitting apparatus are in their marking positions, means for connecting substantially the same potential to said line when said transmitting apparatus are in their spacing positions which is substantially three times the magnitude of the potential connected to said line when said apparatus are in their marking positions but of opposite polarity, and means for regulating the distribution of the line resistance with respect to the distribution of the leakage resistance of said line so that the receiving apparatus at either station responds substantially the same to both the marking and spacing potentials applied to the line at the other station independently of variations of the leakage resistance of the line.

10. An impulse transmitting system comprising a first station, a second station, a line connected between said stations, similar receiving apparatus connected to said line at each of said stations, similar transmitting apparatus connected to said line at each of said stations having a marking and a spacing position, means for connecting substantially the same potential to said line when said transmitting apparatus are in their marking position, means for connecting substantially the same potential to said line when said apparatus are in their spacing position which is opposite in polarity to the potential connected to said line when said apparatus are in their marking position and which has a magnitude which is equal to the magnitude of the potential connected to said marking contacts multiplied by the quantity; two times the ratio of the resistance of the line from the receiving station to the equivalent concentrated leakage resistance of the line to the resistance of the remainder of the line, plus one.

11. A communication system comprising a line, similar receiving apparatus connected to each end of said line, similar transmitting apparatus connected to each end of said line for transmitting two different signaling conditions over said line and having a marking position and a spacing position, means for connecting substantially the same potentials to the ends of said line when said transmitting apparatus are in their marking positions, and means for connecting substantially the same potentials to the ends of said line when said transmitting apparatus are in their spacing positions, said marking and spacing potentials being so related that the bias of the signaling conditions transmitted over the line is substantially independent of variations in the magnitude of the leakage resistance of the line.

12. A two-way non-duplex impulse transmitting system comprising a line, similar impulse transmitting and receiving apparatus connected to each end of said line, a marking and a spacing contact cooperating with both of said transmitting apparatus, means for connecting sources of substantially the same potential to the marking contacts of said transmitting apparatus, means for connecting sources of potential of substantially the same polarity to the spacing contacts of said transmitting apparatus, and means for so adjusting the relative potentials connected to said marking and spacing contacts that the bias of the impulses transmitted over said system is substantially independent of the magnitude of the leakage resistance of said line.

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