Nov. 15, 1938. C. W. SMITH 2,136,984

IMPULSE TRANSMITTING SYSTEM

Filed April 14, 1937

FIG. 1

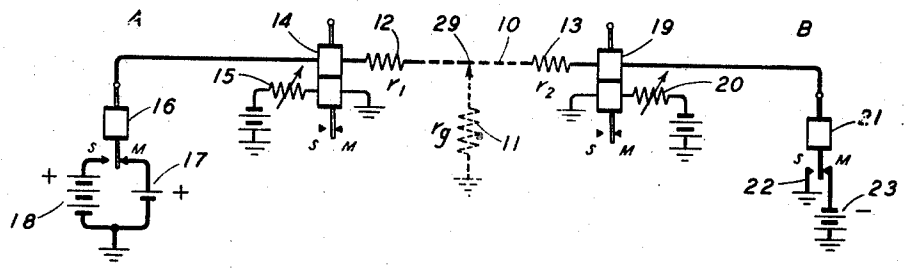
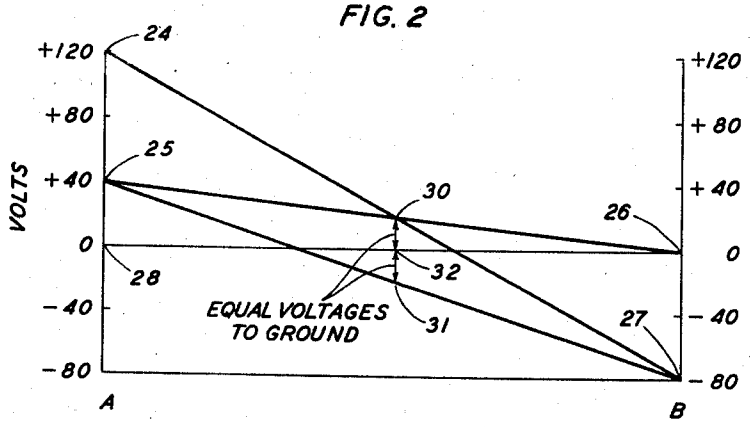


FIG. 2



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IMPULSE TRANSMITTING SYSTEM

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9 Claims. (Cl. 178—58)

This invention relates to an improved communication system for transmitting signaling impulses over communication lines, and more particularly for transmitting these impulses over long open-wire lines subjected to varying weather and leakage resistance conditions.

In the systems in the past varying leakage resistance of the line made it necessary to adjust the receiving equipment connected to the line at frequent intervals of a day or less to compensate for the variations in the leakage resistance. This is true of both telephone and telegraph circuits transmitting signaling impulses over long open-wire lines or telegraph channels of composite toll lines over which both telegraph and telephone signaling currents are transmitted. Variation of the leakage resistance of the line tends to cause a variation in bias of the received signals or pulses which must be compensated for by a variation of the biasing current of the receiving relays or apparatus connected to each end of the line. This adjustment is very undesirable and expensive particularly in the case of an outlying telegraph subscriber's station which is far removed from the central telegraph station or repeater point, as is frequently the case.

It is an object of this invention greatly to reduce the amount of maintenance and adjustment required for the receiving equipment connected to both ends of the line.

It is a further object of this invention to arrange an impulse transmitting system suitable for the transmission of signal impulses by increasing the current in one direction of transmission and reducing the current for transmission in the opposite direction so that the response of the receiving equipment at both ends of the line is substantially independent of variations in the magnitude of the leakage resistance of the line.

A further object of this invention is to provide a telegraph system for transmitting impulses in one direction by increasing the current and in the other direction by decreasing the line current in which the bias of the received signal is substantially independent of variations of the leakage resistance of the line.

Still another object of this invention is to provide a method of operating a telegraph system whereby the potential across the equivalent concentrated leakage resistance of any given value is substantially the same magnitude for all signaling conditions.

In this specification the terms "pulse" and "impulse" mean a signaling or electrical condition of short duration which are used to transmit information or intelligence over the system.

The term "bias" as applied to signals indicates a lengthening of one signal impulse and the shortening of the other signal pulse or impulse. For example, marking bias means that the marking signal pulses or impulses are lengthened and that the spacing pulses are shortened, whereas spacing bias indicates that the spacing signals are lengthened and the marking signals shortened. Thus, signals having greater bias are less satisfactory for operating receiving apparatus than are signals having less bias. Consequently the biased signals are poorer in quality.

A common cause for this lengthening and shortening of the various signal pulses is that the magnitude of the two pulses or current conditions are unequal or vary in a different manner from each other with respect to a fixed basing current or adjustment of the receiving apparatus. For a marking bias the marking current is greater or differs by a greater amount from a fixed biasing or reference current than the spacing current, whereas for spacing bias the spacing current is greater or differs from a given reference current by a greater amount than the marking current.

The terms "marking" and "spacing" as used in this specification differentiate the two line or signaling conditions transmitted from each end of the line. The term "marking" is used to designate the line or signaling condition employed during the time no signal pulses or impulses are being transmitted over the system but the system is energized and ready to transmit the signal impulses when desired. 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 this invention may be more readily 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 telegraph system; and

Fig. 2 shows a diagram used to explain the operation of Fig. 1.

Fig. 1 shows two stations A and B. These stations are connected together by line 10 which is composed of resistance r_1 or 12 and resistance r_2 or 13. Line 10 is also subject to a leakage resistance which is represented by an equivalent concentrated resistance 11, also designated r_g which is shown connected to line 10 at point 29.

Point 29 need not be the electrical center of the line but in order to simplify the explanation it will be assumed that this point is at the center of the line. At station A line 10 passes through the upper operating winding of receiving relay 14 and contacts with the transmitting relay 16 to the transmitting sources of potential 17 and 18. Receiving relay 14 is also provided with a lower biasing winding including an adjustable resistance 15 for adjusting the biasing current. Station B is provided with similar sets of relays. The upper winding of relay 19 is connected in series with line 10 and the contacts of the transmitting relay 21. The receiving relay 19 is also provided with a biasing winding, the circuit of which includes adjustable resistance 20 for adjusting the biasing current of the relay 19.

By proper selection of the potentials supplied to the contacts of the transmitting relays 16 and 21 the operation of relays 14 and 19 may be made substantially independent of the magnitude of the leakage resistance 11. In other words the leakage resistance r_g, which is also designated 11, will equally affect the operation of relays 14 and 19 to their marking and spacing positions and thus introduce no bias into these signals.

In order to secure the optimum or most favorable operation of the receiving relays 14 and 19 at stations A and B respectively, the biasing currents are adjusted by resistances 15 and 20 so that they have a magnetic effect on the relay which is opposite to the average of the magnetic effect of the marking and spacing currents received by the relay from the distant end. The conditions under which the biasing current should not be changed with variations in the magnitude of the leakage resistance r_g may be determined as follows.

Assume first that station A is transmitting signal impulses to station B and that the transmitting relay 21 at station B remains on its marking contact so that source of potential 23 remains in the circuit. Assume further that V is the value of this source of potential. Also assume that the leakage resistance is connected to line 10 at point 29 and that the potential of point 29 is P. Further assume that the source of potential 17 connected to the marking contact M of the transmitting relay 16 at station A is of value of E_m and that the potential 18 connected to the spacing contact of relay 16 has a value E_s. r_1 is the resistance of the line and equipment from the sending end A to the point 29 at which the effective leakage resistance r_g or 11 is connected to the line and r_2 is the resistance of the line and equipment from point 29 to the receiving end. Also assume r_g represents the leakage resistance of the line.

Under dry weather conditions with an infinite line leakage resistance the marking current i_m and spacing current i_s received at station B during the transmission of marking and spacing pulses from station A are as follows:

$$i_m(\text{dry})=\frac{E_m+V}{r_1+r_2} \tag{1}$$

$$i_s(\text{dry})=\frac{E_s+V}{r_1+r_2} \tag{2}$$

Under these conditions the optimum biasing current for the receiving relay 19 would be equal in magnitude but opposite in polarity to half the sum of the two received currents, assuming that both windings of relay 19 have the same number of turns. If the number of turns of the two windings are different, this may be compensated for by an appropriate constant. This biasing current may be determined as follows:

$$i_b=-\frac{i_s+i_m}{2} \tag{3}$$

$$-i_b(\text{dry})=\frac{V}{r_1+r_2}+\frac{E_m+E_s}{2(r_1+r_2)} \tag{4}$$

Under wet weather conditions when the leakage resistance r_g falls to a relatively low value spacing currents i_m and i_s, respectively, are as follows:

$$i_m(\text{wet})=\frac{E_m}{\frac{r_2r_g}{r_2+r_g}+r_1}\times\frac{r_g}{r_2+r_g}+\frac{V}{\frac{r_1r_g}{r_1+r_g}+r_2}=\frac{E_mr_g+V(r_1+r_g)}{r_1r_g+r_1r_2+r_2r_g} \tag{5}$$

$$i_s(\text{wet})=\frac{E_s}{\frac{r_2r_g}{r_2+r_g}+r_1}\times\frac{r_g}{r_2+r_g}+\frac{V}{\frac{r_1r_g}{r_1+r_g}+r_2}=\frac{E_sr_g+V(r_1+r_g)}{r_1r_g+r_1r_2+r_2r_g} \tag{6}$$

As before, the optimum biasing current i_b under wet weather conditions is one-half the sum of these marking and spacing currents but opposite in direction and may be determined as follows:

$$-i_b(\text{wet})=\frac{V(r_1+r_g)}{(r_1r_g+r_1r_2+r_2r_g)}+\frac{(E_m+E_s)r_g}{2(r_1r_g+r_1r_2+r_2r_g)} \tag{7}$$

If the operation of the receiving relay 19 is to be independent of the leakage resistance of the line, its biasing current should be substantially independent of the resistance of the line or the biasing current under dry conditions should equal the biasing current under wet conditions. This condition is as follows:

$$i_b\ (\text{dry})=i_b\ (\text{wet}) \tag{8}$$

Substituting the values of these currents and simplifying, the following condition is arrived at which is necessary for these two currents to be the same:

$$\frac{2V}{E_m+E_s}=\frac{r_2}{r_1} \tag{9}$$

Consequently, if this condition is fulfilled the optimum biasing current of the receiving relay is substantially independent of changes in magnitude of the resistance of the line.

The potentials P_s and P_m of point 29 under marking and spacing conditions E_m and E_s respectively are as follows:

$$P_s\ (\text{dry})=V-r_2i_s=\frac{Vr_1-E_sr_2}{r_1+r_2} \tag{10}$$

$$P_m\ (\text{dry})=V-r_2i_m=\frac{Vr_1-E_mr_2}{r_1+r_2} \tag{11}$$

It has been discovered that if the magnitude of these two potentials is the same but opposite in polarity with any given value of line leakage resistance, the operation of the receiving relay will be independent of the leakage resistance and it will be unnecessary to adjust the biasing current of the receiving relay to compensate for changes in the magnitude in the leakage resistance of the line.

Thus for dry weather conditions:

$$P_m\ (\text{dry})=P_s\ (\text{dry}) \tag{12}$$

Substituting Equations (10) and (11) in (12) the following condition is obtained:

$$\frac{2V}{E_m+E_s}=\frac{r_2}{r_1} \qquad (13)$$

It is apparent that (9) and (13) are identical so that if the potential from the point at which the leakage resistance is considered concentrated is the same in magnitude for both marking and spacing currents but of opposite polarity for any given value of line leakage resistance then the system is self-compensating and the biasing current of the receiving relay need not be adjusted to compensate for changes or variations in the leakage resistance of the line.

The above equations have been developed for the transmission of impulses in one direction over line 10. However, the same equations may be applied to the transmission in the opposite direction in which case the system will be self-compensating for transmission in both directions.

Fig. 2 shows a graphical solution of the conditions for which the potential across the equivalent concentrated leakage resistance is of the same magnitude but of opposite polarity for the different signaling conditions transmitting in both directions over the line. If these conditions are complied with the system will be fully compensating, as pointed out above, and require substantially no change in the bias or other adjustment of the receiving apparatus to compensate for variations of the leakage resistance of the line. In Fig. 2 the horizontal line between points 26 and 28 represents zero or earth potential along the line. The vertical line at the left-hand side above the letter A represents the potentials connected to the line at station A while the vertical line at the right-hand of the drawing represents the potentials connected to the line at station B. A 40-volt potential is assumed to be connected to the line at station A. This is the potential assumed to be connected to the marking contacts of the sending relay 16 at station A. This potential is indicated by point 25, Fig. 2. At station B the source of potential 23 is normally connected to line 10. In the specific case shown in Fig. 2 this is assumed to be −80 volts which is illustrated in Fig. 2 by point 27. The line connecting points 25 and 27 shows the drop in potential along the line from station A to station B so that at any point between these stations the line between these points shows the potential of the line to ground.

In Fig. 2 the line connecting points A and B represents the distance or electrical resistance of the line between stations A and B. Equal divisions along this line represents equal increments of resistance of the line between A and B.

Now assume that the leakage resistance may be replaced by an equivalent leakage resistance at the center of the line. This means that the potential of the line at the point of the effective resistance is shown by point 31 during the time both the transmitting devices are on their marking contacts. Now to secure compensated operation in both directions of transmission the potential from this mid-point to ground should remain the same in magnitude but should reverse in polarity when either of the transmitting devices moves to a spacing contact and the other one remains on its marking contact. In other words, the potential or length of line between points 32 and 31 should be the same as between 30 and 32, point 30 being an equal distance above or positive to the zero or ground potential while point 31 is below or negative to the ground potential. Thus for a spacing condition at station B a line drawn through points 25 and 30 intersects the vertical line at station B at point zero thus indicating that ground potential should be applied to the spacing contact 22 of the transmitting device 21 at station B. Similarly, a line drawn from point 27 through point 30 intersects the vertical line at the left-hand end of the diagram at point 24 indicating that a positive 120-volt source of potential should be connected to the spacing contact of the transmitting device 16 at station A. When these potentials are connected to the contacts of the transmitting devices at stations A and B and the bias of the receiving relays adjusted to their optimum values these receiving devices at the opposite stations will respond equally well to both the marking and spacing conditions substantially independently of the leakage resistance of the line and consequently need not be adjusted to compensate for changes in bias due to the changes in leakage resistance of the line.

It is to be understood that the system is not limited to these specific voltages nor to these specific ratios of voltages. The voltages may assume widely different values, the only requirements being that Equations (9) and (13) are met for both directions of transmission or that the potentials of the line at the points at which an equivalent concentrated leak is connected under dry weather conditions is of the same magnitude but of opposite polarity for marking and spacing conditions transmitted from the respective stations to the opposite stations (Equation 12).

The diagram shown in Fig. 2 may be used to illustrate the effect of shifting the point at which the effective concentrated leakage is connected to line 10. The effect of the equivalent concentrated leakage shifting along the line can be observed or provided for by shifting the line between points 30, 32 and 31, 32 along the zero potential line between points A and B in accordance with the shift of the leakage resistance along the resistance of the line. As assumed in Fig. 2 the leakage resistance was effectively concentrated at the center of the line. Thus point 32 is equally spaced from points 28 and 26. Had the effective leakage resistance of the line 10 been located nearer station A than station B then point 32 would be located correspondingly closer to point 28 of Fig. 2 than to point 26. In this manner the effect of entrance cables comprising a portion of the circuit in which the remainder is open-wire line can be readily considered.

In the foregoing description it has been assumed that the leakage resistance was concentrated at a particular point along the line. The actual leakage resistance of the line is distributed more or less evenly along the exposed portion of the line. The actual line or exposed portion thereof may be replaced by an equivalent line in which the leakage resistance is concentrated usually at the center. In this case, however, the impedance of the line also varies somewhat with variations of leakage resistance. This variation of impedance of itself tends to cause a slight additional variation of the response of the receiving relay. It has been found in practice that this secondary variation appears to be equivalent to the shifting of the concentrated leakage re-

sistance towards one end of the line. The shift further appears to depend upon the direction of transmission so that for transmission in one direction the leak is considered to be shifted in a given direction while for transmission in the opposite direction the leak is considered to be shifted an equal amount in the opposite direction. This merely means that the constants of the equations will assume slightly different values for a line in which the leakage is distributed throughout its length. The difference between the values for the lines with the concentrated leaks and the lines with the distributed leaks is found to be small so that the variations or adjustments directed to these effects are of a second order. Consequently, the arrangements described above compensate for variations in the distributed leakage of a line substantially as well for all practical purposes as they do for variations of concentrated leakage resistance of transmission lines.

It is to be understood that line **10** may comprise telephone or telegraph lines and may include composite apparatus, intermediate and terminal composite sets as well as other apparatus usually employed in long telegraph, toll, or long combined telephone and telegraph lines.

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 signaling and switching impulses over long lines subjected to varying leakage resistance, the only difference being the function performed by the transmitting and receiving apparatus.

The apparatus shown at stations A and B has been limited to the apparatus which cooperates specifically with the line between these stations and which is essential to secure the self-compensating feature whereby the response of the receiving apparatus is very insensitive to changes in the leakage resistance of the line. It is to be understood, however, that this equipment may be employed in suitable types of telegraph apparatus such as transmitting and receiving printers or mechanisms, portions of telegraph repeaters and may be connected to other lines or stations substantially the same as these lines and stations or to other types of lines and stations, such as full metallic, full duplex lines, carrier current telegraph lines, etc.

What is claimed is:

1. In a communication system, a first station, a second station, a direct current impulse signaling channel connected between said stations subjected to a variable leakage resistance, impulse receiving apparatus at each of said stations connected to said channel and impulse transmitting means connected to each of said stations each comprising means for so transmitting two signaling conditions over said channel that impulses of increased current are sent in one direction over said channel and impulses of reduced current are transmitted in the other direction over said channel and potential means connected to said impulse transmitting means so related to the distribution of resistance of said channel that the receiving apparatus at the opposite end responds equally well to both signaling conditions transmitted from the other end substantially independent of changes of the leakage resistance of the line.

2. A communication system comprising a pulse transmitting line, receiving relays connected to each end of said line, transmitting apparatus connected to each end of the line comprising a first signaling position and a second signaling position, sources of potential so connected to said transmitting devices that a line current normally flows over said line when said signaling devices are in their first position, other potentials so connected to the other positions of said transmitting devices that pulses of increased strength are transmitted over the line when one of said transmitting devices moves to its second position and for transmitting pulses of decreased current strength over said line when the other of said pulse transmitting devices moves to its second position, biasing means for biasing each of said receiving relays, said potentials connected to said transmitting devices being so related to each other, said line and said biasing means that the operation of said receiving relays at both ends of the line are substantially independent of the leakage resistance of said line.

3. A method of operating a telegraph system which comprises transmitting impulses in one direction by current increases and in the opposite direction by current decreases and so adjusting the transmitting potentials at both ends of the system that the magnitude of potential across the equivalent concentrated leakage resistance of any given value is substantially the same for all the signaling conditions.

4. A two-way non-duplex telegraph system comprising a telegraph line having an open-wire section subjected to a variable leakage resistance, receiving apparatus connected to each end of said line, transmitting apparatus also connected to each end of said line for so applying two signaling conditions to said line that current impulses of increased magnitude are transmitted in one direction and signaling impulses of decreased magnitude are transmitted in the opposite direction over said line, potential sources connected to said transmitting apparatus having potentials so related to each other and the distribution of leakage resistance and line resistance that the sum of the signaling conditions received at the opposite station is substantially constant and independent of the leakage resistance of the line.

5. In combination, a first station, a second station, a low frequency electrical transmission channel extending between said stations, receiving apparatus at each of said stations, bias means connected to said receiving apparatus, transmitting apparatus at each of said stations for applying two signaling conditions to the ends of said channel for transmitting current pulses of increased magnitude in one direction over said channel and current pulses of decreased magnitude in the opposite direction over said channel, potential means connected to said transmitting apparatus so related to each other and the distribution of the leakage resistance of the line and the line resistance that the magnitude of potential across any given equivalent concentrated leakage resistance is substantially the same for all signaling conditions and means for adjusting the bias of said receiving apparatus to produce a magnetic effect substantially opposite to one-half the effect of the sum of the signaling conditions received from the opposite station.

6. Method of transmitting signaling impulses over a telegraph system which comprises transmitting the impulses in one direction by increases in current and in the opposite direction by decreases in current and applying transmitting potentials to the ends of the system so related to

each other and to the system that the bias of the signaling impulses transmitted thereover is substantially independent of variations of the leakage resistance of said system.

7. Method of transmitting signaling impulses over a telegraph system which comprises transmitting impulses in one direction over the system by increases in current and in the opposite direction by decreases in current, and applying transmitting potentials to said system so related to each other and to said system that the algebraic sum of the current impulses received at either end of the system from the other end thereof is substantially constant and independent of the leakage resistance of the system and then applying a biasing effect to the receiving apparatus at each end of the system which is equal in magnitude to substantially one-half said sum of said received currents but opposite in effect thereto.

8. A communication system comprising a transmitting line, a receiving apparatus connected to each end of said line, transmitting apparatus connected to each end of said line for so transmitting two signaling conditions thereover that impulses of increased magnitude are transmitted in one direction over said line and impulses of decreased magnitude are transmitted in the opposite direction over said line, potential sources so connected to said transmitting apparatus and so related to each other and said line that the bias of the impulses transmitted over said line is substantially independent of variations in the magnitude of the leakage resistance of said line.

9. In a communication system, a first station, a second station, an impulse signaling channel connected between said stations, impulse receiving apparatus at each of said stations connected to said channel impulse transmitting apparatus connected to each end of said channel having a first signaling position and a second signaling position, means for applying sources of potential to said channel for causing current to flow thereover when both of said transmitting apparatus are in their first positions, means for applying another source of potential to said channel for causing current of increased magnitude to flow thereover when one of said transmitting apparatus is in its second position, and means for applying another source of potential to said channel for causing current of decreased magnitude to flow thereover when the other of said transmitting apparatus is in its second position, said sources of potential being so related to each other and to said signaling channel that the bias of the impulses transmitted thereover is substantially independent of variations in the magnitude of the leakage resistance of said channel.

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