Sept. 30, 1941. B. L. BUXTON 2,257,592

DIRECTIONAL MONITORING SYSTEM

Filed July 9, 1940 2 Sheets-Sheet 1

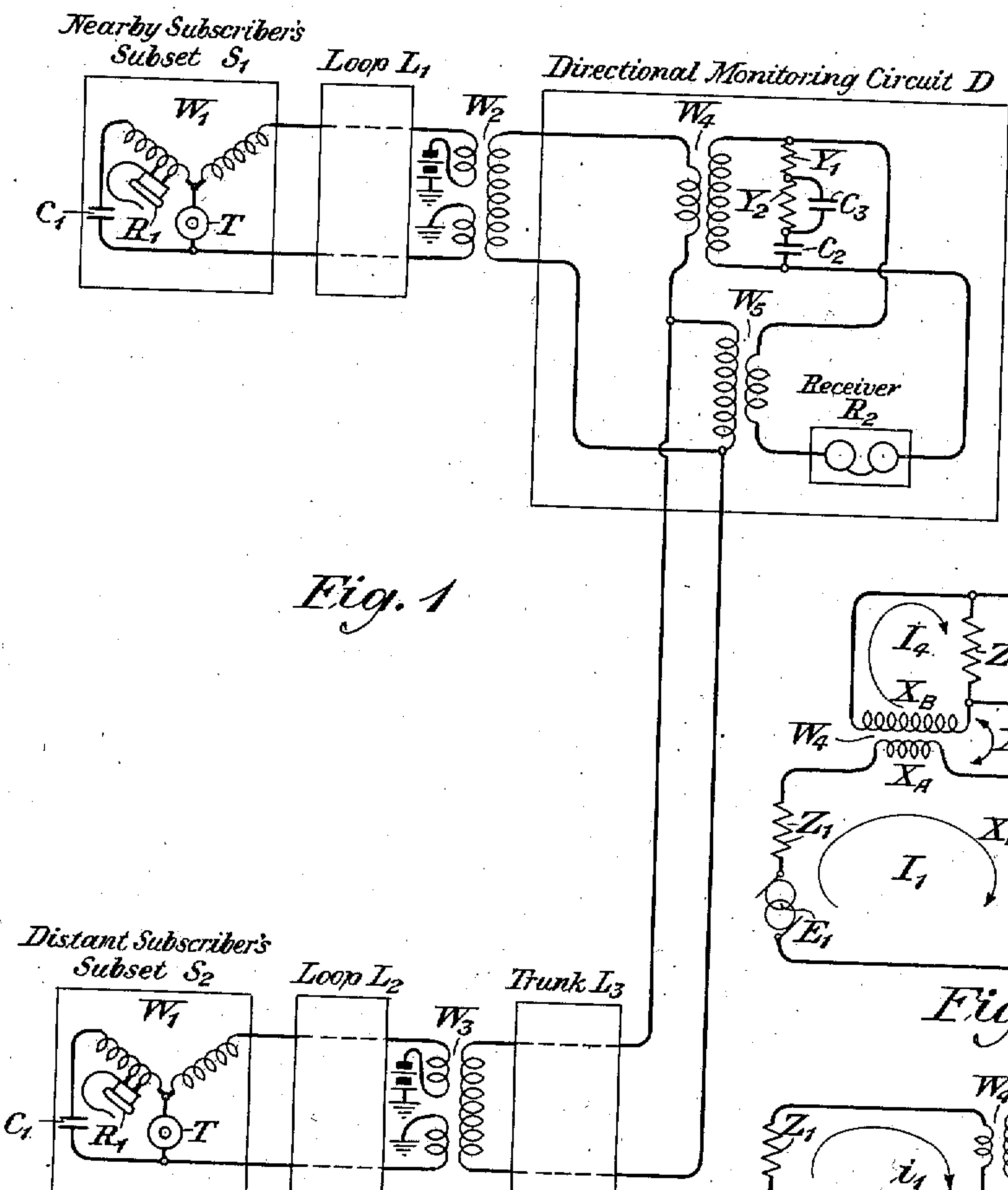

Fig. 1

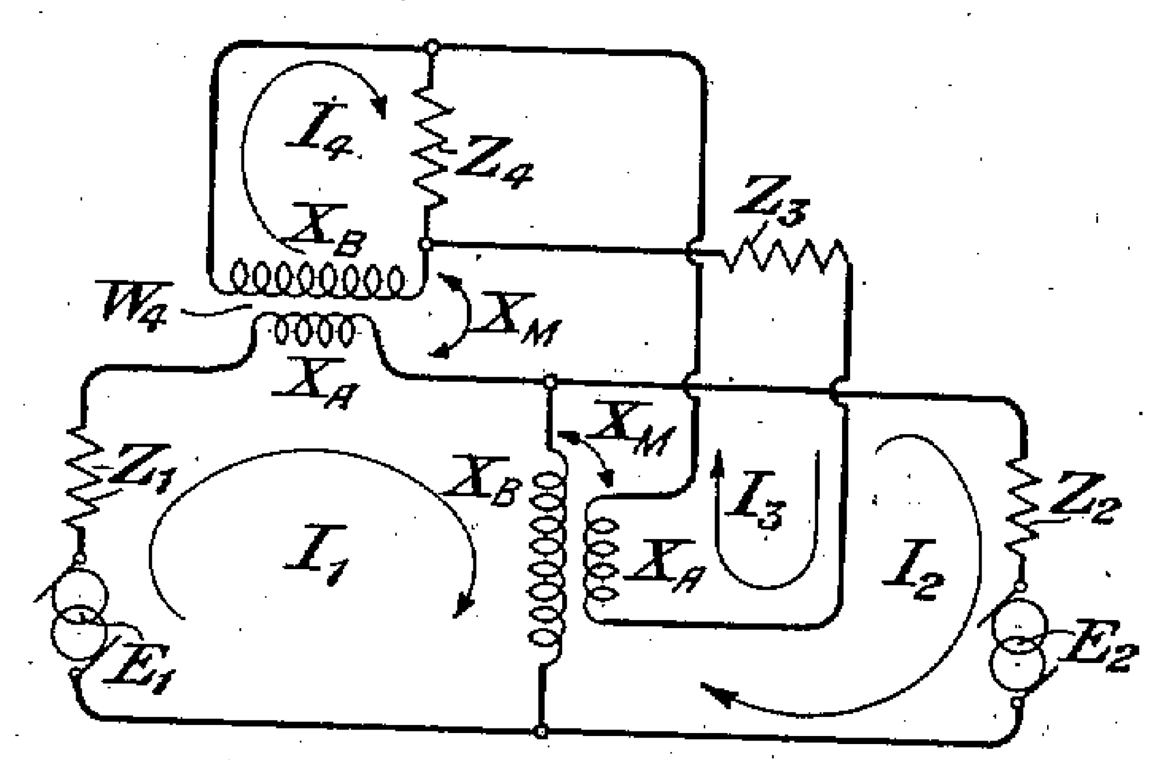

Fig. 2

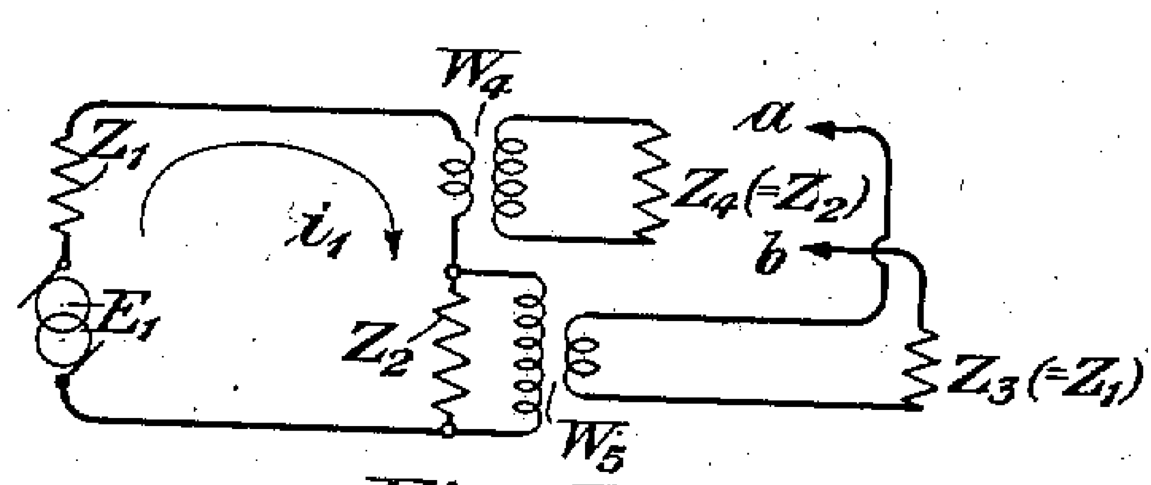

Fig. 3

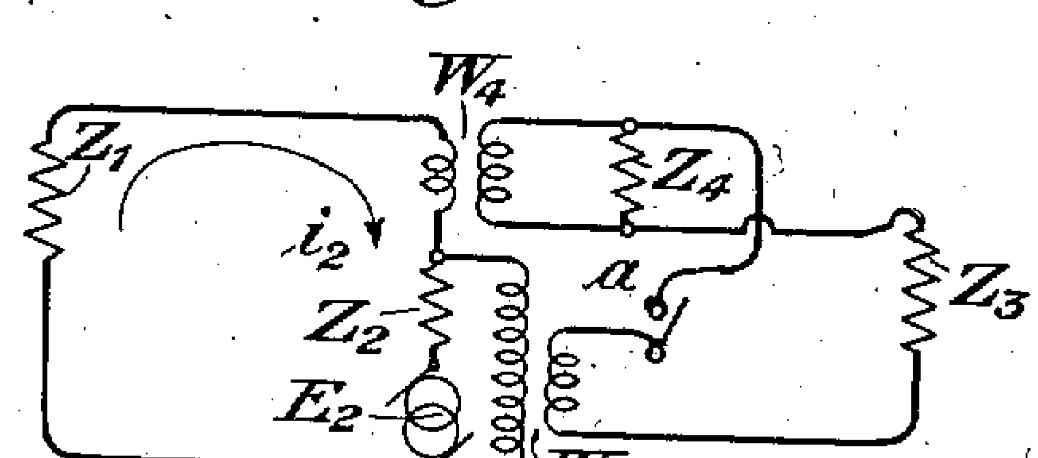

Fig. 4

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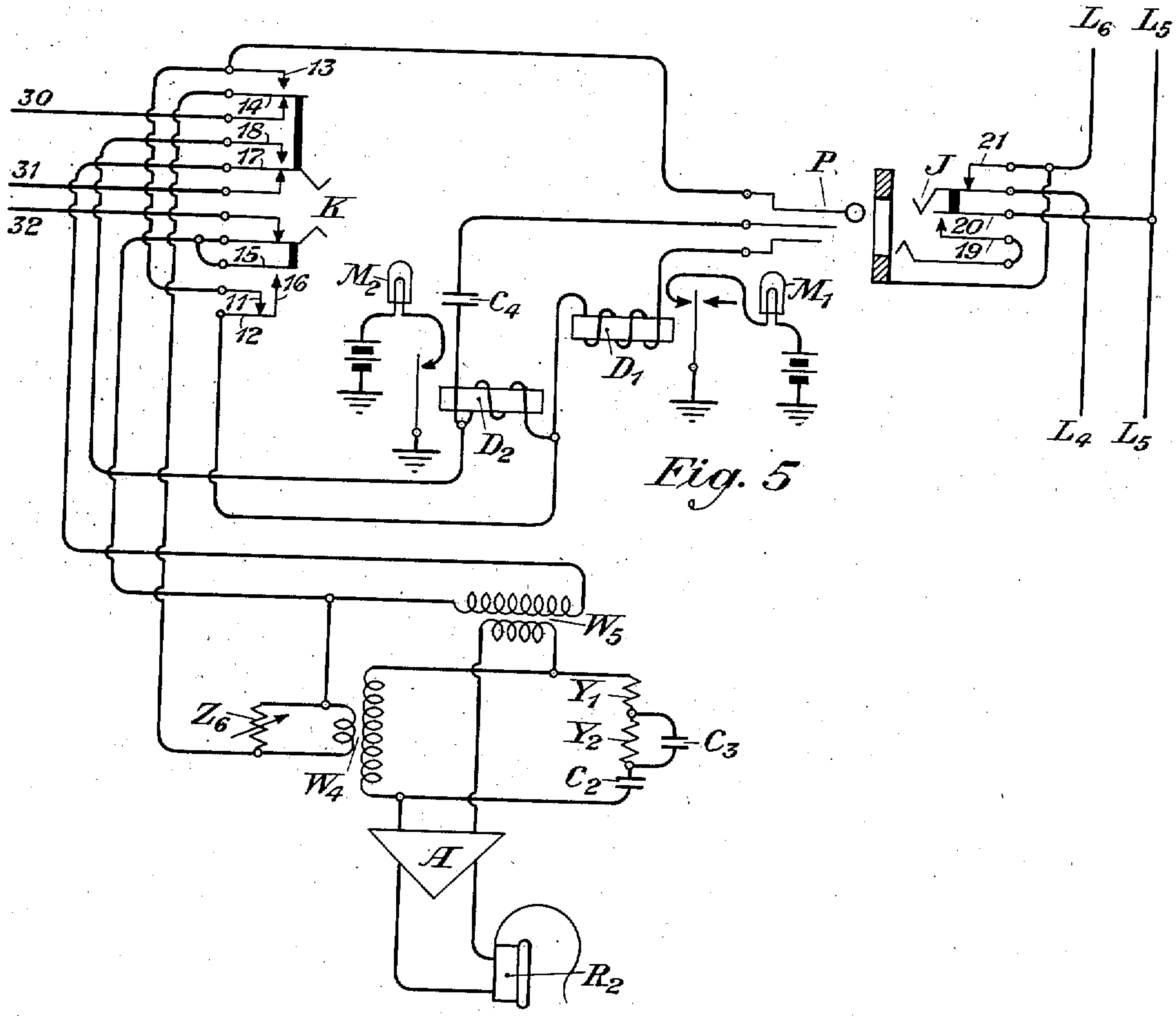

Fig. 5

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DIRECTIONAL MONITORING SYSTEM

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Application July 9, 1940, Serial No. 344,503

9 Claims. (Cl. 179—175.3)

This invention relates to telephone circuits and systems and particularly to monitoring arrangements for telephone circuits or systems. More particularly, this invention relates to monitoring arrangements which provide means for equalizing the volume of the signals received by the monitoring set from the circuits transmitting signals to the monitoring set.

A monitoring set is often used in the telephone plant to observe transmission for example, between two subscribers. Where the two subscribers are at widely different distances from the monitoring set, the observer at the monitoring set will receive the nearby subscriber's signals at a substantially greater volume than the signals of the distant subscriber. Because of the proximity of the nearby subscriber's set to the monitoring apparatus, the observer will also receive room noises audible at the nearby subscriber's set. The difference in the levels of the signals from the two subscribers, with the accompanying noise, is a source of annoyance to the monitoring observer and, moreover, the monitoring operation is rendered difficult by these conditions.

One of the objects of this invention is to provide a monitoring set in which the levels of received signals from two subscribers, for example, will be substantially the same.

Another of the objects of this invention is to substantially reduce room noises as received by the monitoring set from the transmitter of the nearby subscriber's or operator's set.

These and other objects of this invention will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawings in which Figure 1 shows one form of circuit arrangement for practicing the invention, Fig. 2 illustrates a schematic of the circuit arrangement of Fig. 1, Figs. 3 and 4 illustrate circuits used for explaining the operation of the system, and Fig. 5 illustrates another form of circuit showing some of the switching details of the invention.

Fig. 1 of the drawings illustrates two typical telephone subscriber sets S_1 and S_2 each of which may include a telephone transmitter T, a telephone receiver R_1, an induction coil or transformer W_1 coupling the circuits of the transmitter T and receiver R_1 and a condenser C_1 connected across some of the turns of one of the windings of the induction coil or transformer W_1. The usual loop circuits that may be associated with these subscribers' sets are designated L_1 and L_2, respectively. The loop circuit L_1 may be connected through a repeating coil or transformer W_2 to a local office, for example, the local office at which the directional monitoring circuit D is located. The loop circuit L_2 may be connected to the same local office through a similar repeating coil or transformer W_3 and through a trunk circuit or intermediate office L_3 (or series of trunk circuits or intermediate offices). The trunk circuit (or circuits) L_3 is generally required when the distance between one of the subscriber's sets, such as the one designated S_2, is outside the area served by the local office of another subscriber's set to which speech is to be transmitted in the usual way.

By interconnecting the repeating coil W_2 and the trunk circuit L_3, the two subscribers having the subsets S_1 and S_2 may converse with each other in the usual way. An operator may listen in on the conversation by connecting an operator's set or a telephone receiver across the interconnecting circuit as is well known. However, the operator will usually find that the volume of the speech signals received from the subset S_1 will be substantially greater than the volume of the signals received from the subset S_2 and that the greater the distance between the subscriber's set S_2 and the operator's set the greater will be the margin between the two signaling currents. If the latter distance is great enough, the speech currents coming from set S_2 may become only fairly audible or even entirely inaudible. Furthermore, room noise, etc., emanating from the subscriber's station S_1 will be quite audible and alone may overpower the currents arriving from set S_2. Such conditions make supervision difficult and ofttimes impossible. They also sometimes result in reports of service failures when there are in fact no such failures. If an amplifier were interposed between the operator's set and the interconnecting line, the low volume signals of the distanct set could be increased in amplitude to any desired level, but the signals coming from the nearby telephone set would also be increased in amplitude by the same amount and the extraordinarily high level of the latter signals together with the noise currents would still be intolerable. The present invention has been designed to overcome the effects of such conditions by the use of a so-called directional monitoring circuit which will now be described.

The directional monitoring circuit comprises two repeating coils or transformers W_4 and W_5, a receiver R_2 and a balancing network comprising two resistors Y_1 and Y_2 and a condenser C_2

connected in series with said resistors, together with another condenser C_3 connected across the resistor Y_2. The transformers W_4 and W_5 may be of similar construction, each including two windings having some suitable impedance ratio as, for example, about 40 to 1. The low impedance winding of the transformer W_4 is connected to one of the windings of the transformer W_2, as shown, while the high impedance winding of this transformer is bridged by the balancing network above referred to. The low impedance winding of the transformer W_5 is connected in series both with the receiver R_2 and the balancing network, as shown, while the high impedance winding of the latter transformer is connected to the low impedance winding of transformer W_4 and to one of the windings of transformer W_2.

Fig. 2 illustrates a schematic of the circuit arrangement shown in Fig. 1. Here the reference characters E_1 and E_2 represent the voltages generated at the transmitters of the subscribers' sets S_1 and S_2, respectively. Z_1 represents the impedance of the short line, that is, the loop L_1 together with the set S_1, and Z_2 likewise represents the impedance of the long line, that is, the trunk circuit L_3 and the loop L_2 together with the set S_2. The low and high impedance windings of the transformers W_4 and W_5 of Fig. 1 are designated X_A and X_B, respectively, in Fig. 2. The impedance of the observer's receiver is designated Z_3 and the balancing network Z_4.

It will be clear that when currents are transmitted from the set S_1 of Fig. 1 to the set S_2 and none are transmitted in the opposite direction from set S_2, the effect of generator E_2 of Fig. 2 may be neglected. Similarly, when currents originate at set S_2 of Fig. 1 and none at set S_1, the effect of generator E_1 may be neglected.

When currents are generated by both sources of electromotive force E_1 and E_2, currents designated I_1, I_2, I_3 and I_4 will flow through the four meshes indicated in Fig. 2. Four equations may be written for the voltages in these meshes, each equation representing the voltage conditions resulting from the flow of the four currents I_1—I_4. These equations are:

$$E_1=(Z_1+X_A+X_B)I_1 \quad (-X_B)I_2 \quad -(X_M)I_3 \quad -(X_M)I_4 \tag{1}$$

$$E_2=(-X_B)I_1 \quad +(Z_2+X_B)I_2 \quad +(X_M)I_3 \quad 0 \tag{2}$$

$$0=-(X_M)I_1 \quad +(X_M)I_2 \quad +(Z_3+X_A+Z_4)I_3 \quad +(Z_4)I_4 \tag{3}$$

$$0=-(X_M)I_1 \quad 0 \quad +(Z_4)I_3 \quad +(X_B+Z_4)I_4 \tag{4}$$

In these equations X_A and X_B are the impedances of the windings labeled X_A and X_B, respectively, in Fig. 2, and X_M is the mutual impedance between these two windings.

The current I_1 flowing through the nearby subscriber's set is given by the following determinant obtained from the simultaneous Equations 1 to 4:

$$I_1=\frac{A_1E_1-A_2E_2}{\Delta}=\frac{\begin{vmatrix} Z_2+X_B & +X_M & 0 \\ +X_M & Z_3+X_A+Z_4 & Z_4 \\ 0 & Z_4 & X_B+Z_4 \end{vmatrix} E_1-\begin{vmatrix} -X_B & -X_M & -X_M \\ +X_M & Z_3+X_A+Z_4 & Z_4 \\ 0 & Z_4 & X_B+Z_4 \end{vmatrix} E_2}{\begin{vmatrix} Z_1+X_A+X_B & -X_B & -X_M & -X_M \\ -X_B & Z_2+X_B & +X_M & 0 \\ -X_M & +X_M & Z_3+X_A+Z_4 & Z_4 \\ -X_M & 0 & Z_4 & X_B+Z_4 \end{vmatrix}} \tag{5}$$

in which A_1 and A_2 are minors of the values indicated in the expression at the right of the sign of equality and Δ (del) is the usual determinant denominator.

The currents I_2, I_3 and I_4 may be obtained from similar determinants, the general expressions of which are given as follows:

$$I_2=\frac{-B_1E_1+B_2E_2}{\Delta} \tag{6}$$

$$I_3=\frac{+C_1E_1-C_2E_2}{\Delta} \tag{7}$$

$$I_4=\frac{-D_1E_1+D_2E_2}{\Delta} \tag{8}$$

where the coefficients of E_1 and E_2 are corresponding minors of the determinants.

When transmitting current from the nearby transmitter T of set S_1 to the distant telephone set S_2, $E_2=0$, and the ratio of the power, expressed in db., available in the distant receiver to that at the receiver R_2 of the monitoring set D is as follows:

$$10\log\frac{P_2}{P_3}=20\log\frac{-B_1}{C_1}+10\log\frac{Z_2}{Z_3} \tag{9}$$

Likewise, when the distant set S_2 is transmitting current to the set S_1, the ratio of the power, expressed in db., available at the nearby receiver to that at the receiver R_2 is as follows:

$$10\log\frac{P_1}{P_3}=20\log\frac{A_2}{C_2}+10\log\frac{Z_1}{Z_3} \tag{10}$$

The foregoing equations generally define the transmission performance of the arrangement of this invention. The theoretical factors of these equations are supported by experimental proofs obtained from measurements made with circuits actually constructed in accordance with the invention.

The power loss Equation 9 can also be expressed as follows:

$$10\log\frac{P_2}{P_3}=20\log\frac{Z_3+Z_4}{Z_2-Z_4}+10\log\left(\frac{X_B}{X_A}\right)\frac{Z_2}{Z_3} \tag{11}$$

In deriving Equation 11 second order terms have been neglected. In the repeating coils or transformers W_4 and W_5, which were of the Western Electric 94G type, the ratio

$$\frac{X_A}{X_B}$$

is small and hence computations based upon Formula 11 are sufficiently accurate for practical purposes.

From Equation 11 it can be observed that when the impedance of the distant station equals the impedance of the balancing network, i. e., when $Z_2=Z_4$, the denominator of the second term of the equation becomes zero and the loss becomes very large (theoretically infinite). If $Z_4=0$, then Equation 11 may be resolved into the following equation:

$$10 \log\frac{P_2}{P_3}=10 \log\left(\frac{X_B}{X_A}\right)\frac{Z_3}{Z_2} \quad (12)$$

The loss expressed by Equation 12 is that which would be expected if but one repeating coil or transformer were employed for monitoring purposes as is the usual practice.

Thus it will be observed that a large loss will be obtained when $Z_2=Z_4$. When $Z_2\neq Z_4$, the discrimination will depend on the relative magnitudes of Z_2 and Z_4. Hence if additional means were provided for changing the effective values of either of these impedances, the amount of discrimination can be adjusted to any desired amount. As the match between impedances Z_2 and Z_4 becomes poorer, the discrimination will approach zero and the actual loss will approach that obtained with a single repeating coil bridged across the line as is the case in the usual monitoring system of the prior art.

When transmission is taking place in the opposite direction, i. e., from source E_2 to the nearby set of impedance Z_1, the voltage E_1 will be zero and the power loss in db. across Z_3 compared to that across Z_1 will be expressed by the following equation:

$$10 \log\frac{P_1}{P_3}=20 \log\frac{Z_3+Z_4}{Z_1+Z_4}+10 \log\left(\frac{X_B}{X_A}\right)\frac{Z_1}{Z_3} \quad (13)$$

If $Z_1=Z_3$, Equation 13 will be reduced to that for a single repeating coil bridged across the line and the loss will be independent of the value of Z_4. If $Z_1\neq Z_3$, however, then the loss will be changed and will depend on the difference in the magnitude of these two impedances.

The foregoing equations give the current, voltage and power conditions of the system involved in this invention. The operation of the system may now perhaps be better visualized from the circuit of Fig. 3.

Assume that the transformers W_4 and W_5 are equal in all respects and that they have a turn ratio of 1 to $\sqrt{40}$. If the circuit extending between the receiver impedance Z_3 and the balancing network impedance Z_4 is opened as at a and b, then the source of voltage of the nearby set having impedance Z_1 will cause a flow of current i_1 in the circuit, as indicated in the drawings. The voltage drop E_1 will divide between two impedances of magnitudes Z_2 and $Z_2/40$, in proportion to these magnitudes. The voltage across impedance Z_4 with the circuit still open at a and b will be

$$i_1\left(\frac{Z_2}{40}\right)\sqrt{40}$$

since $\sqrt{40}$ is the turn ratio of the transformer. The voltage across Z_4 will hence equal

$$\frac{i_1Z_2}{\sqrt{40}}$$

Furthermore, the voltage across impedance Z_2 will be i_1Z_2. Also, the voltage induced in the smaller winding of transformer W_5 will be

$$\frac{i_1Z_2}{\sqrt{40}}$$

If the contacts a and b are then closed, two equal and opposite voltages of magnitudes

$$\frac{i_1Z_2}{\sqrt{40}}$$

will be simultaneously impressed on the receiver impedance Z_3 and therefore no current will flow through the receiver element. In other words, the current obtained by actuating the transmitter of the nearby subset will produce practically no current in the receiver element Z_3.

When the distant transmitter is operating and applying a voltage E_2, the circuit conditions will be somewhat as shown in Fig. 4. Here the distant voltage E_2 generates a current i_2 in the circuit of impedance Z_1. This current will induce a voltage through transformer W_4 which is effective across the network Z_4 and is of a magnitude

$$\frac{i_2Z_4}{\sqrt{40}}$$

This current will also induce a voltage

$$(E_2-i_2Z_4)\frac{1}{\sqrt{40}}$$

which will appear across the terminals of the low impedance winding of transformer W_5. Hence, upon closure of contact a, a voltage will be impressed upon the receiver element Z_3 which is of a magnitude

$$E_2/\sqrt{40}$$

a value which is the difference of the two coacting voltages.

Thus the distant transmitter will cause a substantial voltage to be impressed upon the receiver element Z_3. The system therefore discriminates against the transmission from the nearby set.

Fig. 5 illustrates an arrangement for observing one or more subscribers' circuits as in the No. 4 service observing desk set well known in the art. The line extending to one of the subscribers is designated L_4 and L_5 and the line extending to a PBX or a central office is designated L_5 and L_6. The latter line may be connected to another subscriber's set as will be clearly understood.

By inserting the plug P into jack J, the operator may be apprised of the fact that the subscriber connected to the line L_4—L_5 has removed his receiver from its hook. Upon the removal of the receiver of this line from its hook, direct current will flow over a circuit extending from conductor L_4 through the tip contacts of jack J and plug P, then through contacts **11** and **12**, then through the winding of relay D_1 and over the sleeve contacts of plug P and jack J and then over conductor L_6. In other words, the line L_4—L_5 will then be connected to line L_5—L_6 through the winding of relay D_1 and the lamp M_1 will be illuminated to indicate to the operator that the circuit to be observed has been completed and is ready for observation.

When the lamp M_1 becomes illuminated, the operator may be connected to the subscriber's circuit for observing the circuit and this is accomplished merely by operating the key K. Upon the operation of key K, the conductor L_4 (of line L_4—L_5) will be connected to conductor L_6 (of line L_5—L_6) through the low impedance winding of transformer W_4. The interconnecting circuit includes conductor L_4, the tip contacts of jack J and plug P, contact **13** and armature **14** of key K, the low impedance winding of transformer W_4, armature **15** and contact **16** of key K, the winding of relay D_1, the sleeve contacts of plug P and jack J and conductor L_6. It will be observed that a rheostat Z_6 is bridged across the low impedance winding of transformer W_4. Also, the balancing network Y_1, Y_2, C_2 and C_3 is connected to the high impedance winding of transformer W_4.

The operation of key K also connects the high impedance winding of transformer W_5 across the lines L_4—L_5 and L_5—L_6. This circuit will include conductor L_6, the sleeve contacts of jack J and plug P, the winding of relay D_1, contacts **12** and **13** of key K, armature **15** of key K, the high impedance winding of transformer W_5, armature **17** and contact **18** of key K, condenser C_4, the ring contacts of plug P and jack J, contact **19** and armature **20** of jack J and conductor L_5. The line L_4—L_5 will have the low impedance winding of transformer W_5 in series therewith.

It will thus be observed that lines L_4—L_5 and L_5—L_6 are normally interconnected through the tip contact and contact **21** of jack J. The interconnecting line will, however, be modified to include the winding of relay D_2 immediately upon the insertion of plug P into jack J. Ringing current flowing over the interconnected line will then operate relay D_2, thereby illuminating lamp M_2. The lamp M_2 hence indicates that ringing current is flowing over the circuit. After the called party answers and removes the receiver from its hook, the relay D_1 will operate. The operator may then operate key K whenever desired to listen in on the circuit. The circuit provided by operating key K fully corresponds to the circuit of Fig. 2.

The rheostat Z_6 is first adjusted to a low and practically negligible value by the listening operator when operating key K. This will reduce the click heard by the subscriber. The operator's receiver is connected to the observing circuit through an amplifier A. This amplifier A is optional to the system. The rheostat Z_6 may then be adjusted to some suitable value to provide proper discrimination between the two speech volumes received at R_2.

The conductors **30**, **31** and **32** may be wired to other cord circuits to be monitored as is the practice with the No. 4 service observing desk set. One key, such as K, and its associated wiring would be provided for each monitoring position as will be understood by those skilled in the art.

The plug and jack arrangements shown in Fig. 5 may be replaced, if desired, by plugs of the usual types at the main frame which are inserted in place of heat coils. It will be understood that relays may be used in place of keys of the kind shown in Fig. 5 to provide suitable connections to the particular lines to be monitored.

The monitoring set disclosed may not only be utilized to equalize the volumes of the signals from two subscribers connected to the monitoring set, but it is equally useful to equalize the volumes of signals received from two operators, or from an operator and subscriber, or any two such sources whatever.

The arrangement disclosed herein may be balanced to ground against longitudinal currents if so desired. This could be done by so arranging transformer W_4, for example, that one-half of its low impedance winding will be in series with one side of the interconnected line and the other half in series with the other side of the line.

While this invention has been shown and described in certain particular arrangements merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. Apparatus for monitoring a circuit interconnecting two telephone substation sets, comprising two transformers each having low and high impedance windings, the low impedance winding of one of the transformers being connected in series with the two telephone substation sets and the high impedance winding of the other transformer being connected in shunt across the interconnecting circuit, a balancing network connected across the high impedance winding of the first-mentioned transformer, the operator's receiver being connected in series with the low impedance winding of the second-mentioned transformer and the balancing network.

2. A system for monitoring a telephone circuit so that the volumes of the signals transmitted in opposite directions over said telephone circuit will be substantially equalized, comprising a coil connected in series with the telephone circuit, a second coil connected in shunt across the telephone circuit, a balancing network bridged across the series coil, and a monitoring receiver interconnecting the shunt coil and the balancing network.

3. A directional monitoring system for a circuit interconnecting two telephone sets, comprising a first transformer, one of the windings of which is connected in series with the interconnecting circuit, a second transformer, one of the windings of which is connected in shunt across the interconnecting circuit, a balancing network bridging the other winding of the first-mentioned transformer, and a receiver interconnecting the other winding of the second transformer and the balancing network.

4. Apparatus for monitoring a circuit interconnecting two telephone sets for equalizing the volume of the signals received from the two sets, comprising first and second transformers, one of the windings of the first transformer and one of the windings of the second transformer being connected in series and in shunt, respectively, with the interconnecting circuit, a balancing network bridging the other winding of the first transformer, and a receiver interconnecting the other winding of the transformer with the balancing network, the balancing network including elements of capacitance and resistance.

5. The combination of two telephone substation sets, a circuit interconnecting said two sets, first and second transformers, one of the windings of the first transformer being in series in the interconnecting circuit, a rheostat bridging said series winding of the first transformer, a balancing network bridging the other winding of the first transformer, one of the windings of the second transformer bridging the interconnecting circuit, a monitoring receiver, the other winding of the second transformer being connected to the balancing network through the monitoring receiver, the balancing network including a plurality of impedance elements.

6. The combination of two telephone sets, a first coil connected in series with the two sets, a rheostat bridging said coil, a second coil connected in shunt across the circuit interconnecting said sets, a third coil coupled to the first coil, a receiver, a fourth coil coupled to the second coil and connected through the receiver to the third

coil, and an impedance network shunting the third coil.

7. The combination of two telephone sets, a long circuit interconnecting said sets, means for monitoring the signals transmitted over the circuit, said monitoring means comprising first and second transformers, one of the windings of the first transformer and one of the windings of the second transformer being connected, respectively, in series and in shunt with the interconnecting circuit, a balancing network shunted across the second winding of the first transformer, and a monitoring receiver interconnecting the other winding of the second transformer with the balancing network.

8. Apparatus for monitoring a long circuit interconnecting two telephone sets at any point along the circuit, comprising first and second transformers, one of the windings of the first transformer and one of the windings of the second transformer being connected, respectively, in series and in shunt across the long circuit, a balancing network, a rheostat, said balancing network and said rheostat being independently connected across the first winding of the first transformer, an amplifier, and a receiver connected to the output circuit of the amplifier, the input circuit of the amplifier interconnecting the second winding of the second transformer with the balancing network.

9. A system for monitoring a long telephone circuit at any point along the circuit comprising a first coil connected in series with the telephone circuit, a second coil connected in shunt across the telephone circuit, a balancing network connected in shunt across the first coil, a monitoring receiver, an amplifier the input circuit of which interconnects the second coil with the balancing network, and a monitoring receiver connected to the output circuit of the amplifier.

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