March 26, 1935. R. N. HUNTER 1,995,454

APPARATUS AND METHOD FOR REMEDYING CROSS TALK

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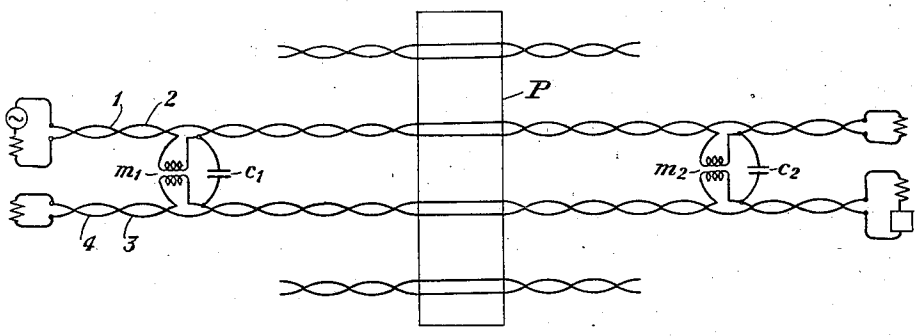
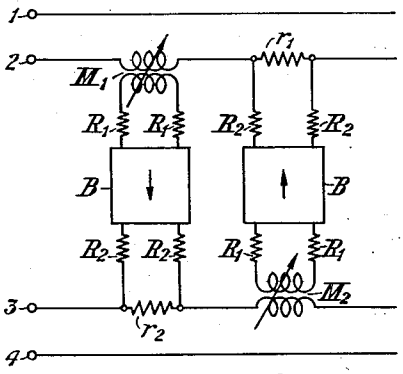
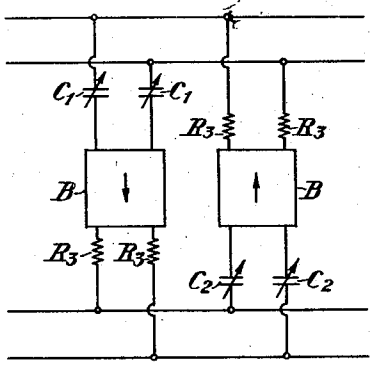


Fig. 1



Mutual Inductance Balancing

Fig. 2



Capacity Balancing

Fig. 3

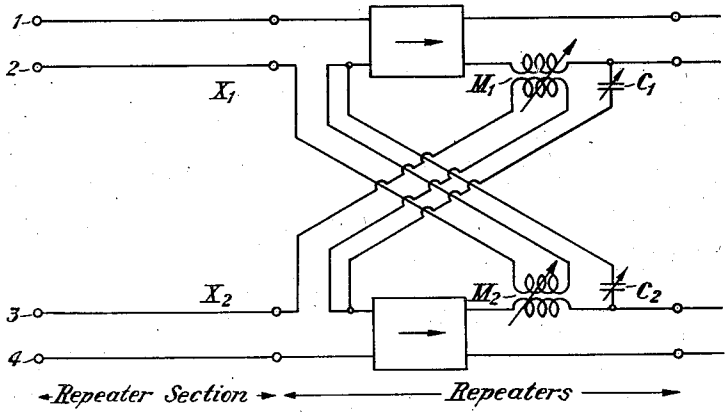


Fig. 4

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APPARATUS AND METHOD FOR REMEDYING CROSS TALK

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8 Claims. (Cl. 179—78)

An object of my invention is to provide a method and suitable apparatus for eliminating crosstalk in signaling circuits. Another object is to correct for crosstalk in a system of transmission lines existing side by side. Other objects are to provide a system of transmission lines with connections across between any two of them, to correct for crosstalk both ways. Still another object is to provide crosstalk correcting means from one pair to another that is effective only in one of the two ways between the two pairs. Still another object is to provide crosstalk correcting means between two pairs that is independently adjustable to correct from the first pair to the second, and from the second to the first. All of these objects, and various other objects and advantages of my invention, will become apparent in connection with the following disclosure of a limited number of specific examples of practice according to the invention which I have chosen to be presented in this specification. It will be understood that this disclosure has relation more especially to these particular examples of the invention, and that the scope of the invention will be indicated in the appended claims.

Referring to the drawing, Figure 1 is a diagram of a transmission system in which my invention may be embodied; Fig. 2 is a diagram showing two opposite one-way mutual inductance balancing connections between two conductor pairs; Fig. 3 is a similar diagram, except that the connections involve capacity instead of mutual inductance, and Fig. 4 is a diagram showing similar connections associated with the regular line repeaters on the two pairs.

When two signaling circuits extend close together the existence of signaling currents in one circuit may have a tendency to set up corresponding currents in the other circuit; this phenomenon is called "crosstalk". The currents in one circuit may act to produce currents in the other circuit by mutual inductance between the two circuits, or by mutual capacity, or both. The objectionable phenomenon may occur when two circuits extend side by side, each in the form of a conductor pair with one and the same cable or each in the form of an open wire line both on the same row of poles. To obviate this tendency, as in a cable, the two conductors of each pair are commonly twisted together so that the inductance and capacity effects on one conductor pair on neighboring pairs are for the most part balanced out. In open wire lines the conductors of each pair are systematically transposed so that the influence upon neighboring pairs, and the influence from them, are for the most part balanced out. However, in many cases of long transmission lines, either in cables or in open wire lines, in spite of the twisting or transposing of the conductors, there will be some accidental dissymmetries and, therefore, some degree of crosstalk between one circuit and another, unless further corrective adjustment is made. In one aspect my invention relates to making compensating adjustments to remedy the crosstalk between the neighboring circuits of long cables or multiple open wire lines, and more particularly, to cases in which different adjustments are required to compensate the crosstalk one way as between two circuits and the crosstalk the opposite way between them.

To illustrate the nature of my invention, I will now describe the apparatus and the procedure for correcting crosstalk between two representative conductor pairs of a long cable. Referring to Fig. 1, this shows several conductor pairs or circuits in a cable which may be, say 25 miles long. At each end there may be repeaters and further 25 mile cable lengths extending therefrom. By the twisting of each conductor pair in the 25 mile length of cable, most of the mutual inductance and mutual capacity between any two circuits will be canceled out. However, there will sometimes be a little unbalanced mutual inductance effect between the circuits at a certain location along their length which may be represented as m_1 in Fig. 1, and likewise, at such a place, there may be a little unbalanced mutual capacity between the two circuits represented by c_1. Whereas, the couplings represented by m_1 and c_1 are toward the left as viewed in Fig. 1, there may be such couplings anywhere along the length of the cable as represented by m_2 and c_2 at the right. Assuming that signaling currents are transmitted from the left on the upper circuit, these couplings, m_1, c_1, m_2 and c_2, will give rise to a small degree of corresponding currents induced in the lower circuit, which will become effective as crosstalk at the right-hand end of the lower circuit. The magnitude of these received crosstalk currents will depend on the net resultant effect of the inductances m_1 and m_2 and the capacities c_1 and c_2. It may be assumed that the two circuits are terminated each in its characteristic impedance, but, in the present case, it is not necessarily assumed that the two circuits are alike, and if they are essentially dif-

ferent the net overall crosstalk effect from the first circuit into the second, may be different from what it is from the second to the first.

At a convenient place along the line a panel for adjusting elements is provided such as P in Fig. 1, and on this panel reactance elements are mounted and connected from one side of one pair to a side of the other pair so as to compensate the crosstalk. If the uncompensated coupling, such as shown by the *m*'s and the *c*'s in Fig. 1, is a mutual inductance coupling, it will require an opposite mutual inductance balancing on the panel P. The appropriate connections are shown in Fig. 2. Each of the symbolic elements B is a one-way device such as a two-electrode vacuum tube that permits currents to flow only in the direction of the respective arrow. To compensate for the resultant inductive coupling from the pair 1—2 to the pair 3—4 the mutual inductive connection M_1 is provided with connection to the appropriate side of each pair to provide the necessary compensation. It is, of course, necessary that proper phase relations of the various currents shall be maintained. For this purpose the resistances represented by R_1 and R_2 should be high compared to the other impedances in the circuits in which they are shown, so that the currents will be nearly in phase with the voltages in these circuits. The resistances r_1 and r_2 should be small so as to avoid introducing considerable impedance in the transmission path. The primary windings of the transformers M_1 and M_2 have few turns so that, if there were no secondaries associated with them, they would offer only slight impedances in the respective lines. The resistances R_1 are of considerable value so that the condition of low impedance in each line for the primaries standing alone is little changed by bringing the respective secondaries in association therewith.

It will be seen that there are two connections in Fig. 2 in opposite directions and quite independent of one another by virtue of the respective opposite one-way devices B interposed in each connection.

If the overall unbalance between the two lines is a capacity effect, then it will require capacity compensation which may be provided as shown in Fig. 3. The values of the capacities C_1 and C_2 should be small in order that the current and voltage of the circuit in which they occur shall be nearly in quadrature. While it is not necessary, it may be feasible and convenient to make the resistances R_3 of Fig. 3 of the same value as the resistances R_1 and R_2 (which may be of equal value) in Fig. 2. The blocking or one-way devices B should introduce negligible phase shift in Fig. 2 and in Fig. 3. For more precise balancing it may be desirable to employ the connections of Fig. 2 and of Fig. 3 simultaneously.

The location of the panel P along the section between the repeaters represented in Fig. 1, may be at any convenient place. There may be a certain advantage in having it halfway between the repeater stations, for if there are impedance irregularities at the ends of the section their disturbing effect may be somewhat less with the balancing panel at this location than if it were at an end of the section.

The balancing cross-connections may be established at a repeater station without necessitating the use of extra one-way devices such as the B's in Figs. 2 and 3. This alternative scheme is indicated in the diagram of Fig. 4 where the coils M_1 and M_2 and the condensers C_1 and C_2 are connected diagonally across, as shown. Adjustments of these connected elements may be made to reduce the crosstalk in the preceding repeater section, that is, the section lying to the left, as viewed in Fig. 4. This method of connection shown in Fig. 4 is not purely one-way between the pair 1—2 and the pair 3—4, but the crosstalk coupling caused by the connections M_1 and C_1 from the pair 1—2 to the pair 3—4 will exceed, by the sum of the gains of the two repeaters, the coupling through the same elements from the pair 3—4 to the pair 1—2. Accordingly, unless the repeater gains are exceptionally low this coupling M_1—C_1 may be regarded as substantially one-way; that is, from the pair 1—2 to the pair 3—4. In case the repeater gains should be so low that the effect could not be said to be substantially one-way, loss pads could be introduced as at X_1 and X_2 and the repeater gains increased so that the substantial one-way effect would be established.

Just as the coupling elements M_1 and C_1 compensate for crosstalk from the pair 1—2 into the pair 3—4, so the elements M_2 and C_2 compensate for the crosstalk from 3—4 into 1—2. This method requires that the gains in the repeaters shall be approximately constant, but not necessarily equal. It also requires that the phase shift in the repeaters shall be small; or, if it is not small, it should at least be constant so that allowance for it may be made by the proper choice of balancing units. As in the case discussed in connection with Figs. 2 and 3, the impedances of the two coils of M_1 or M_2 should be small, and the values of the capacities C_1 and C_2 should be small. In practice, these values will necessarily be small because the crosstalk coupling which they introduce will be amplified by the gain of one repeater.

The methods that have been described in connection with Figs. 2 and 3, and in connection with Fig. 4, are not limited to the mutual inductance and capacity balancing units shown in those figures. Resistances may be combined with either the capacity units or the mutual inductance units to produce desired phase shifts, or more complicated networks may be made up to fit cases where the crosstalk varies in a less simple relation with frequency than has been assumed.

The one-way devices B of Figs. 2 and 3 may be ordinary one-way repeaters, but they need not provide amplification since their only purpose is to block currents in one of the two opposite directions. Repeaters with negative feedback may be suitable for this purpose, being adjusted to give considerable loss and to be very stable under such conditions.

What is claimed is:

1. Means for neutralizing crosstalk effects between two dissimilar conductor pairs comprising a connection from one side of one pair to one side of the other pair, an impedance element in that connection and a one-way device also comprised in that connection.

2. Means for neutralizing crosstalk effects between two dissimilar conductor pairs comprising two connections from one side of one pair to one side of the other pair, respective impedance elements in those connections and respective opposite one-way devices also comprised in those connections.

3. A plurality of dissimilar conductor pairs extending side by side, and means located at a point along their length and connected across between

conductors of certain pairs and conductors of certain other pairs to neutralize the crosstalk between those pairs, said means comprising a one-way device so that the neutralization shall be only one way through such device.

4. A plurality of conductor pairs extending together along a certain length, reactance elements located at a point along that length and each connected across between a conductor of one pair and a conductor of another pair to neutralize the crosstalk between such pairs, and one-way devices associated with said reactance elements so that the neutralization shall be only one way therethrough from pair to pair.

5. At a repeater station, lines and respective repeaters, means for compensating crosstalk from one line to another comprising a connection from the output side of the repeater of the one line to the input side of the repeater of the other line and an adjustable impedance element in said connection.

6. At a repeater station, lines and respective repeaters, means for compensating crosstalk from one line to another comprising a connection from the output side of each of two repeaters to the input side of the other of those repeaters, and adjustable impedance elements in those connections.

7. Means for neutralizing crosstalk effects between two dissimilar conductor pairs comprising a connection from one side of one pair to one side of the other pair, an impedance element in that connection, and means to make the effect therethrough greater from one pair to the other than from the other to the one.

8. Means for neutralizing crosstalk effects between two dissimilar conductor pairs comprising two connections from one side of one pair to one side of the other pair, respective impedance elements in those connections and means to make the effect through each connection greater one way therethrough than the opposite way therethrough, these directions of greater effect being opposite in the two connections.

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