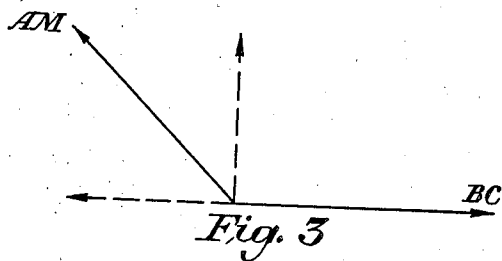
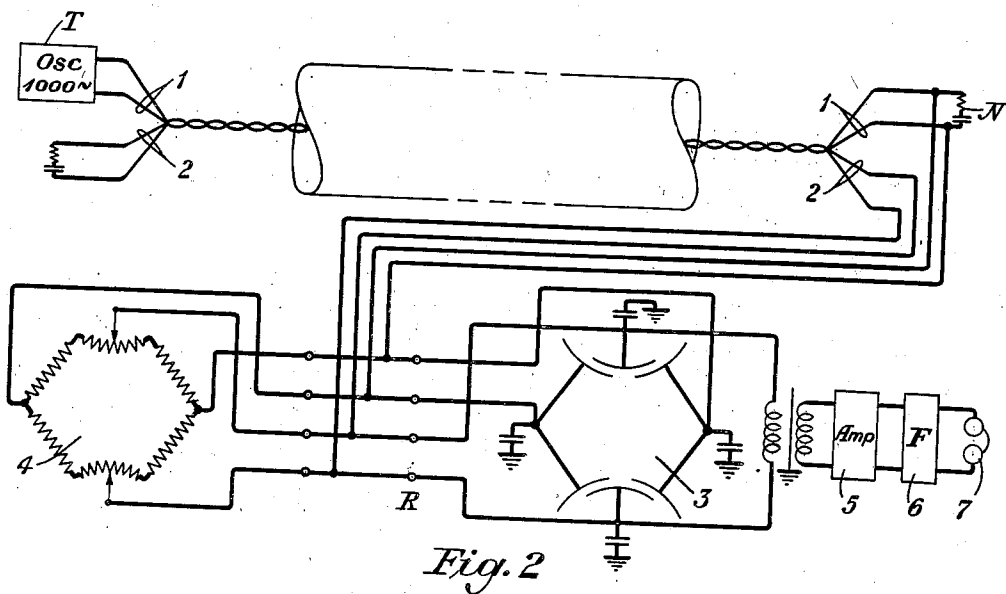
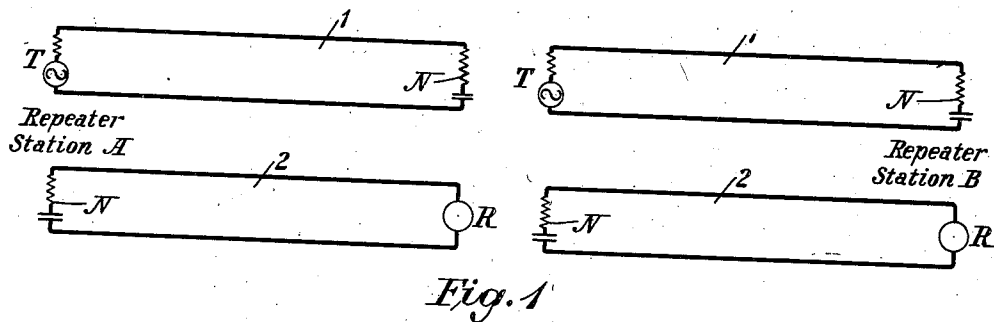


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CROSS-TALK REDUCTION
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CROSS-TALK REDUCTION

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5 Claims. (Cl. 179—78)

This invention relates to reduction of cross-talk in telephone systems and particularly to such reduction in carrier current systems.

5 Cross-talk is commonly considered as being due to electrostatic and electromagnetic couplings between two or more of the talking circuits of such systems. In open-wire circuits both are present and their effects may be to a large extent balanced out by systematic transpositions following one plan or another. In cables used for long distance telephone circuits it has been the common practice to twist the wires in groups of four, constituting a quad of two pairs. Since such cables may contain as many as 150 quads or more, it would be impracticable to devise systematic transposition plans of sufficient effectiveness because of the large number of circuits involved and because the spacing between wires of the pairs, etc., is necessarily much less uniform than it is for open-wire circuits. The method of twisting the wires of the pairs in the manufacture of the cable is, of course, a form of transposing. This twisting is such that the interval between twists for one pair may be different from that for another pair in the same quad or for a pair in an adjacent quad in the same layer. Furthermore, the twist lengths for pairs in one layer may differ from those for pairs in an adjacent layer. When such cables are used for voice-frequency circuits, it has been found heretofore that the cross-talk between quads may be greatly reduced as a result of (1) this twisting, (2) the splicing together of successive lengths of the cable in such manner that the quads adjacent in one length are not adjacent in the second length, and (3) the segregation of different circuits into separate parts of the cable, such as placing east-bound circuits in the center of the cable and west-bound circuits in the outer layers.

50 The circuits within a quad in the voice-frequency case consist of the "side circuits" on each pair and the superposed "phantom circuit". While twisting is of material benefit in reducing the within-quad cross-talk, it alone is not sufficiently effective. Separation of the circuits within a quad similar to that used for circuits in different quads is obviously impossible. It has been found, however, that in the voice-frequency case sufficient additional reduction in the within-quad cross-talk to meet commercial requirements can be obtained by capacitance unbalance test-splicing, i. e., by splicing each two successive sections in such manner that the within-quad electro-

static couplings in the two sections tend to neutralize each other.

If, instead of using the cable for voice-frequency circuits transmitting up to about 4000 cycles, the cable were to be used for carrier telephone signaling operating over a range from about 12,000 to 60,000 cycles, the cross-talk would be higher than permissible since cross-talk increases directly as the frequency, assuming that no change is made in the impedance of the circuits. To obtain satisfactory cross-talk conditions under carrier-frequency operation the addition of supplemental capacitances or inductances, or both, to balance out the cross-talk, might be resorted to, as described in the patent to Chapman 1,863,651, issued June 21, 1932, and the patent to Weaver 2,080,217, issued May 11, 1937.

As would be expected, measurements made before the addition of supplemental balancing units have shown that the within-quad cross-talk is considerably larger than the between-quad cross-talk. Larger balancing units would be required, therefore, for the reduction of within-quad cross-talk than for between-quad cross-talk. It is somewhat undesirable practically to have two sizes of balancing units. The use of a large unit of the inductance type on all combinations (between-quad as well as within-quad) is undesirable because the self-inductance as well as the mutual inductance of such coils, and, consequently, the attenuation of the coils, would be greater. Since the impedance looking into the balancing panel at any point should be fairly close to the characteristic impedance of the cable to which the balancing panel is connected, in order that undue reflection effects will not occur, large units mean greater complications in neutralizing the self-inductance of the coils by means of capacitance.

An object of the invention is to reduce the effects of cross-talk in high frequency telephone systems, particularly cable carrier telephone systems, while avoiding the above-mentioned difficulties.

In accordance with one modification of the invention, cross-talk reduction is obtained in systems of the above-described type, employing a unit of smaller size for balancing both within-quad and between-quad cross-talk by "splitting" the quads, i. e., one pair of a quad in one length is spliced to a pair in a quad in a second length and the other pair of the first quad is spliced to a pair in a different quad in the second length. This would be particularly effective in the carrier case where it is planned to use side circuits

only and not the phantoms. Such splitting would have the effect of diluting the side-to-side cross-talk among all the circuits, reducing the cross-talk for the former side-to-side combinations and increasing the cross-talk for the former between-quad combinations (pair-to-pair). An experimental trial indicated that this method was fairly successful, but that some combinations might result in cross-talk of such value as to necessitate the use of larger balancing units than the general run to obtain the desired reduction, and furthermore that the size of the general run of the units would have to be fairly large.

The latter difficulties are avoided in the preferred form of the invention which may be briefly described as follows: In this method, the quads are not split but are carried through as quads for an entire carrier repeater section. The quads are divided into two substantially equal sections at a mid-point between two repeater stations. The quads in the second half of a repeater section are then "cross-talk-poled" with those in the first half, i. e., the quads in the second half are so connected to those in the first half that they act in effect as cross-talk balancing units for the quads in the first half. The quads to be connected together and the manner of connection is determined from measurements at a chosen frequency of the electromagnetic cross-talk in the half-sections in the manner to be described below. This poling is done for the purpose of reducing the electromagnetic cross-talk since it is the more important in the carrier use of the cable as outlined below, and, incidentally, the electrostatic cross-talk is reduced to some extent by the test-splicing referred to above. When the cable circuits are used on a voice-frequency basis it is customary to load the circuits in order to reduce the attenuation. As a result of loading the characteristic impedance of the circuit is increased, which reduces the electromagnetic cross-talk from one circuit to another and increases the electrostatic cross-talk. When using circuits in the cable on a carrier basis up to 60,000 cycles it becomes necessary to remove the loading coils, in which case the characteristic impedance of the circuit is substantially reduced. This increases the effect of the electromagnetic couplings, since the current flowing in a circuit for a given impressed electromotive force is increased, to a point where it becomes the dominant factor as shown by actual measurements.

The invention will be better understood by reference to the following specification and the accompanying drawing in which:

Fig. 1 illustrates diagrammatically the method of obtaining the measurements used in the poling method of the invention;

Fig. 2 illustrates in greater detail the circuit arrangements and apparatus which may be used for taking measurements of far end cross-talk between the two pairs in a quad in the method of the invention; and

Fig. 3 is a vector diagram of cross-talk effects to be used in an explanation of my invention.

The manner of making the cross-talk measurements used in the poling method of the invention is illustrated diagrammatically in Fig. 1, and some of the apparatus which may be used for this purpose is illustrated in more detail in Fig. 2.

As indicated in Fig. 1, the side circuits 1 and 2 forming each quad in a repeater section of cable are divided at a mid-point into two approximately equal lengths. To measure the far end cross-

talk in the half-section between repeater station A and the mid-point, at station A a source T of a chosen test frequency is connected to side 1 and a terminating network N to side 2, and at the section mid-point a terminating network N is connected to side 1 and a suitable measuring apparatus R to side 2. Similarly to measure the far end cross-talk in the half-section between the mid-point and repeater station B, at the mid-point, the source T of test frequency is connected to side 1 and the network N to side 2, and at repeater station B the terminating network N is connected to side 1 and the measuring apparatus to side 2. To keep the reflected near end cross-talk to a minimum, the impedance networks N should simulate the characteristic impedance of the cable as closely as practicable. As indicated, this impedance may consist of a condenser and resistance of the proper values in series. The side-to-side unbalance at the test frequency for the two half-sections will be measured by the measuring apparatus R.

A mutual inductance bridge may be used for measuring the electromagnetic or mutual inductance couplings giving a measure of the cross-talk, but I prefer to use an admittance unbalance measuring set. This set, as indicated, may consist of a well-known capacity unbalance bridge 3 and a bridge 4 comprising four fixed resistances and two slide-wire potentiometers, connected to each other, as indicated, so as to provide in effect a single bridge circuit comprising a calibrated variable resistance shunted by a calibrated variable condenser in each of the four bridge arms. In addition, the measuring apparatus R comprises, connected to the output of the bridge, an amplifier 5 to raise the volume of the testing tone to compensate for the attenuation introduced in transmission over the half-section, a filter 6 for eliminating noise above and below the measuring frequency and a standard telephone receiver 7. When making a cross-talk measurement with the bridge the variable condensers in bridge 3 and the variable resistances in bridge 4 are adjusted until the cross-talk is balanced out, indicated when the testing tone is no longer heard in the telephone receiver 7. If desirable, the cross-talk in phase and magnitude can be computed from the readings of the resistance dial and of the condenser dial.

The resistance dial setting is a measure of that part of the inductance component of the cross-talk which is at right angles to the capacitance component and the condenser dial setting is a measure of the capacitance component plus the "in-phase" portion of the inductance component. This is made more clear by reference to Fig. 3. Let M stand for mutual inductance and C for mutual capacitance between the two circuits under measurement. Then if A and B are suitable proportionality constants, AM indicates the total cross-talk current due to mutual inductance coupling and BC indicates the total cross-talk current due to capacity coupling. It will be evident that the vector AM may be resolved into two components, one in phase with BC and the other at right angles to it. The resultant of the two "in-phase" components may be an inductance current or a capacitance current, usually the latter. This resultant is measured by the condenser dial setting while the component at right angles thereto, which is due entirely to the mutual inductance coupling, is measured by the resistance dial setting, this for the reason that the electromagnetic com-

ponent is 90 degrees out of phase with the electrostatic component at low frequencies. It will be observed that the component shown as vertical in Fig. 3 is proportional to the mutual inductance unbalance and so may be taken as a measure thereof. This mutual inductance unbalance component, being measured as 90 degrees out of phase with the capacity unbalance, from one point of view, may be looked upon as a conductance unbalance. Strictly speaking, it is not a conductance effect and so in the specification and claims the term "equivalent conductance unbalance" is, at times, used to indicate that portion of the mutual inductance unbalance measured by the resistance setting of the bridge.

The question arises as to the frequency at which measurements with the unbalance bridge should be made. Since the signaling is to be conducted at carrier frequencies, which may range from about 12,000 to 60,000 cycles, it would appear that the measurements should be taken at some frequency or frequencies within that band and this I find to be satisfactory. On the other hand, as the result of numerous experiments, I find that the conclusion to be arrived at by taking measurements at a frequency of about 1,000 cycles leads to substantially the same results as to the quads to be spliced and in view of the greater convenience and flexibility of making measurements at such a low frequency, I prefer to use some such low frequency.

The complete method or plan for carrying out the actual side-to-side cross-poling operation consists of the following:

1. The repeater section of cable is divided into two approximately equal lengths.

2. The far end cross-talk at 1,000 cycles in the first half-section is measured in phase and magnitude by means of an admittance unbalance bridge, sending at the repeater station and receiving at the mid-point. This measurement is made for each and all of the quads of interest.

3. Similarly the far end cross-talk at 1,000 cycles is measured in the second half-section, sending at the mid-point and receiving at the second repeater station.

4. The quads to be connected together are selected on the basis of the magnitudes of the resistance dial readings of the admittance unbalance bridge, that is, the quad with the maximum reading in the first section will be selected for splicing to the quad with the maximum reading in the second section, next highest to next highest, etc. In addition, the manner in which the pairs of the quads are to be connected together or poled must be determined. If the dial readings have the same sign, one pair must be transposed with respect to the other.

5. After the quads have been connected together in accordance with the above, a check to determine whether mistakes have been made can be obtained by bridge measurements at 1,000 cycles over the complete repeater section, sending at the first repeater station and receiving at the second repeater station.

While the poling has been described as being determined on the basis of the resistance dial readings, there will be occasional cases where these readings will be relatively small and the capacitance readings will be quite high. In this event it may be desirable to splice two sections in such a manner as to balance out the capacitance effects. There will also be occasions when a quad with a large resistance setting of one sign may be paired against either of two quads

of substantially equal resistance settings. In this event that quad of the two should be used which will result in the most effective canceling or neutralization of the mutual capacitance unbalance.

The reduction in the side-to-side cross-talk due to the poling steps defined above may not be sufficient to meet cross-talk requirements. It would be necessary in such cases to obtain additional reduction by means of balancing units by the methods described in the Chapman and in the Weaver patents referred to above, but the magnitude which must be given to these balancing units is kept to a substantially lower value than would otherwise be necessary, thus avoiding the complications referred to above which result from large balancing units.

While the bridge which has been described as suitable for measurements is one in which the arms consist of capacitance and resistance in parallel, it should be pointed out that a measuring set consisting of mutual inductance and capacitance could be used. With a properly designed set of this type a measure of the total inductance unbalance instead of the component of that unbalance which is at right angles to the capacitance unbalance could be obtained. In some instances such a bridge would be preferable but in most practical work the one specifically described has the advantage of greater flexibility, convenience and simplicity.

While this invention has been described quite specifically in terms of a special type of circuit, this has been for the purpose of greater clarity but it is to be understood that it is applicable to other types of circuits and to the reduction of pair-to-pair across-talk as well as side-to-side cross-talk.

What is claimed is:

1. The method of reducing cross-talk in a high frequency signaling cable comprising a plurality of two-pair quads, which consists in dividing the quads in each section of cable into two portions of approximately equal length, and splicing the quads in the first half of each section to the quads of the second half of the section on the basis of nearest equivalence in magnitude of measured far-end equivalent conductance unbalances between the pairs in each quad for the two half-sections, with or without transposition of pairs, depending on whether the unbalances of the quads in the two half-sections to be spliced together are of like or opposite phase, whereby the quads in each half of each section of cable serve to balance the far-end cross-talk unbalances within the quads of the other half-section of cable.

2. The method of reducing cross-talk in a repeated cable employed for high frequency signaling and comprising a plurality of two-pair quads, which consists in dividing each repeater section of said cable into two portions of approximately equal length, measuring the far-end equivalent conductance unbalances between the pairs in each quad of both half sections at a selected test frequency, selecting on the basis of these measurements and splicing together the pairs in the quads of the two half-sections having conductance unbalances nearest in magnitude with transposition of the pairs in the quads in the two half-sections spliced together if the measured unbalances therein are of like phase, and neutralizing the residual cross-talk in the cable by reactance elements of suitable value connected between the conductor pairs.

3. The method of reducing cross-talk in a re-

- peatered signaling cable comprising a plurality of two-pair quads used for carrier frequency signaling, which consists in dividing the cable in each repeater section into two portions of approximately equal length, measuring at a selected test frequency the far-end equivalent conductance and capacitance unbalances in magnitude and phase between the pairs of each quad in the first half-section, measuring at the same test frequency the far-end equivalent conductance and capacitance unbalances between the pairs of each quad in the second half-section, and selecting from these measurements and splicing together the pairs of the quads in the respective half-sections having conductance unbalances of the nearest equivalent magnitude and capacitance unbalances within tolerable limits, the pairs in the quads being spliced with transpositions if the measured conductance unbalances therein are of like phase.
4. The method of cross-talk reduction in a high frequency communication cable comprising

a plurality of pairs which consists in dividing the cable at or near its mid-point into two sections, measuring the far-end mutual inductance unbalance between pair and pair in each of the sections, and splicing together pairs in the respective sections having inductance unbalance of opposite phase and of nearest equivalent magnitude.

5. The method of reducing cross-talk in a high frequency signaling cable comprising a plurality of two-pair quads, which consists in dividing the cable into a plurality of sections, splicing each pair of a quad in each section to a pair in a different quad in a succeeding section, so as to dilute the cross-talk between all the pair-to-pair combinations, and connecting supplemental reactance elements of suitable values between the pairs within each quad and between the pairs of different quads to neutralize the residual cross-talk in each section of the cable.

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