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M. A. WEAVER

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CROSS TALK REDUCTION

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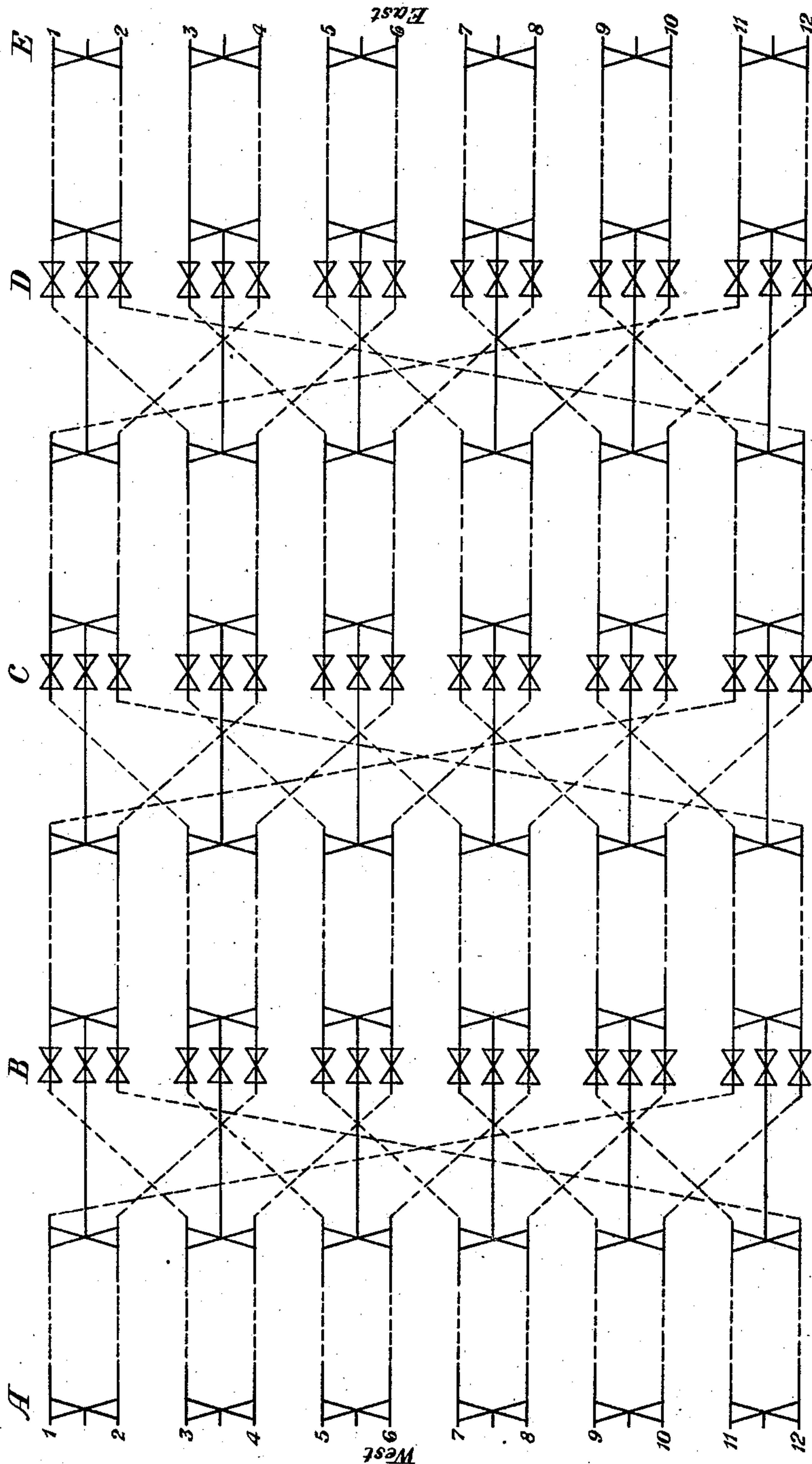


Fig. 1

Phantom Equipment:
Side 1
Phantom
Side 2
Fig. 1a

Two-wire Repeater

Fig. 1b

INVENTOR
M.A. Weaver
BY
J. H. 102
ATTORNEY

UNITED STATES PATENT OFFICE

MYRON A. WEAVER, OF RYE, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

CROSS-TALK REDUCTION

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This invention relates to a method and means for reducing crosstalk between telephone circuits, particularly telephone circuits in cable.

5 In cable circuits the conductors are arranged in groups of four called a squad. Each group of four conductors serves for carrying three ordinary telephone conversations, one pair of conductors forming one so-called side circuit, the other pair forming another so-called side circuit and the conductors of each pair when connected in parallel forming one side of a so-called phantom circuit. From the standpoint of crosstalk, it is desirable to reduce as far as practicable the number of sections of cable between repeater points in which any two of these circuits are carried in the same cable quad. For example, if two cable circuits, say one phantom and one side circuit, are routed over the conductors of the same quad though the entire system from end to end, the crosstalk from one end to the other, due to their adjacent relation, is augmented in each repeater section and will be obviously much greater than if the same two circuits are only routed over the conductors of the same quad through one repeater section. If the two circuits in question have their connections shifted at each repeater point so that a given one of the circuits will only be related to the other in close crosstalk relation throughout one repeater section, and throughout each successive repeater section is related to entirely different circuits in the same cable, the crosstalk in the first circuit will be relatively small from each of the other circuits with which it is related. While the total crosstalk may be as great as though the circuits were routed in the same relation throughout the entire system, it will be made up of a number of small components from a number of different circuits so that the resultant crosstalk is not intelligible but is in the nature of unintelligible noise.

10 If all of the circuits are treated in this manner any particular circuit will no longer receive crosstalk in a large number of repeater sections from any given circuit in the same quad with it, but will receive crosstalk

from many circuits any one of which is in the same quad with it for only one repeater section. The crosstalk overheard in each circuit will then consist of a multiplicity of relatively weak conversations, and the chance of understanding any one conversation taking place on another circuit will be much reduced.

The method of cross-connecting the circuits in accordance with the present invention results in an approach to the desirable condition of equal and very small crosstalk from all of the circuits in the cable into any one circuit. Observations on circuits arranged in accordance with the present invention have shown that a condition is approached where there is practically no intelligent crosstalk but simply unintelligible noise. The system has in addition to the advantages above outlined the further advantage that the inter-connection of the circuits at the repeater stations gives a considerable reduction in the ratio between maximum and average noise (including crosstalk effects). In other words, considering a group of circuits, the noisiest circuit of the group will not be considerably noisier than the average for the whole group.

In shifting the connections at the repeater point in a manner to accomplish the results above outlined, it is, of course, necessary to use the best methods known in the art in construction, installation and maintenance, for the purpose of limiting the maximum values of crosstalk between the side circuits and between the phantom and side circuits of each quad in a single repeater section. Furthermore, the best methods known in the art must be used to limit the maximum values of crosstalk between circuits of different quads in the same repeater section. In short, the method and arrangement of the present invention are intended to supplement the best known practices of the art from the standpoint of reducing crosstalk so that not only the crosstalk reduction due to these prior methods obtains but the advantages of the present invention in addition.

The invention may now be more fully understood from the following detailed descrip-

tion thereof when read in connection with the accompanying drawing, Figure 1 of which is a symbolic representation of how the side and phantom circuits of each quad of a group of quads in a cable may be cross-connected and re-routed at each successive repeater point in accordance with the present invention, while Figs. 1a and 1b show respectively the symbol representing the connection between a phantom and its two associated side circuits, and the symbol representing a two-wire repeater. In Fig. 1 of the drawing each pair of conductors constituting a side circuit is represented, for the sake of simplicity, by a single line instead of a pair of lines one for each conductor.

Referring to Fig. 1, which shows a schematic layout in accordance with the invention, it is assumed that a cable extends between terminal points A and E through repeater points B, C and D. This cable may include any desired number of quads, of which, for purposes of illustration, six quads, each involving two side circuits of two conductors each and a common phantom, are treated as a group. In order to accomplish the purpose of the present invention the connections of each side circuit of a quad are shifted at each repeater point so that each side circuit will be connected to the conductors of other side circuits in different quads. Likewise, the connections are so shifted that the phantom, while in effect continuing straight through from section to section, is, due to the cross-connection of the side circuits, actually associated with a different pair of side circuits in each successive repeater section.

In making the cross-connections involved, the pairs corresponding to each side circuit are numbered in regular order, and in the case illustrated in Fig. 1 these numbers run from 1 to 12, inclusive, although the method is applicable independently of the number of quads to be treated and of the number of repeater stations in the system. The phantom circuits, as already stated, are so connected as to proceed straight through each repeater station. The side circuits, however, incoming from each preceding repeater (or terminal) are connected individually to the repeaters of the next lower odd numbered side circuits, if they are normally connected to odd numbered side circuits, or to the repeaters of the next higher even numbered side circuits if they normally connect to even numbered side circuits. The repeater that was normally connected to the highest odd numbered side circuit in the group (which in the case assumed is 11) is connected to the lowest odd numbered side circuit (1), while the repeater that was normally connected to the lowest even numbered side circuit (in this instance 2) is connected to the highest even numbered side circuit (12) in the

group. In short, the even numbered side circuits in the group have their connections shifted or rotated in one direction and the odd numbered side circuits have their connections shifted or rotated in the opposite direction.

If we now consider the phantom which in the first section from A to B is superimposed on side circuits 1 and 2, we find that in the section from B to C it is superimposed upon side circuits identified as 3 and 12 at station A, while in the section from C to D this same phantom is superimposed upon side circuits which are identified as 5 and 10 at station A, etc. Likewise, considering the side circuit 1 at station A, while it is in the same quad with side circuit 2 in the section from A to B it is in the same quad in the section from B to C, with what was originally side circuit 10, and in the same quad in the section from C to D, with what was originally side circuit 6, etc.

In two-wire circuits it is desirable and usually necessary to rotate the connections at each repeater station in a certain unit such as a regulator section. At the ends of these circuit lengths it is also desirable to provide these special cross-connections in cases where this can be done without undue difficulty. In four-wire circuits satisfactory crosstalk conditions will normally prevail if the rotation of connections is carried out only at the ends of regulator sections (each of which would include a number of repeater sections). This is because in four-wire circuit arrangements the circuits transmitting in one direction are all arranged in one group and those transmitting in the opposite direction in another group. Since the transmission on the three units of a quad in four-wire circuits is always in the same direction, the energy levels on the three units are about the same, and crosstalk between the units is not amplified to the extent it is when the units may transmit in opposite directions as in two-wire circuits. In four-wire circuits the condition does not arise, however, in which the sending end of a circuit is crosstalking into the receiving end of a circuit in the same quad and thereby competing in the latter with the attenuated currents transmitted from the sending end thereof. In four-wire circuits, therefore, the cross-connections in accordance with the present invention need not be made as frequently as in the case of two-wire circuits.

With two-wire circuit groups rotated as described above no side-to-phantom duplications will be experienced in a given length of cable providing the number of quads in the rotated group is at least equal to the number of sections between repeaters. There will, however, be a duplication of side-to-side crosstalk exposure if the number of quads is

even and not at least twice as great as the number of repeater sections.

For example, considering Fig. 1 and the side circuits 1 and 2, if we trace these side circuits through stations B, C and D, which include three repeater sections, we do not find these same side circuits arranged in the same quad again until after they have passed through repeater point D, when they will then be associated in the cable section between D and E in the quad comprising the side circuits identified at station A as numbers 7 and 8. Likewise, side circuits 7 and 8 at station A do not appear in the same quad again until they arrive at station D, where they will again be together in the quad comprising the side circuit conductors identified as 1 and 2 at station D. Thus, it is apparent that to avoid duplication of side-to-side crosstalk exposure in more than one repeater section the number of quads in the group to be rotated must be at least twice as great as the number of repeater sections.

From the standpoint of phantom-to-side cross talk, however, no duplications will occur, as already stated, if the number of repeater sections does not exceed the number of quads in the group. For example, let us consider the phantom circuit which is superposed at station A upon side circuits 1 and 2. Between A and B this phantom is associated in intimate crosstalk relation with side circuit 1; between B and C it is associated with the side circuit which is identified as 3 at station A; between C and D it is associated with the side circuit identified as 5 at station A; between D and E it is associated with the side circuit identified as 7 at station A. If we consider the process of cross-connection as being extended through successive repeater points F, G and H (not shown), it is evident that between E and F the phantom will be associated with the side circuit identified as 9 at station A, and between F and G it will be associated with the side circuit identified as 11 at station A. The phantom has now been extended through six repeater stations in a system of rotation employing six quads without having been associated with the side circuit 1 more than once. If, however, the system is extended on to a succeeding station H, then between stations G and H the phantom under consideration will again be associated with the side circuit originally identified as 1 at station A in the same relation as existed between A and B.

From the foregoing it is evident that to prevent side-to-side duplication twice as many quads must be included in the cross-connecting arrangement as is necessary to prevent side-to-phantom duplication. However, side-to-side crosstalk exposure is less serious than side-to-phantom crosstalk exposure, and if the layout is sufficient to prevent duplication of side-to-phantom crosstalk a more com-

plicated scheme would not be justified in order to prevent duplication of side-to-side crosstalk exposure.

In general, it is of course desirable that the number of phantom groups of circuits involved in a given rotation group should be as large as conditions will permit. On the other hand, where different conditions obtain it may be advantageous from the standpoint of circuit flexibility to limit the number of quads in a rotatable group to a moderately small number as, for example, from four to six quads. This, of course, will not result in duplication of exposures where the system is comparatively short, and under such conditions a given cable may have its total number of quads divided up into a number of separate rotation groups. In any event, it is in general desirable that the number of quads involved in a given rotation scheme should be the same throughout the same regulator section.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a cable system the conductors of which are arranged in a plurality of quads, each quad comprising a pair of side circuits upon which a phantom circuit is superimposed, the method of reducing the effect of crosstalk which consists in shifting the connections of the conductors of the quads and the phantom circuits at each of a plurality of junction points between cable sections so as to superimpose the phantom upon a different pair of side circuits in each of a plurality of successive sections.

2. In a cable system the conductors of which are arranged in a plurality of quads, each quad comprising a pair of side circuits upon which a phantom circuit is superimposed, the method of reducing the effect of crosstalk which consists in shifting the connections of the conductors of the quads at each of more than two junction points between cable sections without shifting the phantom connections so that each side circuit of any given quad in one section will be routed through successively different quads in each of more than two succeeding sections and the phantom will be superposed on different side circuits in different sections.

3. In a cable system the conductors of which are arranged in a plurality of quads, each quad comprising a pair of side circuits upon which a phantom circuit is superimposed, the method of reducing the effect of crosstalk which consists in shifting the connections of the conductors of the quads and the phantom circuits at each of a plurality of junction points between cable sections so that each side circuit of any given quad in one

section will be routed through different quads in each of a plurality of succeeding sections and each phantom circuit will be superposed upon a different pair of side circuits in each of a plurality of successive sections.

4. In a cable system the conductors of which are arranged in a plurality of quads, each quad comprising a pair of side circuits upon which a phantom circuit is superposed, and in which correspondingly numbered quads are grouped in each succeeding section, the method of reducing the effect of cross-talk which consists in shifting the connections of the conductors of the quad at each of a plurality of junctions between sections so that one side circuit of each quad will be connected to the corresponding side circuit of a quad of a succeeding numerical order in one direction in the next cable section, and the other side circuit of each quad will be connected to the corresponding side circuit of a quad of a succeeding numerical order in the opposite direction.

5. In a cable system the conductors of which are arranged in a plurality of quads, each quad comprising a pair of side circuits upon which a phantom circuit is superposed, and in which correspondingly numbered quads are grouped in each succeeding section, the method of reducing the effect of cross-talk which consists in shifting the connections of the conductors of the quad at each of a plurality of junctions between sections so that one side circuit of each quad will be connected to the corresponding side circuit of a quad of a succeeding numerical order in one direction in the next cable section, and the other side circuit of each quad will be connected to the corresponding side circuit of a quad of a succeeding numerical order in the opposite direction, and connecting the conductors of the phantom circuit of each quad of one section to the phantom conductors of the corresponding quad of the succeeding section at each junction point between sections.

6. A cable system comprising a plurality of cable sections each comprising a plurality of conductors arranged in quads, each quad comprising a pair of side circuits and a phantom circuit superposed on the pair of side circuits, the conductors of the side circuits and the phantom of each quad of each section being cross-connected to the conductors of the side circuits and phantoms of the quads of the succeeding section so as to superpose the phantom of each quad upon a different pair of side circuits in each of a plurality of successive sections.

7. A cable system comprising a plurality of cable sections each comprising a plurality of conductors arranged in quads, each quad comprising a pair of side circuits and a phantom circuit superposed on the pair of side circuits, the conductors of the side circuits of each quad to each section being cross-con-

nected to the conductors of the side circuits of the quads of the succeeding section without shifting the phantom connections so that each side circuit of any given quad in one section will be successively routed over conductors of different quads in each of more than two succeeding sections and the phantom will be superposed on different side circuits in different sections.

8. A cable system comprising a plurality of cable sections each comprising a plurality of conductors arranged in quads, each quad comprising a pair of side circuits and a phantom circuit superposed on the pair of side circuits, the conductors of the side circuits and the phantom of each quad of each section being cross-connected to the conductors of the side circuits and phantoms of the quads of the succeeding section so that each side circuit of any given quad in one section will be routed over conductors of different quads in each of a plurality of succeeding sections, with the phantom of each quad of a given section superposed upon a different pair of side circuits in each of a plurality of successive sections.

9. A cable system comprising a plurality of cable sections each comprising a plurality of conductors arranged in quads, each quad comprising a pair of side circuits and a phantom circuit superposed on the pair of side circuits, a corresponding number of quads of each section being grouped and numbered so that the quads in a group in each section will be correspondingly numbered in the same successive order in each section, the conductors of the side circuits of each quad of a group in each of a plurality of cable sections being cross-connected to conductors of quads of the corresponding group of the next section so that one side circuit of each quad of the group will be connected to the corresponding side circuit of a quad of succeeding numerical order in one direction in the next cable section, and the other side circuit of each quad of the group will be connected to the corresponding side circuit of quad of succeeding numerical order in the opposite direction.

10. A cable system comprising a plurality of cable sections each comprising a plurality of conductors arranged in quads, each quad comprising a pair of side circuits and a phantom circuit superposed on the pair of side circuits, a corresponding number of quads of each section being grouped and numbered so that the quads in a group in each section will be correspondingly numbered in the same successive order in each section, the conductors of the side circuits of each quad of a group in each of a plurality of cable sections being cross-connected to conductors of quads of the corresponding group of the next section so that one side circuit of each quad of the group will be connected to the corre-

5 sponding side circuit of a quad of succeeding
numerical order in one direction in the next
cable section, and the other side circuit of
each quad of the group will be connected to
the corresponding side circuit of a quad of
succeeding numerical order in the opposite
direction, and the conductors of the phan-
tom of each quad in a group of one cable sec-
tion being connected to the phantom con-
10 ductors of the corresponding quad of the
group of the succeeding section at each junc-
tion point between sections.

11. In a cable system the conductors of
which are arranged in a plurality of quads,
15 each quad comprising a pair of side circuits
upon which a phantom circuit is superposed,
the method of reducing the effect of cross-
talk which consists in shifting in effect the
connections of the phantom circuits at each
20 of a plurality of junction points between the
cable sections so as to superimpose the phan-
tom upon a different pair of side circuits in
each of a plurality of successive sections.

25 In testimony whereof, I have signed my
name to this specification this 24th day of
October, 1928.

MYRON A. WEAVER.

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