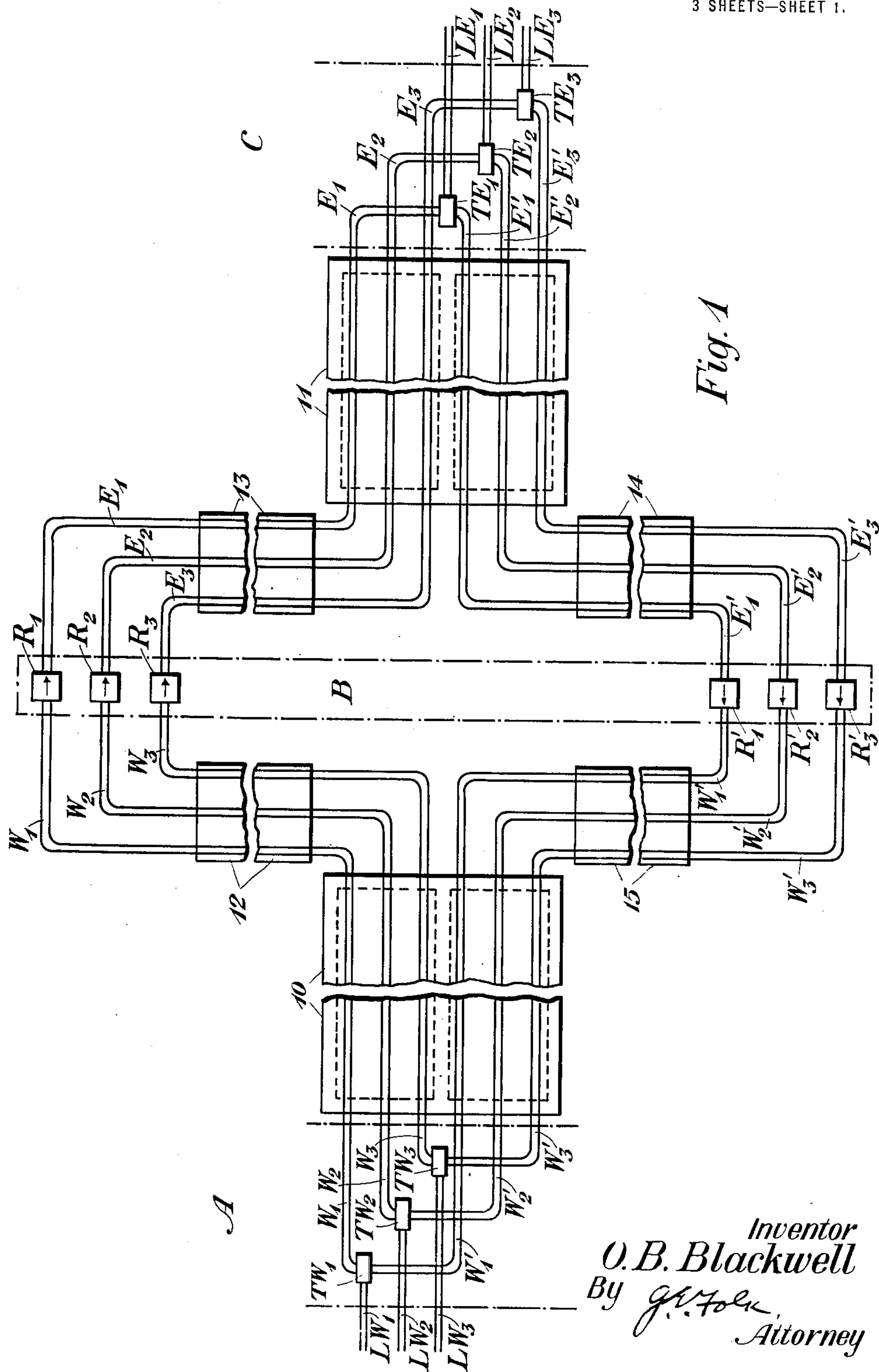


MEANS FOR AND METHOD OF REDUCING CROSS TALK IN FOUR WIRE CIRCUITS.
APPLICATION FILED MAY 20, 1918.

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Patented Oct. 18, 1921.

3 SHEETS—SHEET 1.



Inventor
O. B. Blackwell
By *J. V. Folger*,
Attorney

O. B. BLACKWELL.

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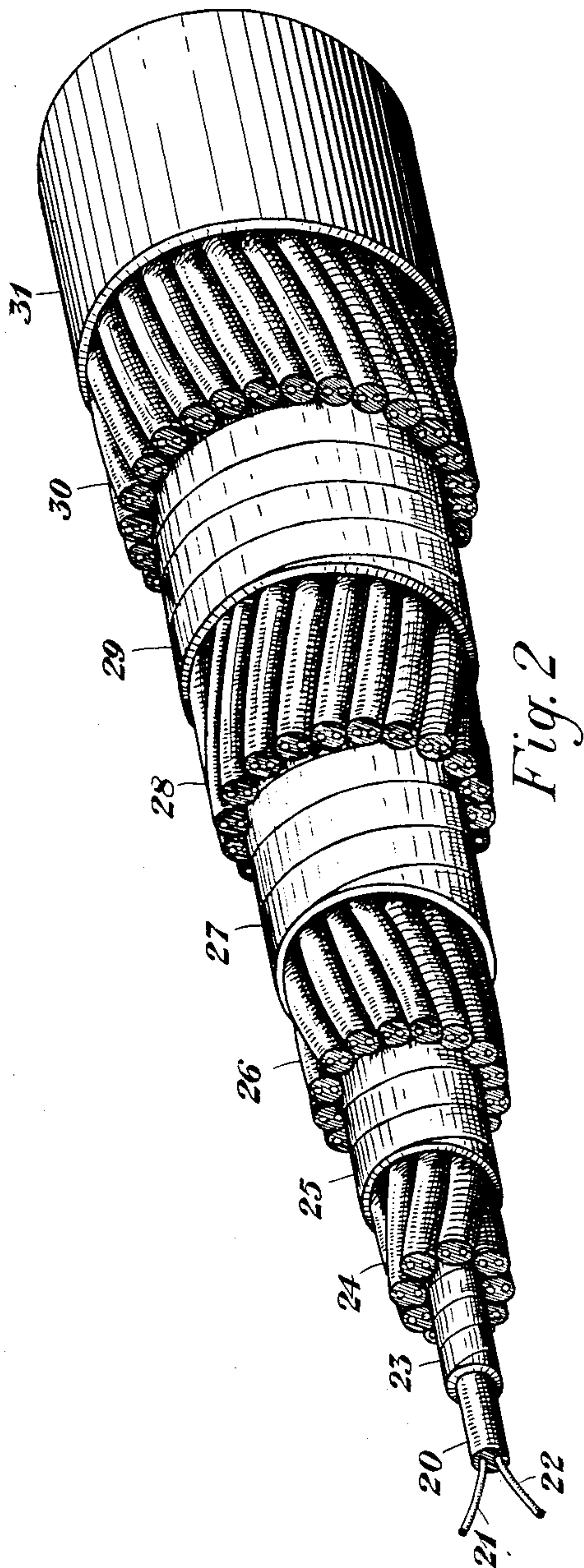


Fig. 2

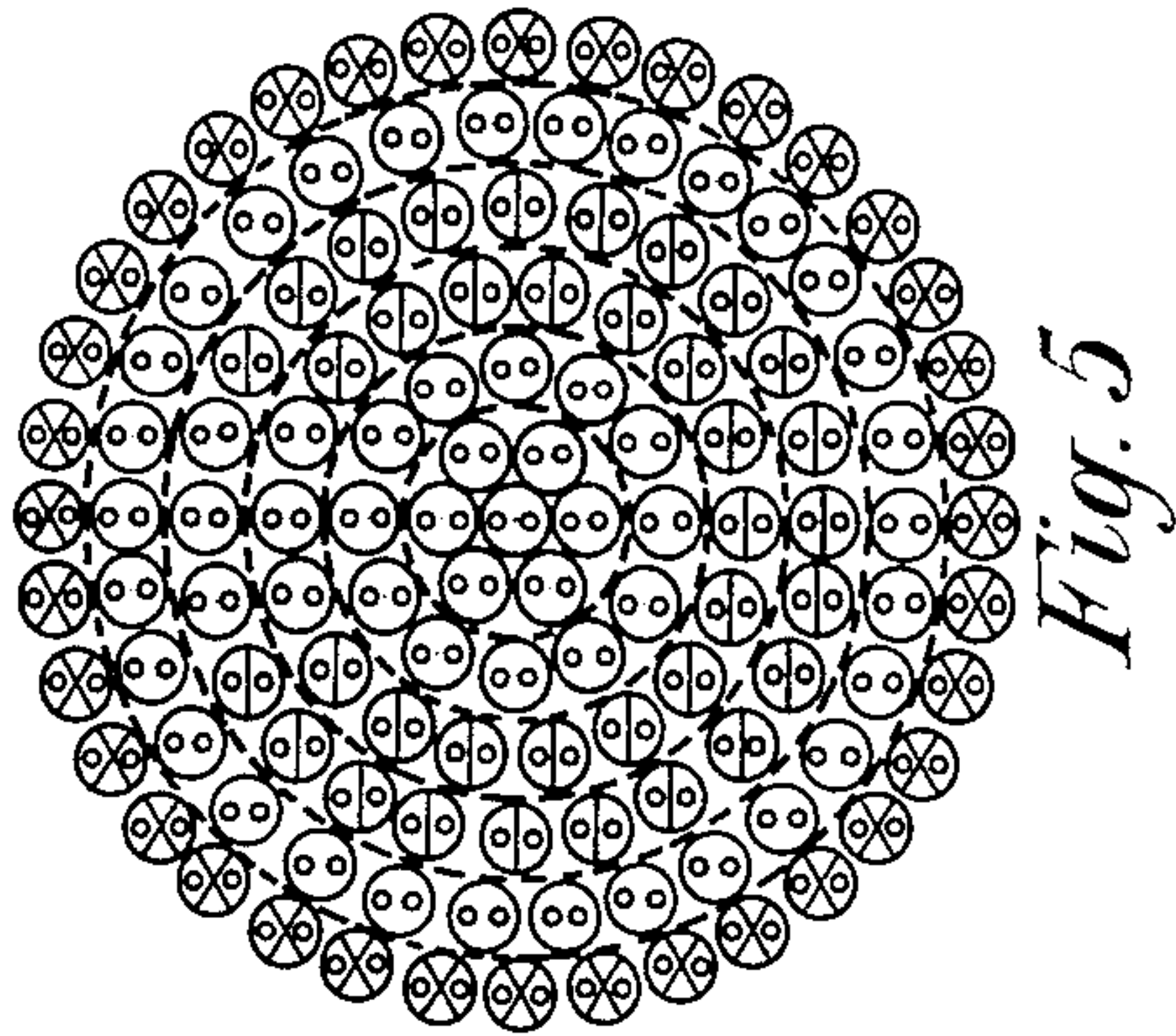


Fig. 5

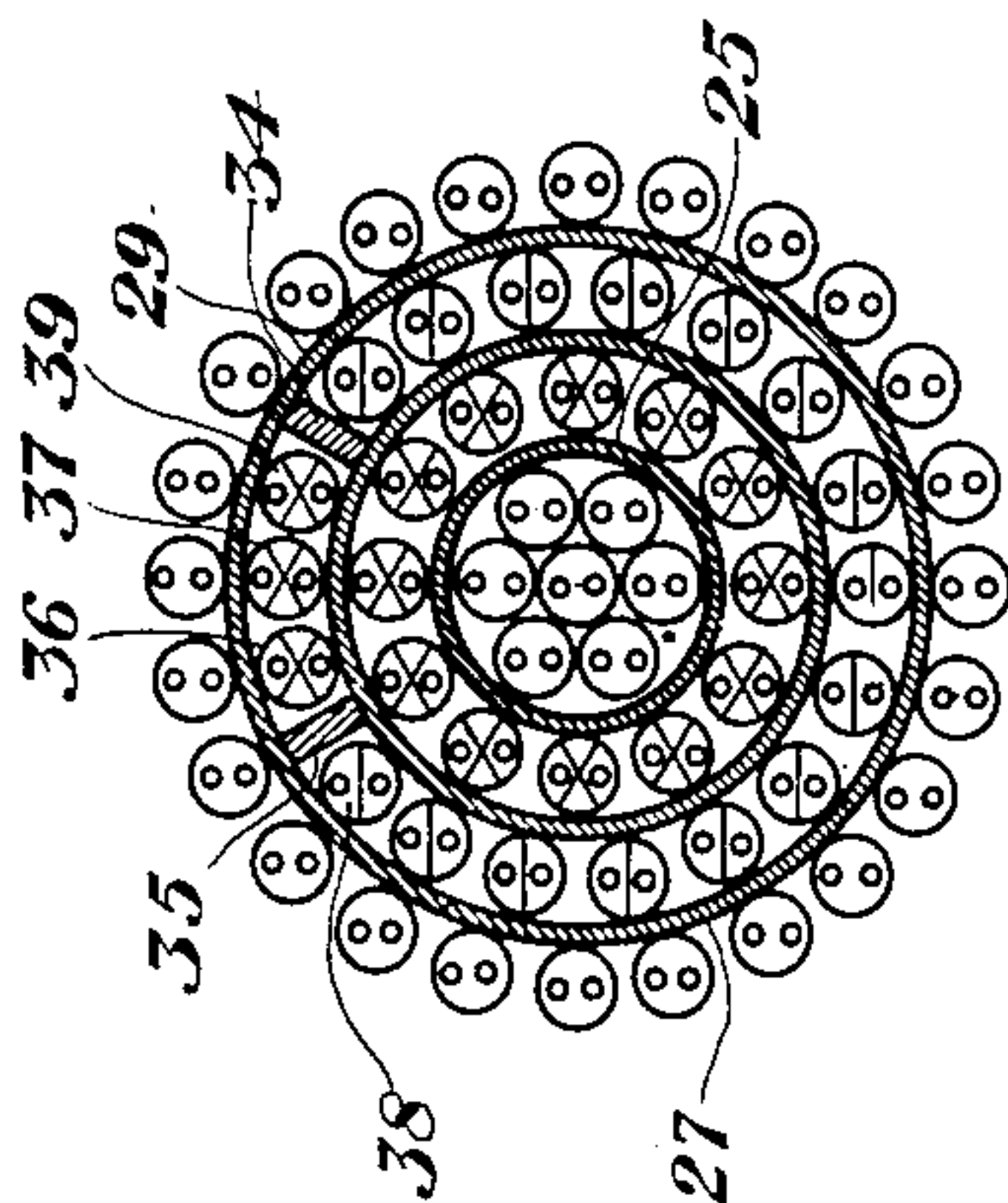


Fig. 4

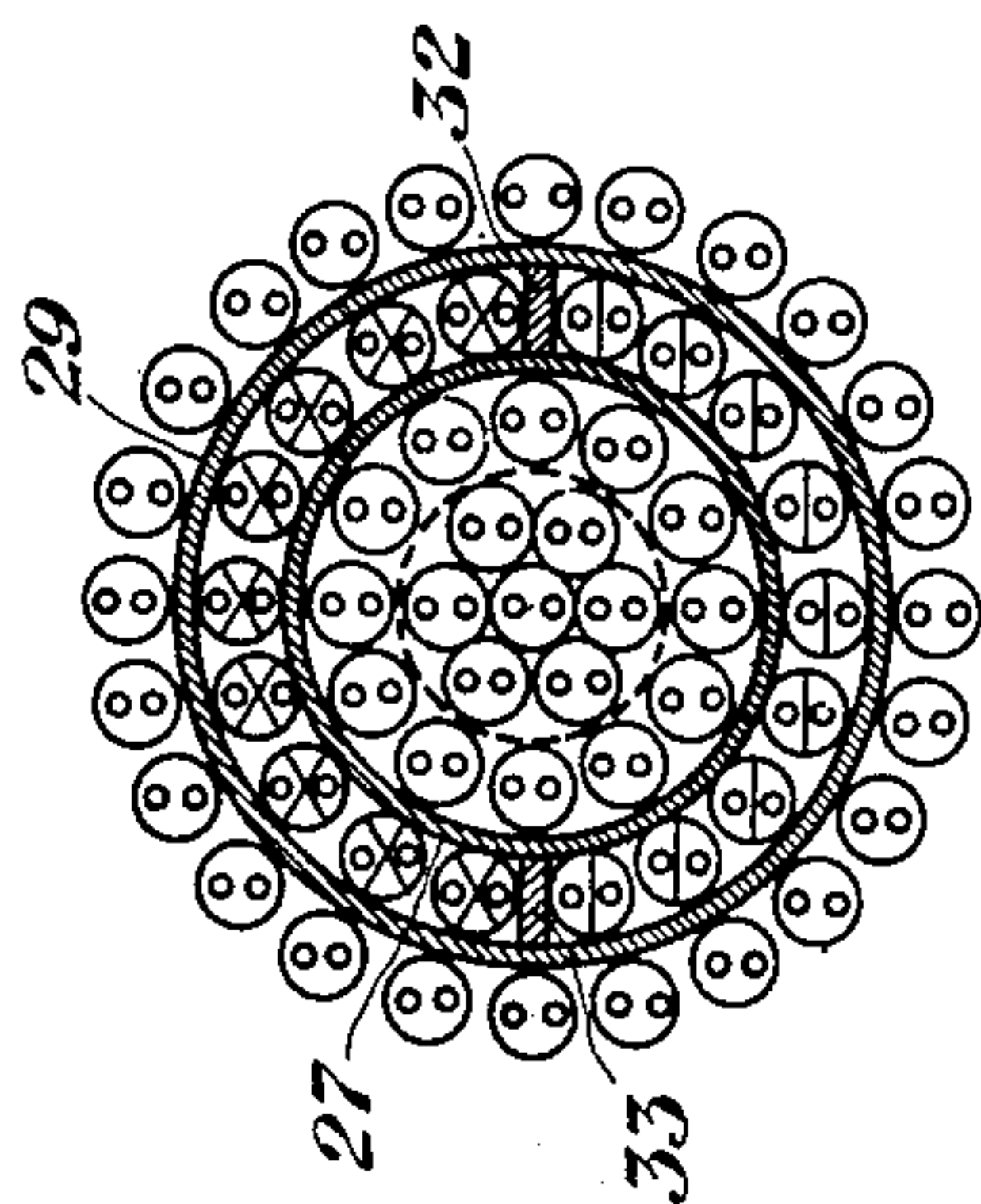


Fig. 3

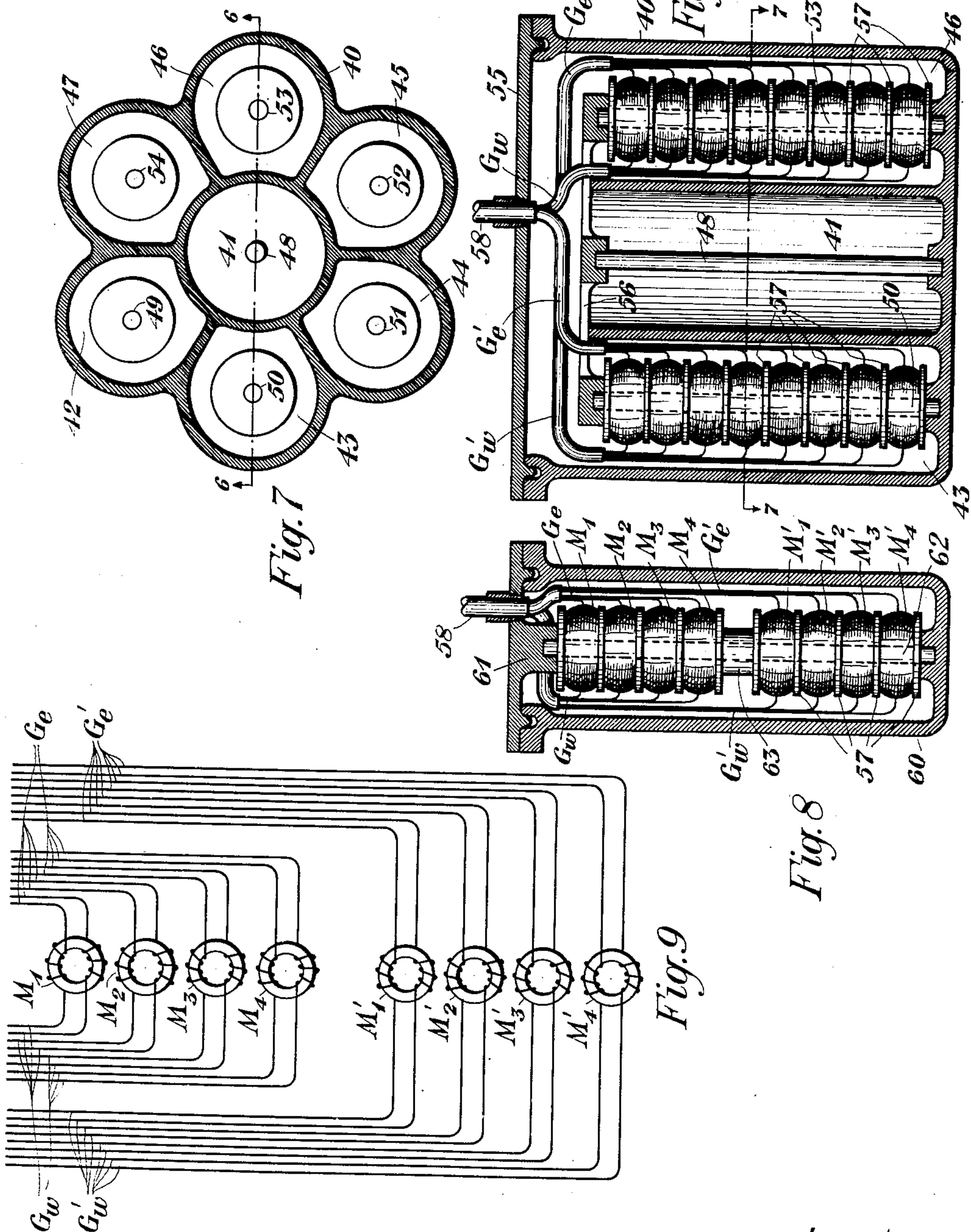
Inventor
O. B. Blackwell
By *J. C. Forster*
Attorney

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3 SHEETS—SHEET 3.



Inventor
 O. B. Blackwell
 By *g. v. fol.* Attorney

UNITED STATES PATENT OFFICE.

OTTO B. BLACKWELL, OF GARDEN CITY, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR AND METHOD OF REDUCING CROSS-TALK IN FOUR-WIRE CIRCUITS.

1,394,062.

Specification of Letters Patent.

Patented Oct. 18, 1921.

Application filed May 20, 1918. Serial No. 235,680.

To all whom it may concern:

Be it known that I, OTTO B. BLACKWELL, residing at Garden City, in the county of Nassau and State of New York, have invented certain Improvements in Means for and Method of Reducing Cross-Talk in Four-Wire Circuits, of which the following is a specification.

This invention relates to transmission systems, and more particularly to transmission systems of the type known as four-wire repeater systems.

Where a number of four-wire transmission systems parallel each other, serious cross-talk difficulties are encountered, owing to the high degree of amplification that it is desirable to employ in these circuits, and it is one of the objects of this invention to reduce the cross-talk to a minimum, especially where cable circuits are used. Other and further objects of the invention will be clear from the detailed description to be given later.

In four-wire transmission systems, as is well known, two separate transmission lines are employed, one for transmission in each direction, each line including one or more one-way repeaters for amplifying the transmitted current. Where a number of circuits of this character closely parallel each other, the current transmitted in a line employed for transmission in one direction induces cross-talk in all of the transmission lines associated with it, regardless of the direction in which transmission takes place over the other lines. I have discovered, however, that the cross-talk currents induced in lines transmitting in the opposite direction from the inducing line are much more serious than those induced in lines transmitting in the same direction. The cross-talk currents in the latter case are relatively unimportant, as this difficulty can be sufficiently overcome by so constructing the individual lines that a small degree of mutual unbalance exists between the lines, it being understood that it is the mutual unbalance condition which results in cross-talk.

The reason for the relatively greater seriousness of the cross-talk currents induced in lines transmitting in the opposite direction will be clear from a consideration of the condition existing at repeater points. At a point adjacent the output of a one-way repeater in a transmission line employed for

transmission from east to west, transmission currents of considerable amplitude occur due to the amplification of the repeater. While such currents induce cross-talk currents in adjacent lines transmitting from east to west, these cross-talk currents will be relatively small as compared with the transmission currents appearing in said lines, especially if good conditions as to mutual unbalance exist, for the transmission current occurring adjacent the output of the repeaters in said lines will also be large. Cross-talk currents of equal magnitude induced in lines transmitting from west to east will be quite serious at these points, however, as the transmission currents in these lines are just arriving at the input of a repeater after having been greatly attenuated in being transmitted from distant points. Under such conditions it is conceivable that the cross-talk currents in such lines might be comparable in magnitude to the transmission currents transmitted thereover.

In order to overcome this difficulty, it is proposed, in accordance with this invention, to electrically separate the conductors of lines transmitting in one direction from those transmitting in the opposite direction. While this might be accomplished by carrying the conductors employed for transmission in one direction in a separate cable from those employed for transmission in the opposite direction, this would not often be practicable as one cable would frequently be sufficient to supply all the transmission circuits necessary between two points. It is therefore proposed in such cases to carry all of the conductors in a single cable and electrically shield the conductors employed for transmission in one direction from those employed for transmission in the opposite direction.

Since, as above pointed out, the worst condition so far as cross-talk is concerned occurs at repeater points, it is further proposed to segregate the repeaters transmitting east from those transmitting west. It is also desirable that the conductors entering the repeater station and leading to the input sides of repeaters transmitting in one direction should be electrically separated from those leading from the output sides of said repeaters, as well as from the conductors leading to the input and output sides of repeaters transmitting in the opposite direc-

tion. As the sections of cable leading into the repeater stations are comparatively short, this result may be quite readily and economically accomplished by providing four separate branch cables, one leading to the input sides of repeaters transmitting east, one leading from the output sides of said repeaters, and the other two similarly leading to the input and output sides of repeaters transmitting west.

Where the lines are loaded, some additional difficulty may arise due to the fact that the loading coils of a plurality of lines are inclosed in a common casing so that cross-talk is induced in adjacent loading coils. The invention therefore contemplates grouping the loading coils in the casing so that the coils of lines transmitting in opposite directions will not be in the same group, and so arranging the groups as to be electrically separated from each other.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, in which—

Figure 1 is a schematic diagram of a transmission system embodying a plurality of four-wire circuits, the two sides of which are electrically separated to reduce cross-talk;

Fig. 2 is a perspective view of a section of cable in which certain conductors are electrically shielded from each other;

Figs. 3, 4 and 5 are sectional views showing schematically several modified arrangements of the cable;

Fig. 6 is a sectional view—taken on the line 6—6 of Fig. 7—of a multi-spindle loading coil casing, showing an arrangement whereby the loading coils of a plurality of circuits may be electrically separated;

Fig. 7 is a sectional view of the loading coil casing of Fig. 6, taken on the section line 7—7;

Fig. 8 is a sectional view of a single spindle loading coil casing, showing another method of mounting the coils to reduce cross-talk between different groups of coils; and

Fig. 9 is a diagram schematically indicating the arrangement of the stub cable leading from the loading coils in the casing to the main line cable.

Referring to Fig. 1, a four-wire transmission system is shown extending between stations A and C through an intermediate repeater station B. A cable extends from station A to station B, and a similar cable extends from station B to station C. Each cable includes the conductors of a plurality of four-wire transmission circuits. For purposes of illustration, three distinct four-wire transmission circuits are shown, but it will be understood that this number is merely illustrative and any desired number

of circuit may be provided. Each of the four-wire circuits terminates in two-wire lines, such as LW_1 , LW_2 and LW_3 at station A and LE_1 , LE_2 and LE_3 at station C. The two-wire line LW_1 and LE_1 are interconnected by means of a four-wire circuit, including two-wire line sections W_1 and E_1 , connected together at the repeater station B by means of a one-way repeater R_1 , these line sections being used for transmission from west to east. For transmission from east to west lines the four-wire circuit is provided with line sections E_1' and W_1' , these line sections including a repeater R_1' at the station B. The four-wire transmission circuit thus formed may be associated with line LW_1 at the station A by the usual three winding transformer schematically indicated at TW_1 . Similarly, it may be associated with the line LE_1 at station C by means of a similar three winding transformer arrangement TE_1 . The remaining two four-wire circuits illustrated are similar in all respects to that just discussed, and need not be further described.

In a system as that just outlined, considerable cross-talk difficulty may be encountered owing to the high degree of amplification employed, unless some means are provided to separate the group of lines transmitting from west to east from the group of lines transmitting from east to west. Assuming that transmission is taking place through the repeater R_1 from station A to station C, owing to the high amplification of the repeater R_1 currents of considerable amplitude will appear in the line section E_1 adjacent the output of the repeater. Assuming that no special precautions are taken to reduce cross-talk, these currents would induce cross-talk currents in line sections E_2 and E_3 as well as line sections E_1' , E_2' and E_3' . The cross-talk currents induced in the line sections E_2 and E_3 would not cause serious difficulty, however, for the reason that the transmission currents appearing in these line sections would be of large value owing to the amplification of the repeaters R_2 and R_3 . The cross-talk currents appearing in the line sections E_1' , E_2' and E_3' adjacent the repeaters R_1' , R_2' and R_3' , however, would be much more serious, as they would be proportionately greater as compared with the transmission currents appearing in said lines, said transmission currents being greatly attenuated during transmission from station C to station B. It is therefore necessary to take precautions to electrically separate the circuits used in transmitting from east to west from those used in transmitting from west to east. Since the most serious condition so far as cross-talk is concerned is at the repeater station, even greater precaution must be taken at this point. Therefore, the repeaters R_1 , R_2 and R_3 used for trans-

mission from west to east are grouped together at one point, as indicated, while the repeaters R_1' , R_2' and R_3' used for transmission from east to west, are grouped together at a somewhat distant point in the repeater station.

The two sets of conductors used for transmission in opposite directions are carried by the same cable sections 10 and 11, but are grouped in the cable and electrically separated from each other as indicated schematically by the dotted lines. In order to connect the conductors of the cable sections 10 and 11 to the repeaters at the repeater stations, it is desirable to provide separate branch cables 12, 13, 14 and 15 for carrying the two sets of conductors. Thus the lines W_1 , W_2 and W_3 are connected to the input sides of repeaters R_1 , R_2 and R_3 by means of a branch cable 12, while the lines E_1 , E_2 and E_3 are connected to the output sides of said repeaters by the branch cable 13. In a similar manner the two sets of line sections for transmitting from east to west are connected to the input and output sides, respectively, of the repeaters R_1' , R_2' and R_3' by means of branch cables 14 and 15. The conductors in one branch cable will be electrostatically and electromagnetically separated from those in the other cables, and, assuming that proper precautions are taken to maintain an electrical separation between the two sets of conductors in the cable sections 10 and 11, it will be seen that by means of the arrangement thus far described cross-talk induced in circuits transmitting in one direction, from circuits transmitting in the opposite direction, may be substantially reduced. It will be understood, of course, that cross-talk between circuits transmitting in the same direction will be kept at a minimum value by employing the usual precautions to prevent mutual unbalance between the circuits.

The method by which an electrostatic, and, if desired, a magnetic separation is maintained between two sets of conductors in a cable section such as 10 or 11, may be understood from Fig. 2. In this figure a cable is shown made up of an interior strand or core 20, comprising a pair of insulated conductors, such as 21 and 22. About this strand a metallic tape 23 may be spirally wound. A layer of strands 24, similar to strand 20, is then twisted about the core thus formed. This layer as shown consists of six strands of two conductors each, the conductors being electrostatically separated from those of strand 20 by means of the metallic tape 23. On the outside of this layer metallic tape 25 is spirally wound, and upon this is superposed another layer of strands 26, this layer being electrostatically separated from layer 24 by the tape 25. In a similar manner additional layers 28 and 30

are provided, separated as usual from the adjacent layers by metallic tape 27 and 29. Upon the outside will be placed a metallic sheath 31 of the usual type. It will be seen that the conductors in each layer of the cable are electrostatically separated from the conductors of adjacent layers by means of the layers of metallic tape.

Since cross-talk in cable is mainly due to the electrostatic unbalance between conductors, it will ordinarily be sufficient to separate them electrostatically by means of the metallic tape. If, however, as a further precaution it is desired to prevent magnetic interaction between the conductors of two layers, the metallic tape may be constructed of some magnetic material. The strands constituting the core of the several layers of the cable, as shown, each consists of two insulated conductors, but it will be readily understood that instead of pairs of conductors each strand may consist of a quad of four conductors, or, in exceptional cases, of a set of eight conductors.

In a cable as thus constructed it is not generally possible to utilize all of the conductors for four-wire circuits inasmuch as it is necessary to employ the strands in two sets of equal number. In the cable shown, assuming that the core consists of one strand, the first layer of six strands, the second layer of twelve strands, the third layer of eighteen strands and the fourth layer of twenty-four strands, it will be seen that since the total number of strands is an odd number one or more of the strands cannot be used for four-wire circuits. Since, however, it will be generally necessary to employ some of the strands for two-wire circuits, it is possible to group certain of the layers in two sets of equal number for four-wire circuits. For instance, the first and second layer consisting of six and twelve strands, or eighteen altogether, may be used for lines of four-wire circuits transmitting in one direction while the third layer of eighteen strands may be used for lines of four-wire circuits transmitting in the opposite direction. The center strand and the outside layer may then be used for two-wire circuits. This will provide for a total of eighteen four-wire circuits, assuming that each strand consists of a pair of conductors. If a greater number is desired, the outer layer of twenty-four strands may be used for the lines of four-wire circuits transmitting in one direction, while the first and third layers of six and eighteen strands, respectively, may be used for the lines transmitting in the opposite direction. The core and second layer may then be used for two-wire lines. This arrangement provides for twenty-four four-wire circuits, assuming that each strand consists of two conductors.

Fig. 3 shows schematically an alternative

arrangement of the strands of a cable in which two sets of four-wire circuits are secured from one layer of the cable, the two sets being electrostatically separated from each other. As shown, the third layer is utilized for this purpose, the two sets of strands in this layer being distinguished in the figures by designating one set by X's and the other set by dashes. Layers of metallic tape 27 and 29 are provided on the inside and outside of this layer of strands. The two sets of strands in the layer may be separated from each other by inserting in interstices of certain of the strands a pair of metallic strips, such as 32 and 33. By means of this construction it will be seen that each of the two sets of strands making up the third layer of the cable are wholly surrounded by a screening material, so that each set is screened from the other and from the adjacent conductors in other layers, which latter, it will be understood, may be employed for two-wire circuits. Instead of using the metallic strips 32 and 33, a pair of idle strands may be used for screening the two sets of conductors, as these strands constitute a mass of metal separating the two sets of conductors. These idle strands may, if desired, be used for two-wire circuits, as it is not always essential that an electrostatic separation be maintained between two-wire and four-wire circuits.

Fig. 4 illustrates another arrangement, whereby two adjacent layers may be utilized for the two sets of four-wire circuits, notwithstanding the fact that the two layers do not contain the same number of strands. As illustrated, the second and third layers are utilized for the four-wire circuits. The second layer contains twelve strands and the third layer eighteen strands, making a total of thirty. The several layers of the cable are separated by means of the metallic tape screens 25, 27 and 29, and three strands of the third layer are screened from the remaining strands of that layer by means of metallic strips 34 and 35. The remaining fifteen strands of that layer may constitute one set of conductors for four-wire circuits, while the other three strands, together with the twelve strands of the second layer, may constitute the second group of conductors for four-wire circuits. Instead of using the metallic strips 34 and 35 for screening material, two idle strands may be utilized for this purpose. Thus, if the strands 36 and 37 be screened from the remaining strands of the third layer by means of the strands 38 and 39, two sets of fourteen strands each may be secured.

In the several arrangements thus far described, not only have the two sets of conductors employed in four-wire circuits been electrostatically separated from each other, but the conductors used for two-wire cir-

cuits have been in general electrostatically separated from the four-wire circuits. This latter precaution is not always necessary, however, as it has been found that the cross-talk difficulty due to the interaction between two-wire and four-wire circuits is not as great as that encountered in connection with two sets of conductors of four-wire circuits.

An arrangement is schematically indicated in Fig. 5, in which this fact is taken advantage of by utilizing the conductors employed for two-wire circuits to screen the two sets of conductors employed for four-wire circuits without employing any metallic tape as a screening material. For purposes of illustration, the cable shown in Fig. 5 is indicated as made up of a core and six layers of strands, the layers consisting of six, twelve, eighteen, twenty-four, thirty and thirty-six strands, respectively. The outer layer of thirty-six strands is used as one set of four-wire conductors. The fifth layer of thirty strands is used for two-wire circuits and screens the outer layer from the fourth and third layers, certain of the strands of which are used for the other set of four-wire conductors. Since the third and fourth layers consist of eighteen and twenty-four strands, respectively, or a total of forty-two, six strands of these layers may also be utilized for two-wire circuits. The core and the first and second layers of strand will likewise be used for two-wire circuits. It will be seen that by means of this arrangement two sets of strands of thirty-six each are provided for four-wire working, the two sets being fully screened from each other by means of intervening strands utilized for two-wire working. This latter modification has the advantage that it does not involve any special construction of the cable, other than that in splicing adjacent sections of cable some precautions must be taken to indicate the character of the separate groups of strands, as, for instance, by using a color designation scheme.

Where lines are loaded, it is customary to inclose the loading coils in a common casing for purposes of protection. As the coils are closely associated in the casing, it is necessary to take suitable precautions to prevent cross-talk between the coils. One form of loading coil casing is shown in Figs. 6 and 7. The casing 40 may comprise a plurality of chambers 41, 42, 43, 44, 45, 46 and 47, in each of which a plurality of loading coils may be placed. The casing 40 is also provided with a suitable cover 55 having a water-tight engagement with the casing. Suitably secured to the walls of the inner chamber 41 is a spider 56 provided with a series of bosses, and centrally arranged in the chambers between the bosses of the spider and corresponding bosses in the bottom of the

casing are a plurality of spindles 48, 49, 50, 51, 52, 53 and 54. The loading coils are placed upon these spindles, one above the other, and in order to reduce cross-talk due to magnetic action between adjacent coils, the coils are separated by washers or spacers of magnetic material 57.

Referring to Fig. 9, which shows the wiring arrangement for a plurality of loading coils, it will be seen that each set of coils is provided with a set of terminals leading to the line east, such as G_e , and another set leading to the line west, such as G_w . It is necessary to provide some means for leading these conductors from the casing. This arrangement is shown in Fig. 6, in which a stub cable 58 is brought through the cover 55 of the casing and a plurality of branches of the cable, such as G_e , G_w , G_e' and G_w' , are led to opposite sides of the loading coils and individual conductors of these branches are connected to the individual coils.

The arrangement so far described is illustrative of the usual practice in connection with incasing loading coils. Where the loaded lines are used for four-wire circuits, it is necessary to provide additional means to prevent cross-talk between the coils of the two sets or groups of lines which transmit in opposite directions. Fig. 9 illustrates schematically the arrangement employed, the loading coils M_1, M_2, M_3 and M_4 constituting one group and the loading coils M_1', M_2', M_3' and M_4' constituting another group. The two groups of coils are separated and the conductors leading from the coils to lines east and west are arranged in two sets electrically separated from each other. The two sets of coils may be very readily separated electrically by placing them in separate chambers of the multi-spindle casing shown in Fig. 6, in which the coils placed in the chamber 46 are connected in lines transmitting in one direction, while those in the chamber 43 are connected in lines transmitting in the opposite direction. The electrical separation of the branches of the stub cable in the casing is readily secured by physically separating the branches as shown. The electrical separation of the branches in the stub cable 58 proper may be secured by means of any of the expedients already described with reference to the line cable.

Where a single spindle loading coil casing is used, a somewhat different problem arises. Such a casing is illustrated in Fig. 8 and consists of a casing proper 60, a cover 61 and a spindle 62 held between bosses on the cover and the bottom of the casing. The two sets of coils M_1, M_2, M_3, M_4 , and M_1', M_2', M_3', M_4' , are placed upon the spindle 62 and the individual coils are separated as before by means of washers or spacers 57. The two groups of coils are separated by means of a special spacer 63, so

designed that the distance between the two adjacent coils of each set will be at least equal to the width of a coil, it having been found that a separation of this amount will be sufficient to reduce the cross-talk between the two sets of coils to the desired limit. In this arrangement it is not practicable to secure a physical separation between the two sets of conductors G_w and G_w' and between the two sets of G_e and G_e' . The two sets of conductors may therefore be separated electrically both in the casing and in the stub cable 58 by any of the expedients above described with reference to the line cable.

It will be seen that by means of the invention heretofore described it is possible to reduce the cross-talk in a system involving a plurality of four-wire circuits, notwithstanding the increased amplification which it is desirable to employ in connection with said circuits. Furthermore, while certain specific apparatus and certain arrangements of parts have been described in connection with the practice of this invention, 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 appended claims.

It will also be understood that the term "four-wire circuit" as herein used refers to a circuit where there is one path for transmission in one direction and a second path for transmission in the opposite direction while the term "two-wire circuit" has reference to circuits in which the same path serves for transmission in both directions. In either case the path may comprise two wires used for that purpose exclusively, or it may be a phantom circuit, or one side of a phantom circuit, or it may be any other type of path which may be used for telephonic transmission.

What is claimed is:

1. In a transmission system comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk, which consists in electrically separating the two sets of conductors so employed.

2. In a transmission system comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk, which consists in electrostatically separating the two sets of conductors so employed.

3. In a transmission system comprising a cable including a plurality of sets of conduc-

tors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in grouping the conductors in sets according to the direction in which transmission takes place, and electrostatically separating the two sets of conductors.

4. In a transmission system comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in grouping the conductors in sets, so that conductors used for transmission in the same direction will be in the same set, and electrostatically separating the two sets of conductors.

5. In a transmission system, comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in magnetically separating the two sets of conductors so employed.

6. In a transmission system, comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in grouping the conductors in sets so that conductors used for transmission in the same direction will be in the same set, and magnetically separating the two sets of conductors.

7. In a transmission system, comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in shielding one of the sets of conductors so employed against electrostatic induction from the other set.

8. In a transmission system comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in grouping the conductors in sets according to the direction in which transmission takes place, and shielding one of the sets against electrostatic induction from the other set.

9. In a transmission system comprising a

cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in grouping the conductors in sets so that the conductors used for transmission in the same direction will be in the same set, and shielding one set against electrostatic induction from the other set.

10. In a transmission system comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in shielding one of the sets of conductors so employed against magnetic induction from the other set.

11. In a transmission system comprising a cable including a plurality of sets of conductors, certain of which are employed for the transmission of signals in one direction and others of which are employed for the transmission of signals in the opposite direction, the method of reducing cross-talk which consists in grouping the conductors in sets so that conductors used for transmission in the same direction will be in the same set, and shielding one set against magnetic induction from the other set.

12. The method of reducing cross-talk between four-wire transmission circuits, which consists in grouping such elements of the several circuits as materially contribute to the production of cross-talk, so that elements employed for transmission of signals in one direction will be in one group and elements employed for transmission of signals in another direction will be in another group, and electrostatically separating the two groups.

13. The method of reducing cross-talk between four-wire transmission circuits, which consists in grouping such elements of the several circuits as materially contribute to the production of cross-talk, so that elements employed for transmission of signals in one direction will be in one group and elements employed for transmission of signals in another direction will be in another group and magnetically separating the two groups.

14. A transmission system comprising a plurality of transmission circuits each including a pair of transmission lines, one for transmitting signals in one direction and the other for transmitting signals in the opposite direction, one-way repeaters in each line, said repeaters being segregated into groups according to the direction in which transmission takes place through them, said lines being also grouped so that lines transmitting

in the same direction are in the same group, and means for electrically separating the two groups of lines.

15. A transmission system comprising a plurality of transmission circuits each including a pair of transmission lines, one for transmitting signals in one direction and the other for transmitting signals in the opposite direction, one-way repeaters in each line, said repeaters being segregated into groups according to the direction in which transmission takes place through them, said lines being also grouped so that lines transmitting in the same direction are in the same group, and means for electrostatically separating the two groups of lines.

16. A transmission system comprising a plurality of transmission circuits each including a pair of transmission lines, one for transmitting signals in one direction and the other for transmitting signals in the opposite direction, a repeater station, one-way repeaters for each of said lines at said stations, connections from each line to the input of a corresponding repeater, similar connections between each line and the output of its corresponding repeater, said connections being arranged in electrostatically separated groups so that the connections of lines transmitting in one direction are in separate groups from the connections of lines transmitting in the opposite direction and the input connections are in separate groups from the output connections.

17. A transmission system comprising a plurality of transmission circuits each including a pair of transmission lines, one for transmitting signals in one direction and the other for transmitting signals in the opposite direction, each of said lines being divided into sections, one-way repeaters for each line between the sections, said sections being arranged in electrostatically separated groups so that sections employed for transmission in one direction are in a different group from sections employed for transmission in the opposite direction, and the repeaters being segregated into groups so that repeaters transmitting in one direction will be in a different group from repeaters transmitting in the opposite direction.

18. A transmission system comprising a repeater station and terminal stations, cables from each terminal station to the repeater station, each cable comprising a plurality of conductors one group of which are employed in lines transmitting signals in one direction and another group of which are employed in lines transmitting signals in the opposite direction, means to electrostatically segregate the groups, repeaters corresponding to the lines, said repeaters being segregated in groups so that repeaters transmitting in opposite directions are in separate groups, branch cables connecting the in-

put sides of the groups of repeaters to corresponding groups of conductors in the cables, other branch cables connecting the output sides of the groups of repeaters to corresponding groups of conductors in the cable, said branch cables being electrostatically separated.

19. A transmission system comprising a cable including a plurality of electrical conductors certain of which are used for transmission of signals in one direction and others of which are used for transmission of signals in the opposite direction, said conductors being grouped so that conductors transmitting in opposite direction will be in separate groups, and means for electrostatically separating the groups.

20. A transmission system comprising a cable including a plurality of electrical conductors certain of which are used for transmission of signals in one direction and others of which are used for transmission of signals in the opposite direction, said conductors being grouped so that conductors transmitting in opposite directions will be in separate groups, and means for magnetically separating the groups.

21. A transmission system comprising a cable including a plurality of electrical conductors certain of which are used for transmission of signals in one direction and others of which are used for transmission of signals in the opposite direction, said conductors being grouped so that conductors transmitting in opposite directions will be in separate groups, and an electrostatic shield between separate groups.

22. A transmission system comprising a cable including a plurality of electrical conductors certain of which are used for transmission of signals in one direction and others of which are used for transmission of signals in the opposite direction, said conductors being grouped so that conductors transmitting in opposite directions will be in separate groups, and a magnetic shield between separate groups.

23. A transmission system including a plurality of conductors certain of which are used for transmission of signals in one direction and others of which are used for transmission of signals in the opposite direction, loading coils in said conductors, said loading coils being arranged in groups so that loading coils in conductors used for transmission in opposite directions will be in separate groups, and means for electrically separating the groups.

24. A transmission system including a plurality of conductors certain of which are used for transmission of signals in one direction and others of which are used for transmission of signals in the opposite direction, loading coils in said conductors, said loading coils being arranged in groups so

that loading coils in conductors used for transmission in opposite directions will be in separate groups, and means for magnetically separating the groups.

5 25. A transmission system including a plurality of conductors certain of which are used for transmission of signals in one direction and others of which are used for
10 transmission of signals in the opposite direction, loading coils for said conductors, said loading coils being arranged in groups so that loading coils for conductors used for
15 transmission in opposite directions will be in separate groups, means for magnetically separating the groups, and separate sets of stub conductors for connecting the loading coils to the corresponding conductors, said sets of conductors being electrostatically separated from each other.

20 26. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of
25 said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in electrically separating the two sets of conductors so that conductors in which
30 large currents flow will be separated from conductors in which small currents flow.

27. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of
35 said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in electrostatically separating the two sets of conductors so that conductors in which large currents flow will be
40 separated from conductors in which small currents flow.

45 28. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of said conductors being large as compared
50 with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in grouping the conductors in sets so that conductors in which currents of the same relative magnitude flow will be
55 in the same set, and electrically separating the two sets of conductors.

29. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of
60 said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk
65 nals, the method of reducing cross-talk

which consists in grouping the conductors in sets so that conductors in which currents of the same relative magnitude flow will be in the same set, and electrostatically separating the sets of conductors.

70 30. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of said conductors being large as compared
75 with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in magnetically separating the two sets of conductors so that conductors in
80 which large currents flow will be separated from conductors in which small currents flow.

31. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of
85 said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in grouping the conductors in sets so that conductors in which currents of relatively similar magnitude flow will be in
90 the same set, and magnetically separating the two sets of conductors.

32. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of
100 said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in shielding the set of conductors in
105 which relatively small currents flow against electrostatic induction from the set of conductors in which relatively large currents flow.

33. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of
110 said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in grouping the conductors in sets in accordance with the magnitude of the currents flowing in the conductors at points exposed
115 to cross-talk, and shielding one of the sets against electrostatic induction from the other set.

34. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of said conductors being large as compared
125 with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk
130

nals, the method of reducing cross-talk which consists in grouping the conductors in sets so that conductors in which currents of the same relative magnitude flow will be in the same set, and shielding one set against electrostatic induction from the other set.

35. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in shielding the conductors in which relatively small currents flow against magnetic induction from the conductors in which relatively large currents flow.

36. In a transmission system comprising a cable having a plurality of conductors employed for the transmission of signaling currents, the currents transmitted by certain of said conductors being large as compared with the currents transmitted by other of the conductors in a region near the terminals, the method of reducing cross-talk which consists in grouping the conductors in sets so that conductors in which currents of the same relative magnitude flow will be in the same set, and shielding one set against magnetic induction from the other set.

In testimony whereof, I have signed my name to this specification this fourteenth day of May 1918.

OTTO B. BLACKWELL.