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1,931,601

SYSTEM OF SIGNALING CIRCUITS IN A MULTICONDUCTOR CABLE

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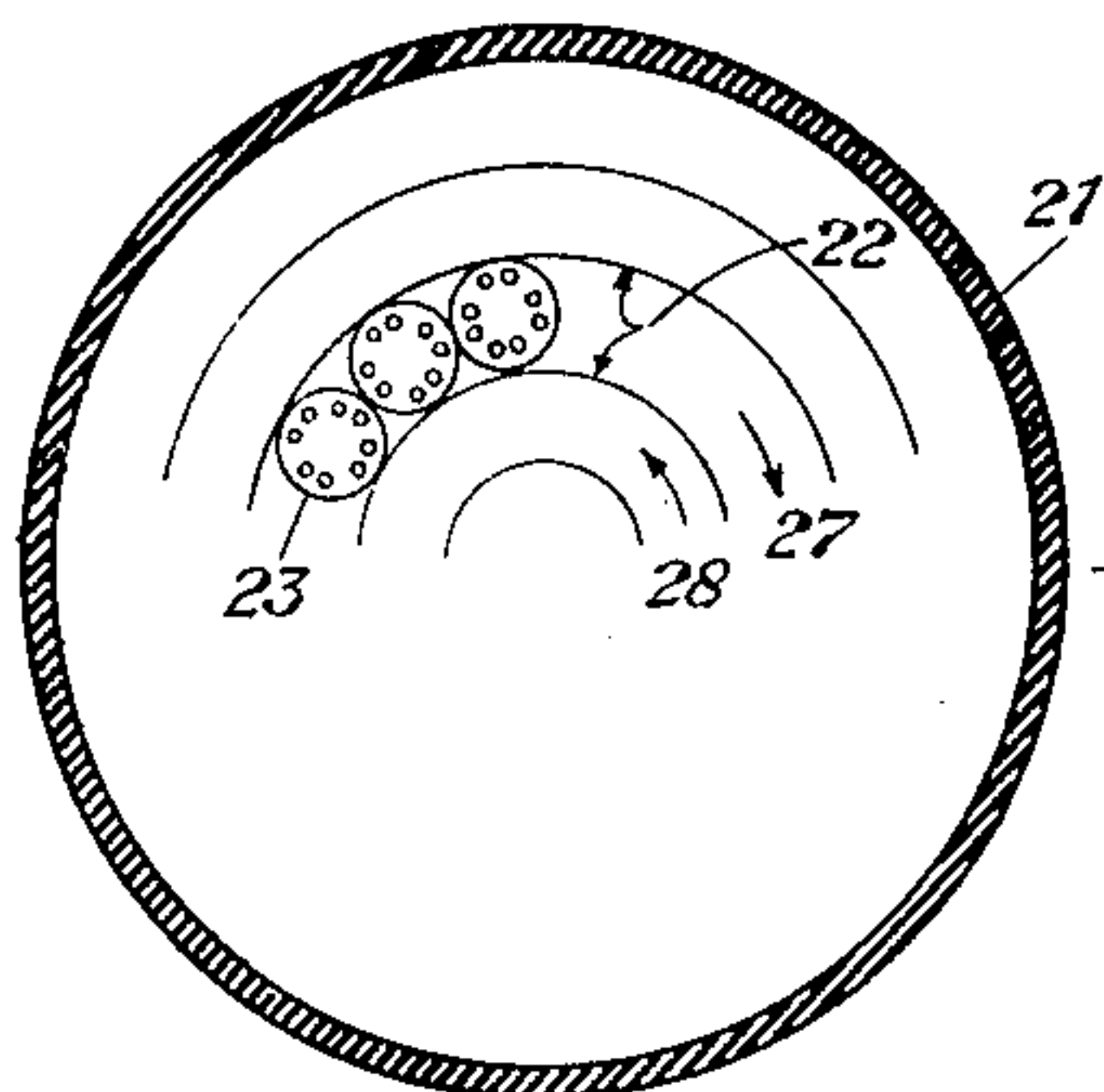


Fig. 1

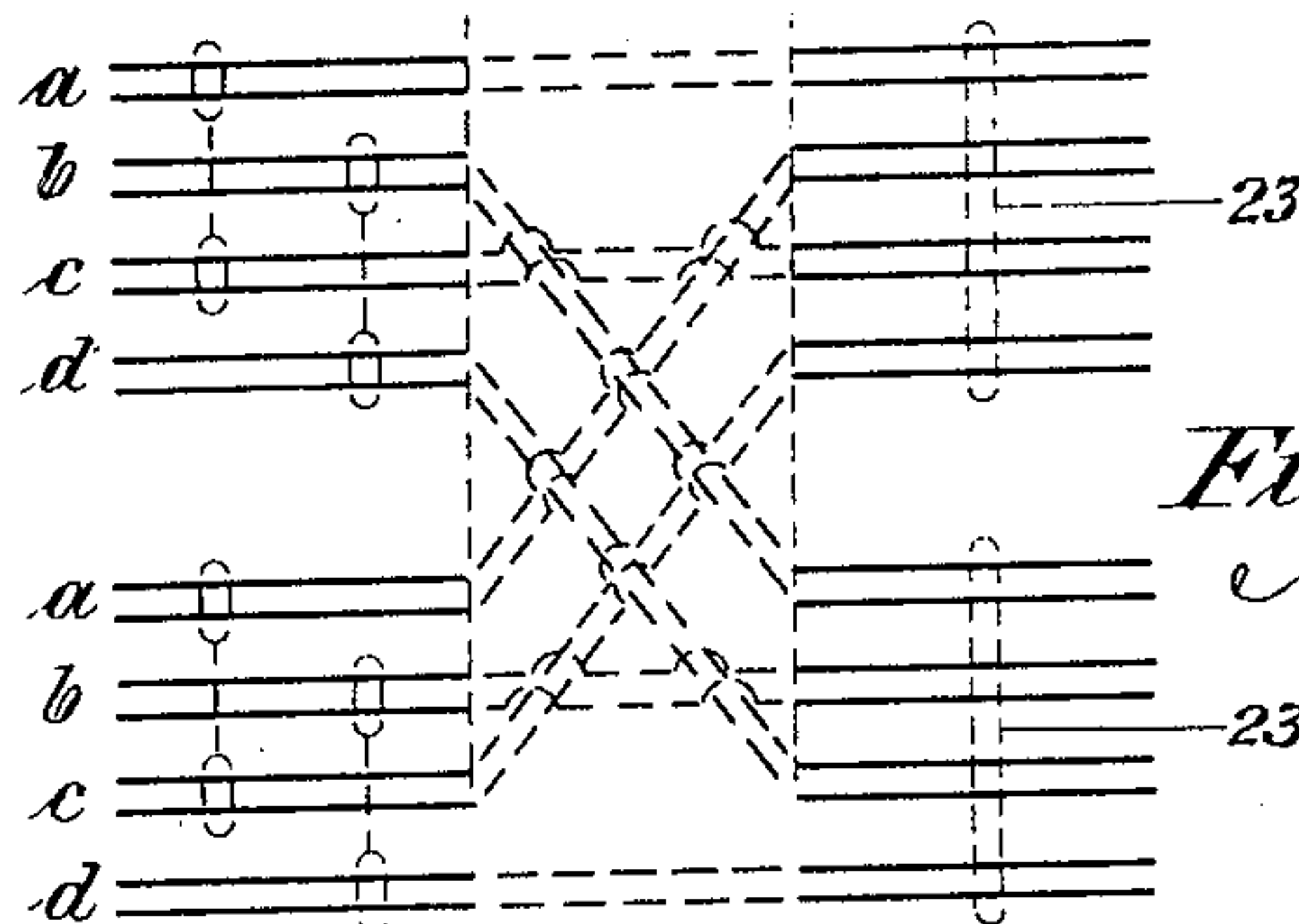


Fig. 3

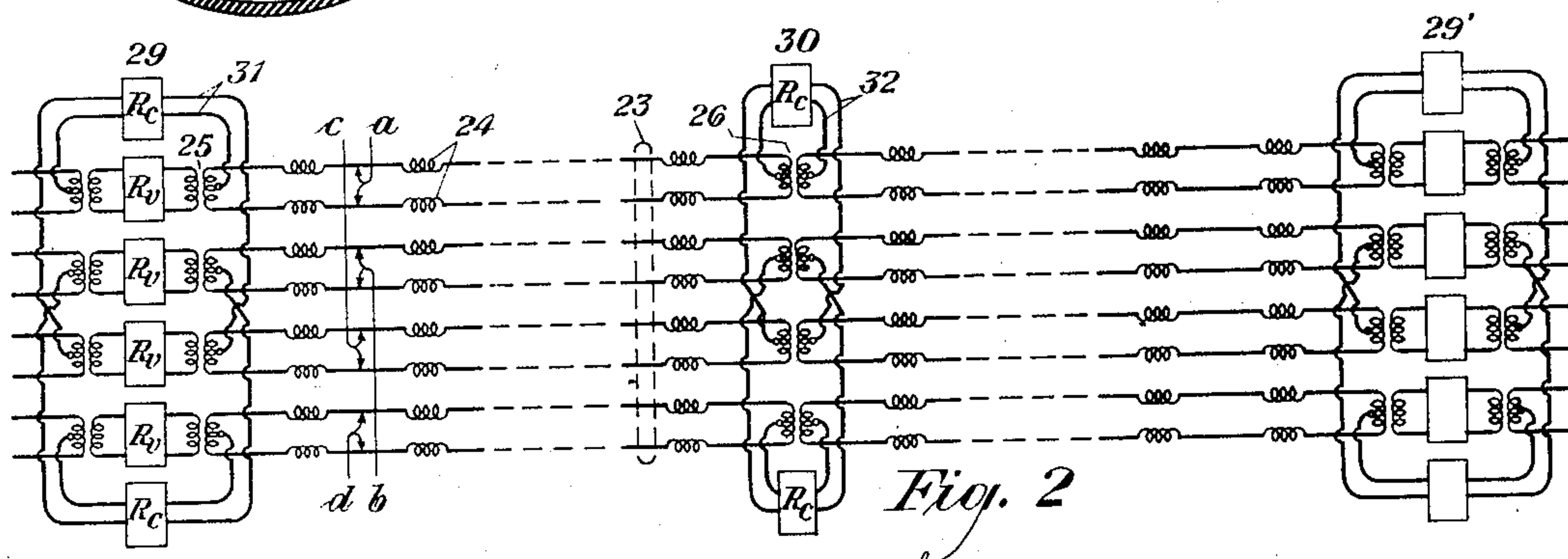


Fig. 2

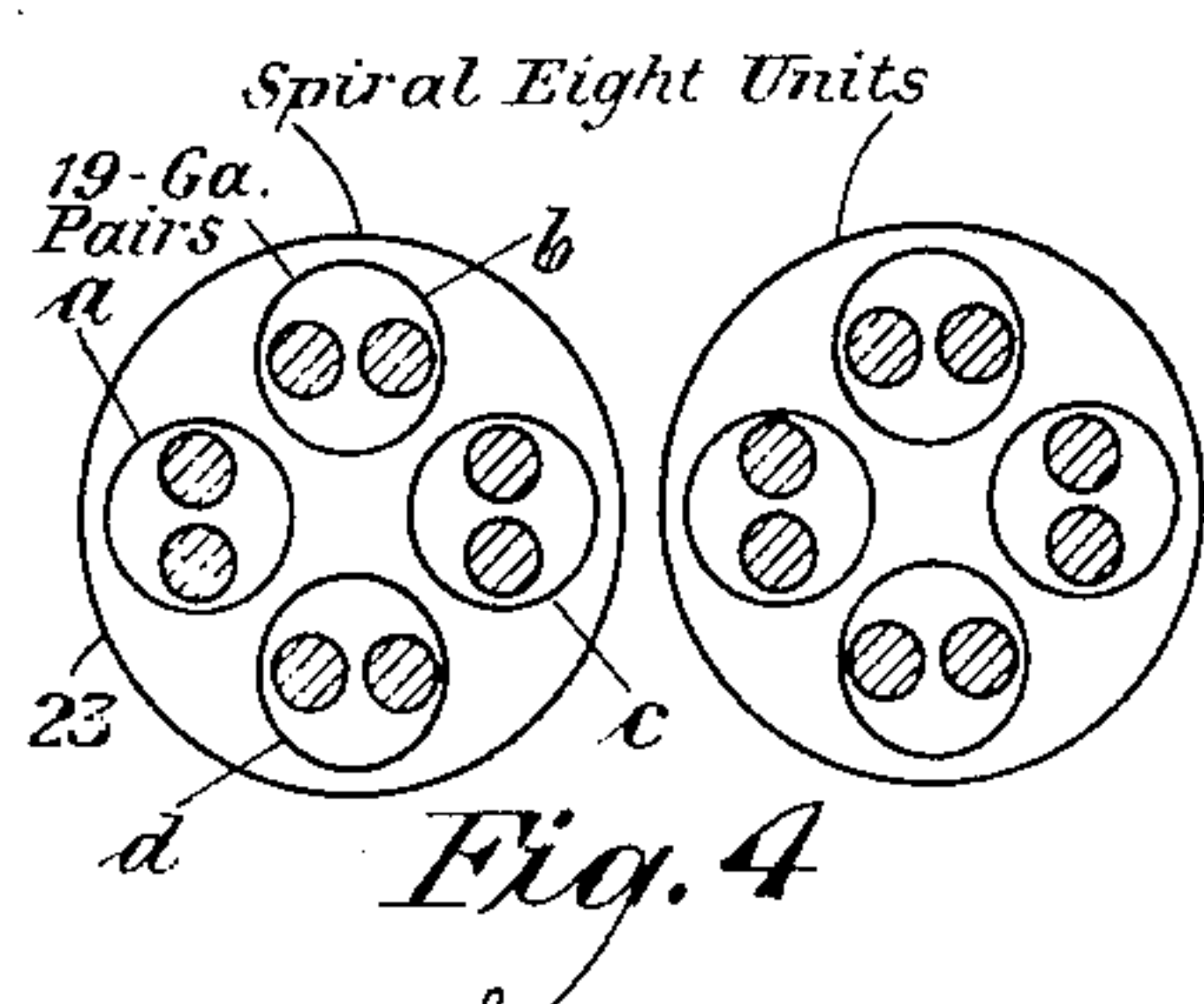


Fig. 4

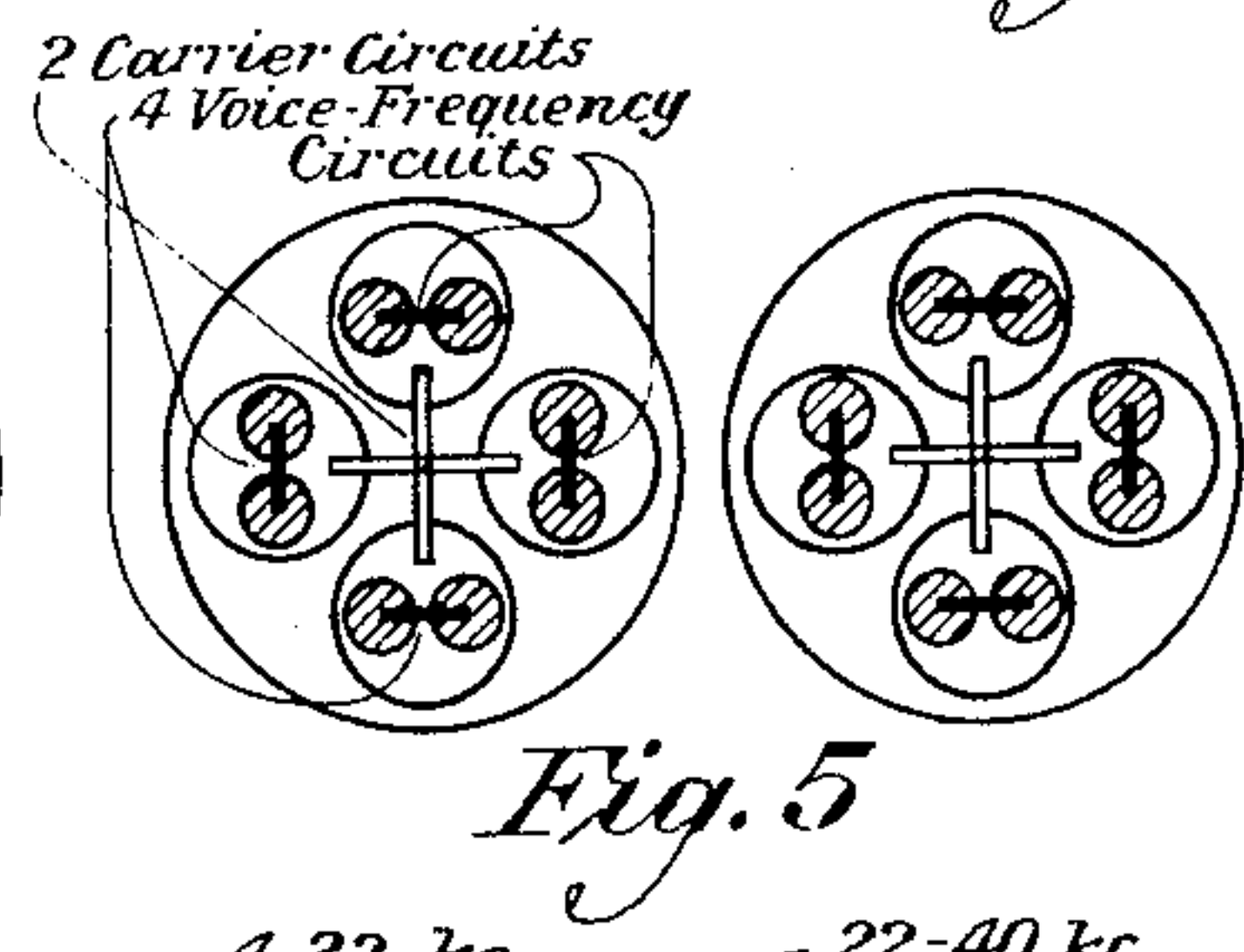


Fig. 5

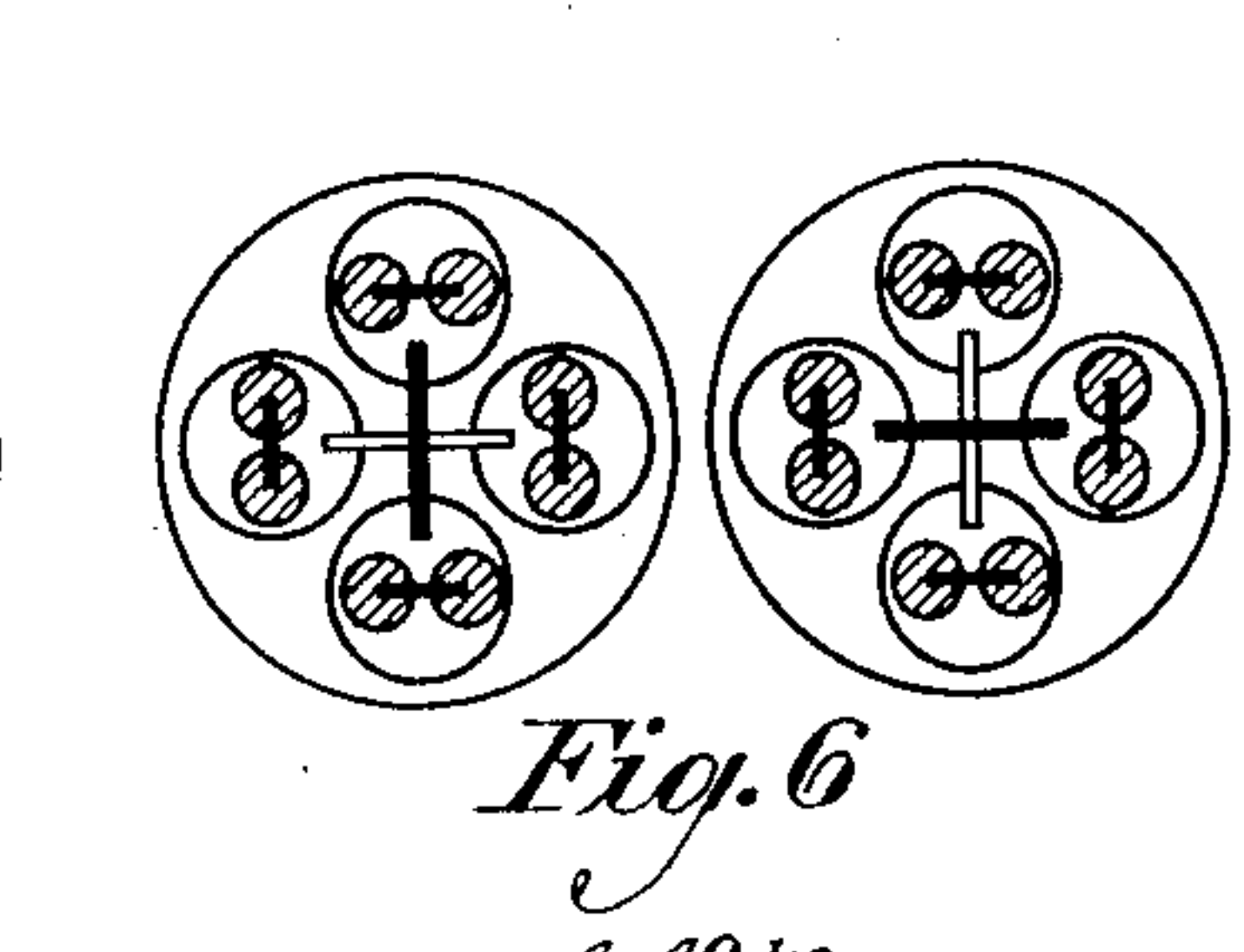


Fig. 6

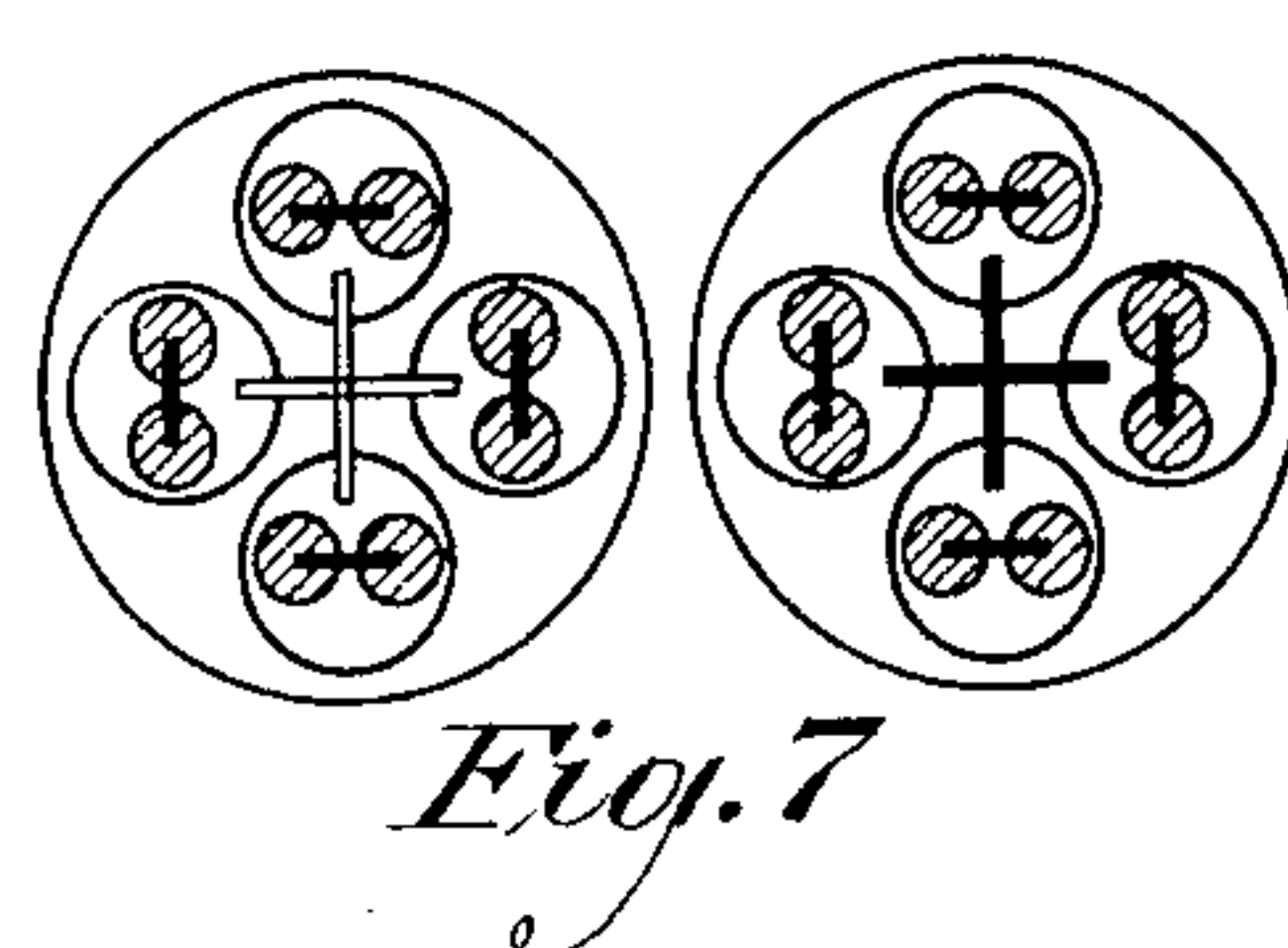


Fig. 7

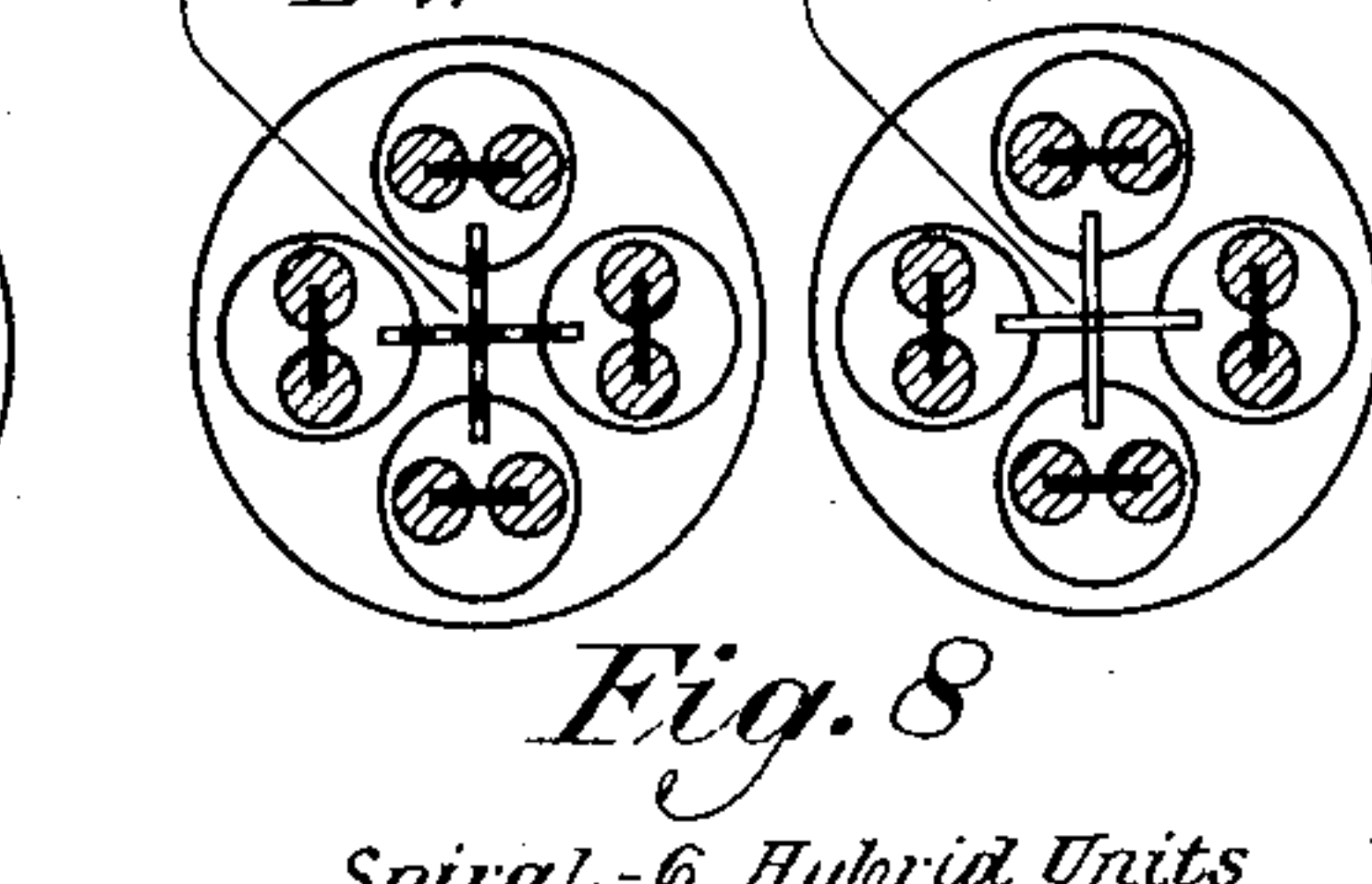


Fig. 8

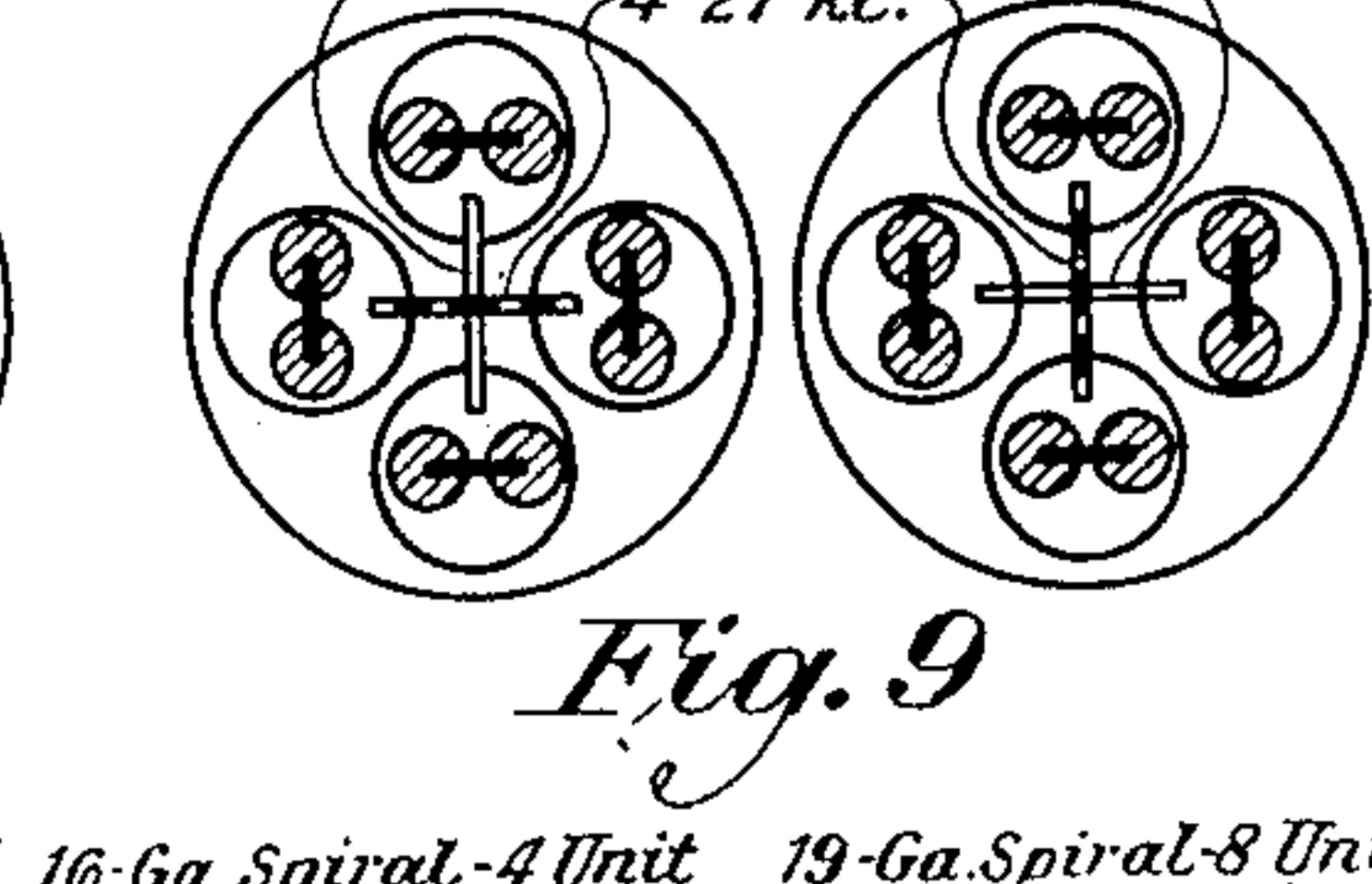


Fig. 9

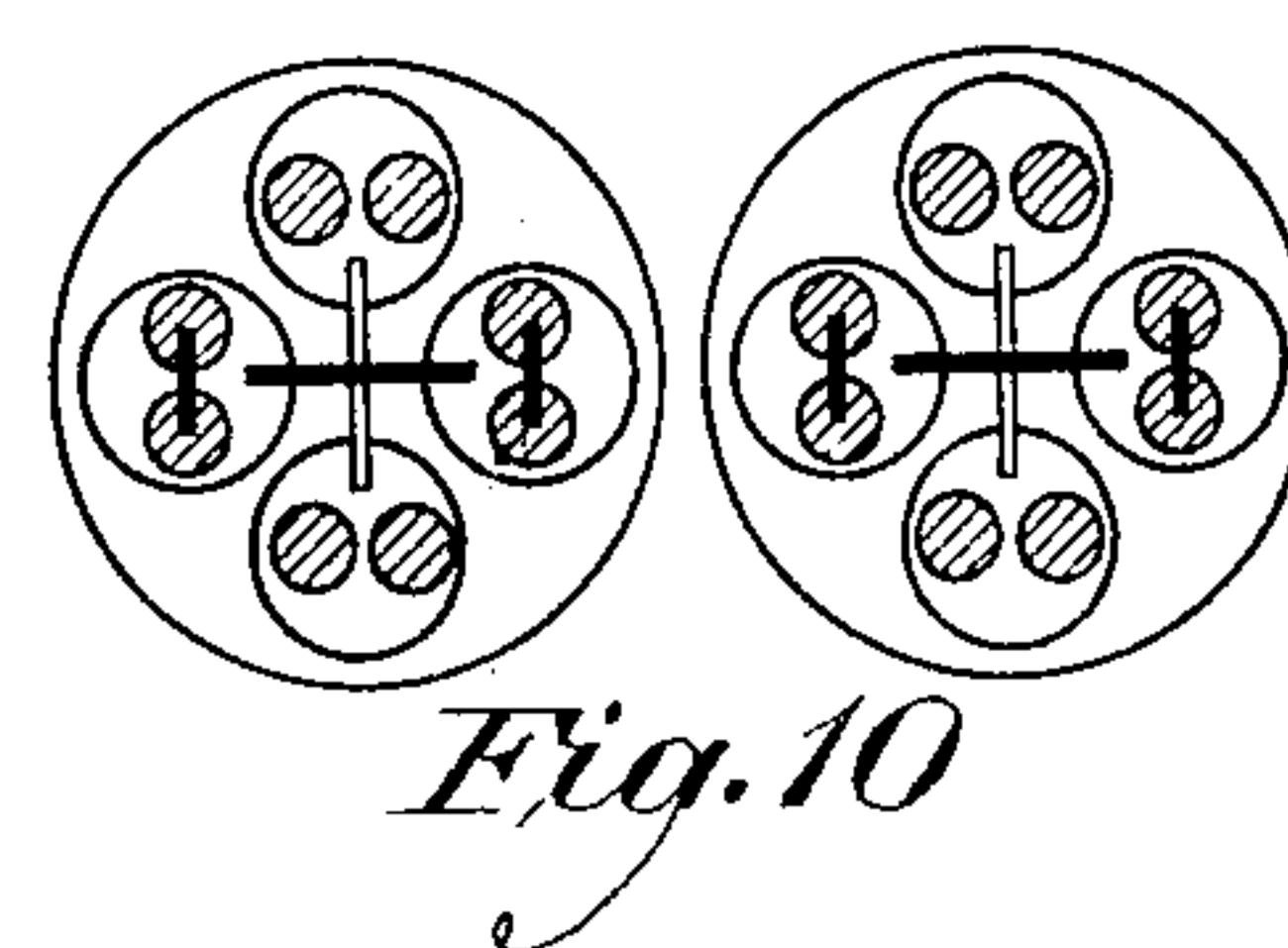


Fig. 10

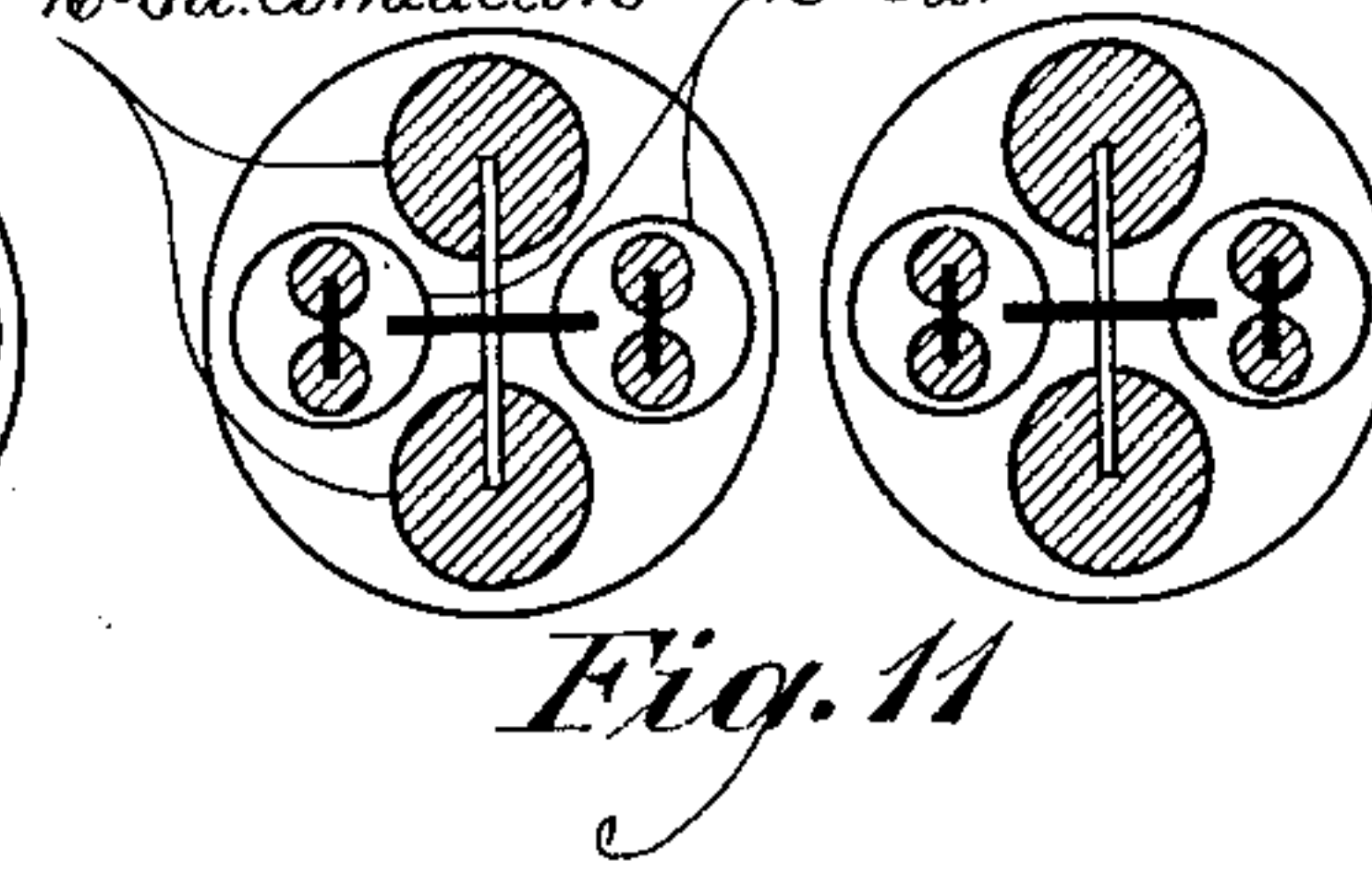


Fig. 11

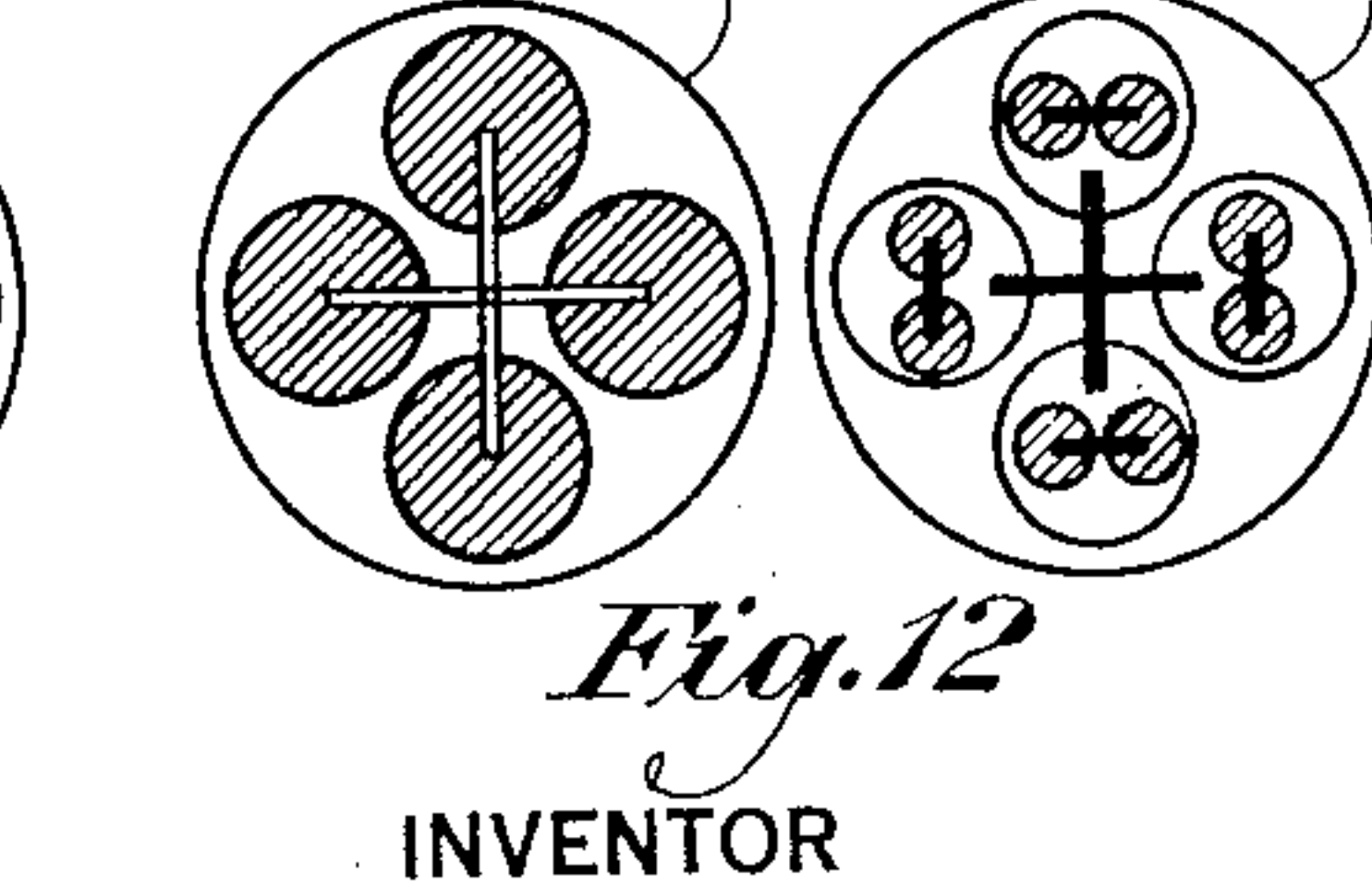


Fig. 12

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UNITED STATES PATENT OFFICE

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SYSTEM OF SIGNALING CIRCUITS IN A
MULTICONDUCTOR CABLEArthur G. Chapman, Butler, N. J., assignor to
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Application March 2, 1931. Serial No. 519,705

13 Claims. (Cl. 179—15)

Among the objects of my invention is to provide a new and improved system for utilizing a multi-conductor cable for both voice frequency signaling circuits and high frequency carrier current signaling circuits. Another object is to provide in such a cable voice frequency side circuits and high frequency carrier current phantom circuits. Still another object is to provide in such a cable units of six or eight conductors, certain of these conductors in pairs forming voice frequency signaling circuits and certain of them forming high frequency carrier current signaling circuits; more specifically, with eight conductors in a unit, certain of these are utilized in pairs as voice frequency side circuits and certain of the pairs are paired as high frequency carrier current phantom circuits. Such phantoms are advantageous for carrier frequency transmission. The tendency to greater attenuation with the high frequencies is offset to some extent by the lower resistance of the phantom as compared with the side circuit. With ordinary phantom circuits this advantage is largely lost due to increased capacitance of phantom over side. With this eight-conductor unit the capacitance of phantom does not differ greatly from that of the side. Other features of my invention have relation to transposing at the splices to reduce crosstalk, the combination of the circuits mentioned above with repeaters, and the disposition of loading coils. All these objects and various other objects and advantages of my invention will become apparent on consideration of a limited number of specific embodiments of the invention which I have chosen for disclosure by way of example in the following specification. It will be understood that this disclosure relates principally to these particular examples of practice under the invention, and that the scope of the invention will be indicated in the appended claims.

Referring to the drawing, Figure 1 is a diagrammatic cross-section of a multi-conductor cable built in accordance with my invention; Fig. 2 is a diagram showing a "spiral-8" unit in relation to repeaters; Fig. 3 is a diagram illustrating transposition of conductors at a splice; Fig. 4 is a diagram showing the spiral-8 units; Figs. 5, 6, 7, 8, 9 and 10 are diagrams showing various ways in which the available side and phantom circuits of Fig. 4 may be utilized for voice frequency circuits and high frequency carrier current circuits; Fig. 11 is a diagram showing spiral-6 units; and Fig. 12 is a diagram showing spiral-8's and spiral-4's disposed alternately in a layer in the cable.

The cable having the sheath 21 shown in Fig. 1 has twisted pairs assembled in groups, four pairs in each group, these four pairs being twisted together to form units each of which I call a "spiral-8". These spiral-8's as units are assembled in coaxial cylindrical layers, one such layer being indicated by the reference numeral 22 in Fig. 1. In each layer the unit spiral-8's are given a like helical course around the axis of the cable, and looking along this axis this helical course of the spiral-8's in one layer 22 will be right-hand as indicated by the arrow 27, left-hand in the next layer as indicated by the arrow 28, and so on in alternation.

The eight conductors of the spiral-8 23 are grouped in four twisted pairs, as already mentioned, and these pairs as units may be looked upon as forming a quad, as shown in Fig. 4, where the four pairs of one spiral-8 are lettered consecutively in order around the cross-section, *a*, *b*, *c* and *d*. Each of these pairs may be utilized as a side circuit and the two opposite pairs *a* and *c*, or the two opposite pairs *b* and *d*, may be utilized as a phantom circuit. In general, and with a few exceptions that will be noted later, I use each of the pairs such as *a* or *b*, etc., as a voice frequency side circuit, and I use the phantom *a—c* or *b—d* as a high frequency carrier current circuit.

The cable will be laid in consecutive lengths of about 750 feet, joined by splices. At greater intervals there will be loading coils, such as 24 in Fig. 2, and at still greater intervals there will be repeater stations, of which three are shown in Fig. 2. This figure shows a single complete spiral-8 unit extending through three consecutive repeater stations. At each splicing point, these points being about 750 feet apart, two opposite pairs such as *b* and *d* of the upper spiral-8 23 in Fig. 3, will be transposed with two opposite pairs such as *a* and *c* of another spiral-8 23'. These transpositions will be made systematically at the splicing points all along the length of the cable, and in accordance with well known principles will greatly reduce the tendency to crosstalk on the phantom circuits.

In Figs. 5 to 12 I employ the following symbolism which is also indicated by the legends in certain of these figures. A solid bar or dash connecting two conductors or pairs of conductors represents that they are utilized for a voice frequency circuit; an outline or skeleton bar or dash in the same relation indicates that the members are utilized for a high frequency carrier current circuit; and a dotted or checked bar or

dash indicates that the related members are used only for a limited lower part of the complete high frequency range that may be available.

In Fig. 5, according to this symbolism, the spiral-8's are all utilized alike, and in each such unit the four side circuits are used for voice frequency and the two phantom circuits are used for high frequency carrier currents. The arrangement of Fig. 5 is also involved in Fig. 2. At the repeating station 29 each side circuit such as *a* or *b* goes in and out of its corresponding repeater R_v through repeating coils 25, which are tapped at the middle point of one winding of each by the conductors such as 31, and through these the phantom circuits are continued through their respective repeaters R_c . Thus at the repeating station 29 all the four voice circuits and the two phantom circuits of the spiral-8 shown are carried through respective repeaters R_v and R_c . At the next repeating station to the right each pair such as *a* or *b*, is continued through a single repeating coil 26 and there are no repeaters such as R_v for the voice frequency side circuits. But from the midpoints of the windings of the repeating coils 26 branch conductors such as 32 are taken off, and through these and the repeaters R_c the phantom circuits are continued. Thus it will be seen that if the distance between the repeater stations such as 29 and 30 is 25 miles, then there are repeaters at 50-mile intervals for the voice frequency side circuits, but at 25-mile intervals for the high frequency carrier current phantom circuits.

The magnetic and electric coupling between the circuits such as *a*, *b*, etc., increases with frequency, and therefore the problem of crosstalk may become more acute for the carrier phantom circuits than for the voice side circuits. Accordingly, in some cases it may be advantageous to utilize only one phantom in each spiral-8 for carried frequency and used the other phantom for voice frequency, as indicated in Fig. 6. Another plan that gives the same apportionment of voice frequency and high frequency circuits is indicated in Fig. 7; here in a layer of spiral-8's both phantoms of one spiral-8 are used as carrier circuits, then in the next adjacent spiral-8 they are both used as voice frequency circuits, and so on around that layer in alternation.

Since the greatest crosstalk trouble comes with the highest frequencies as mentioned above, the plan of Fig. 8 may be advantageous to work the two phantoms of one spiral-8 at the limited upper range of 22 to 40 kilocycles but to work the two phantoms of the next adjacent spiral-8 in the same layer at the limited lower range of 4 to 22 kilocycles. In this case the upper range may be used for signaling west to east while the lower range may be used for signaling east to west.

In Fig. 9, in each spiral-8, one phantom is worked at the full high frequency range from 4 to 40 kilocycles but the other phantom is worked at the limited lower range from 4 to 27 kilocycles, thus cutting off some of the higher frequencies that would be likely to give the most crosstalk trouble.

In Fig. 10, in each spiral-8, only two of the four side circuits are utilized for voice circuits and the phantom based on these two is also used for a voice circuit. The circuit of the two remaining pairs is used for a high frequency carrier circuit; thus the conductors involved in the high frequency carrier circuits are not used for carrying voice currents. In Fig. 11, this idea is carried a little further and instead of the paired con-

ductors not used for voice currents, single solid conductors are placed as shown. This reduces the number of conductors in the unit from eight to six, and the system of Fig. 11 is called a "spiral-6".

In Fig. 12, spiral-8 units, as at the right, are laid in alternation with quads shown at the left, each of these quads being used only as two pairs for high frequency carrier currents.

In general, the transmission over the voice frequency side circuits will be two-way; that is, the two conductors will afford facility for carrying on a conversation both ways between the terminal apparatus of the two subscribers. But the carrier current circuits will be operated only one way and all their channels will be operated in the same direction within a given spiral-8, the return facility being found in some other spiral-8 of the same cable or another cable. In case part of the carrier circuits are worked one way and part the other way in one and the same cable, it may be desirable to have a shield in the cable between the two classes of circuits. The full number of channels afforded by one carrier current circuit may, for example, be nine, but obviously it will take two carrier current circuits to give nine times the facility afforded by a single voice frequency side circuit operated two ways. Accordingly, in Fig. 5 and likewise in Fig. 2, a single spiral-8 gives four voice frequency channels and nine carrier current channels. The facility afforded in the remaining Figs. 6 to 12 is generally a little less than this.

It will be seen that while the voice frequency side circuits are loaded in the usual manner, as shown in Fig. 2, it may not be advantageous to load the phantom carrier current circuits.

In a long cable stretching many hundred miles, the voice frequency side circuits will be used principally for comparatively short distance conversations, that is, for conversations between cities located at distances apart, say of the order of 100 miles. In such circuits slowness of transmission is not objectionable because the distance is too short for it to become perceptible. But for the conversations between places many hundreds of miles apart, the non-loaded phantom circuits are advantageous. A disadvantage of loading for these circuits would be the slowness that loading would introduce so that the speaker at one end would think the delay in getting his reply was because he had not been heard. However, without loading or with very light loading, the phantom carrier circuits are quick enough for the long distances.

The principle is well known that the resistance of a conductor increases somewhat at high frequencies. On the other hand, stranding the conductor obviates this disadvantage somewhat. In each of Figs. 5 to 10 the high frequency circuit conductor consists of two parallel strands, and to this extent there is distinct improvement at high frequencies as compared with putting the copper in a single conductor of the same cross-section.

I claim:

1. In combination, a multi-conductor cable comprising spiral-8 sets, each such set consisting of four twisted pairs all twisted together making four side circuits and two phantoms, apparatus limited to voice frequency range associated with certain of said side circuits, these side circuits being limited to voice frequency range, and multi-channel carrier current apparatus limited to high frequency range associated with certain of said

phantom circuits, these phantom circuits being limited to high frequency carrier range.

ratus associated only with the phantom or phantoms of opposite pairs.

2. In connection with a multi-conductor cable having the conductors grouped in spiral-8's, the method of signaling which consists in limiting the working of the side circuits of each spiral-8 to two-way voice frequencies and limiting the working of at least one phantom thereof to one-way carrier current high frequencies.

8. In a multi-conductor cable, spiral-8 units, the four pairs in each such unit forming voice frequency side circuits and the two sets of opposite pairs forming high frequency carrier phantom circuits, said side circuits being limited to voice frequency currents and said phantom circuits being limited to high frequency carrier currents.

3. A multi-conductor cable comprising spiral-8 units, each such unit having four side circuits and two phantom circuits, and in combination, voice frequency signaling apparatus associated with at least some of the side circuits, and high frequency carrier current signaling apparatus associated with at least one of the said phantom circuits, voice frequency apparatus being associated only with said side circuits and high frequency apparatus being associated only with said phantom circuit or circuits.

9. In a multi-conductor cable, spiral-8 units, the four pairs in each such unit forming voice frequency side circuits, one set of opposite pairs forming a voice frequency phantom circuit and the remaining set of opposite pairs forming a high frequency carrier current phantom circuit, said side circuits and said first-mentioned phantom circuit being limited to voice frequencies, and said last-mentioned phantom circuit being limited to high frequency carrier currents.

4. In combination, a multi-conductor cable comprising spiral-8 sets, each set affording four side circuits and two phantoms, and repeaters at certain intervals on the phantom circuits and on the side circuits at double these intervals or more.

10. In a multi-conductor cable, spiral-8 units in coaxial layers, in one unit all four side circuits and both phantom circuits being worked at voice frequencies, in the next unit of the same layer the four side circuits being worked at voice frequencies and the two phantom circuits of the same unit being worked at carrier current high frequencies, and so on around the layer.

5. A multi-conductor cable comprising spiral-8 units, each such unit having four side circuits and two phantom circuits, and in combination, voice frequency signaling apparatus associated with at least some of the side circuits, high frequency carrier current signaling apparatus associated with at least one of the said phantom circuits, and repeaters at certain intervals on said carrier current circuits and at double these intervals on said voice frequency circuits.

11. In a multi-conductor cable, spiral-8 units, the four pairs in each such unit forming voice frequency side circuits and the two sets of opposite pairs forming high frequency carrier current phantom circuits, certain of the said phantom circuits formed from the various spiral-8 units being worked at the lower part only of the entire high frequency range and certain other of said phantom circuits being worked at the upper part of the entire high frequency range.

6. In a multi-conductor cable, twisted pairs, these pairs being grouped and twisted together in spiral-8's, and these spiral-8 units being assembled in cylindrical layers, the units of one layer having a right-hand helical course, those of the next adjacent layer having a left-hand helical course, and so on along a radius of the cable, voice frequency apparatus associated with the side circuits of the spiral-8's and said side circuits being limited to voice frequency currents, and high frequency carrier current apparatus associated with certain phantoms within non-adjacent spiral-8's in each layer, the high frequency carrier currents being limited to these particular phantom circuits.

12. In a multi-conductor cable, spiral-8 units in coaxial layers, in all the units the side circuits being worked at voice frequencies, and in one unit both phantoms being worked in one direction of transmission at the lower half of the carrier frequency range and in the next adjacent unit of the same layer both phantoms being worked in the opposite direction of transmission at the upper half of the carrier frequency range, and so on around the layer.

7. A multi-conductor cable comprising spiral-8 sets, each set consisting of four twisted pairs these being twisted together compactly, said cable being spliced at intervals, and at splices two opposite pairs of each spiral-8 being transposed to another spiral-8, and in combination therewith voice frequency apparatus associated only with said pairs and high frequency apparatus

13. In a multi-conductor cable, spiral-8 units, voice frequency apparatus associated with two opposite side circuits and the phantoms thereof, said side circuits and said phantoms being limited to voice frequencies, the remaining side circuits of each spiral-8 unit being limited to frequencies outside the voice frequency range, and high frequency carrier current apparatus associated with their phantom, said phantom being limited to such frequency.

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