

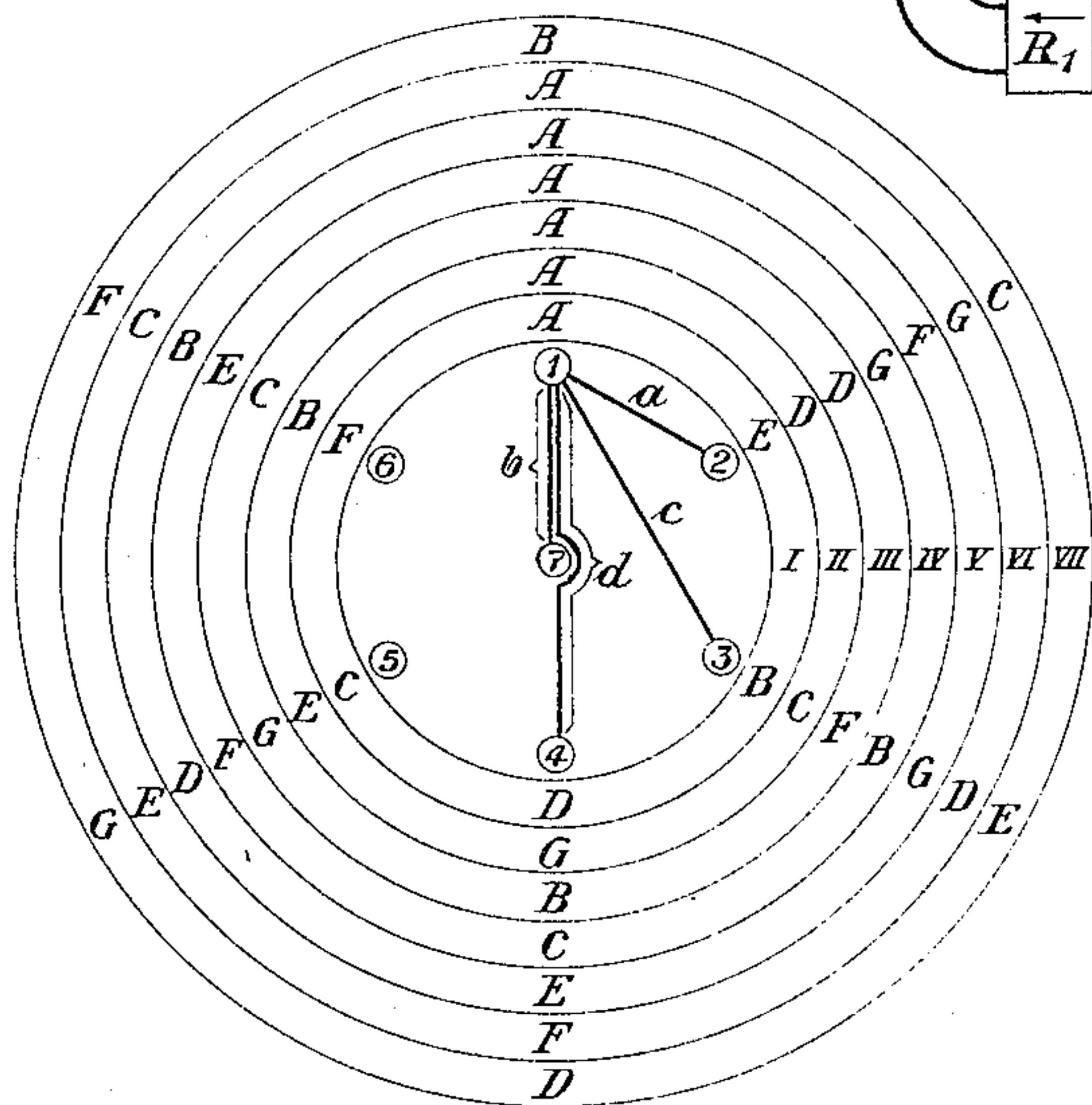
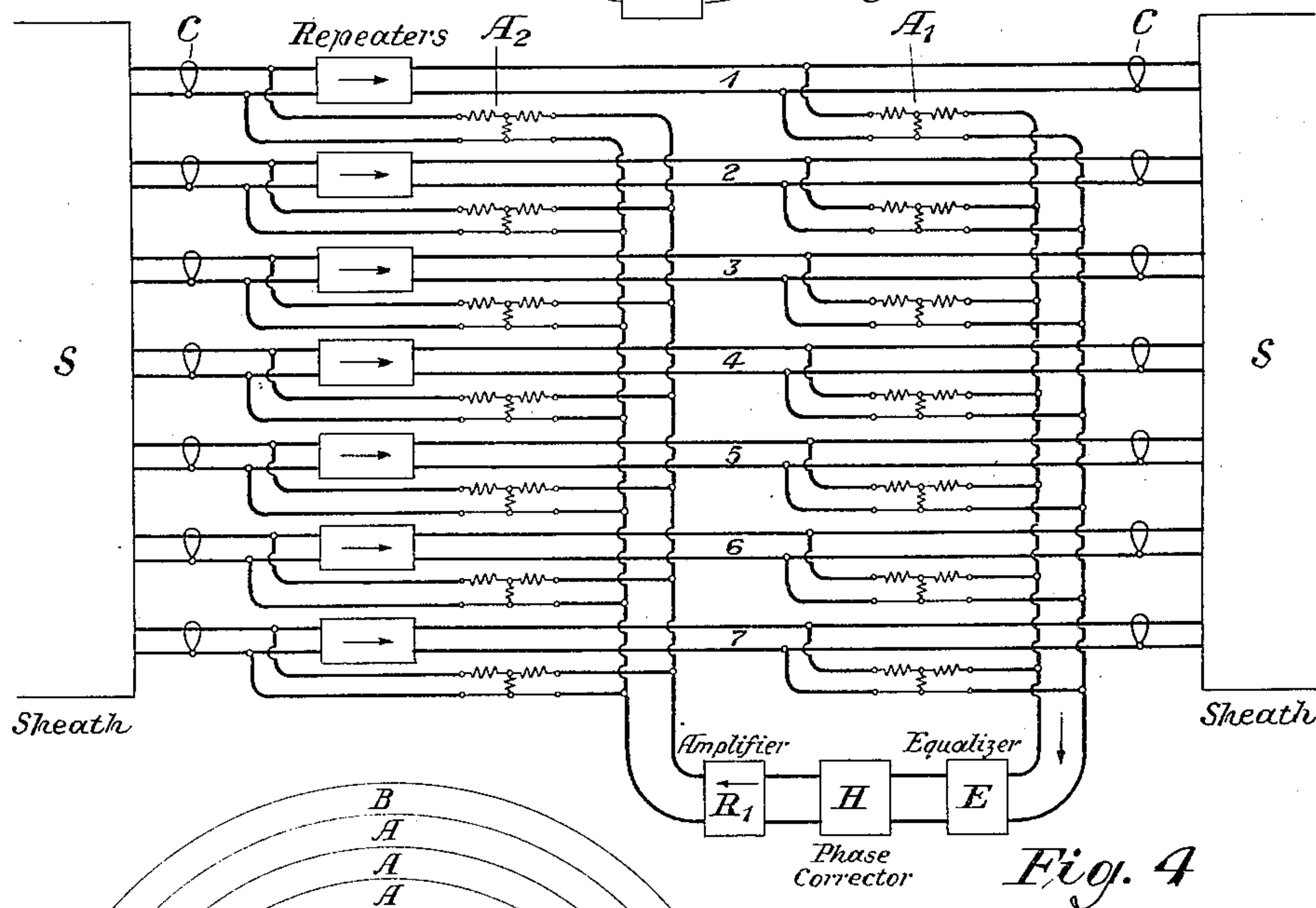
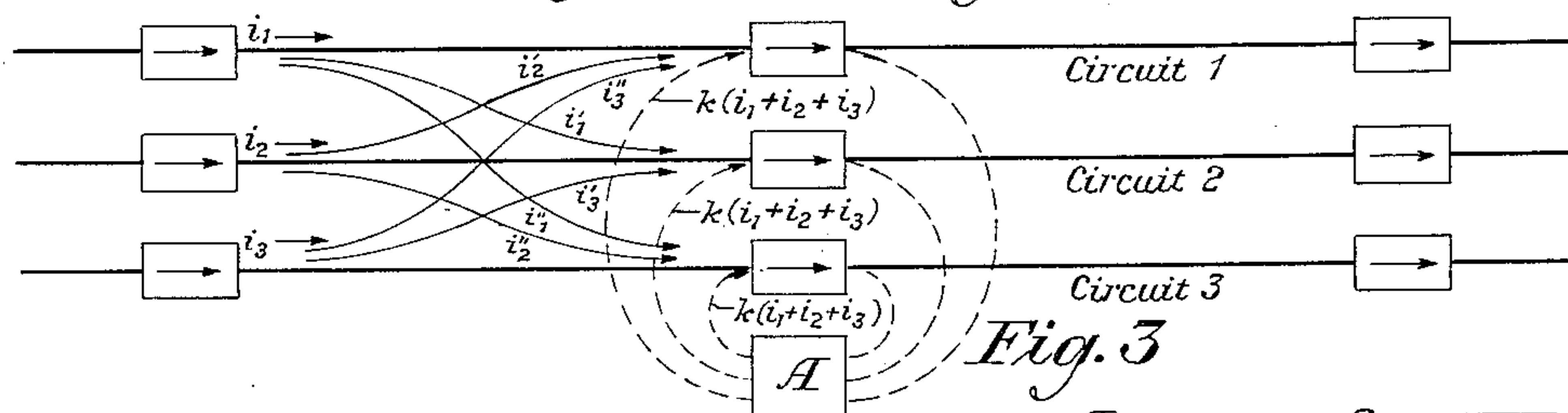
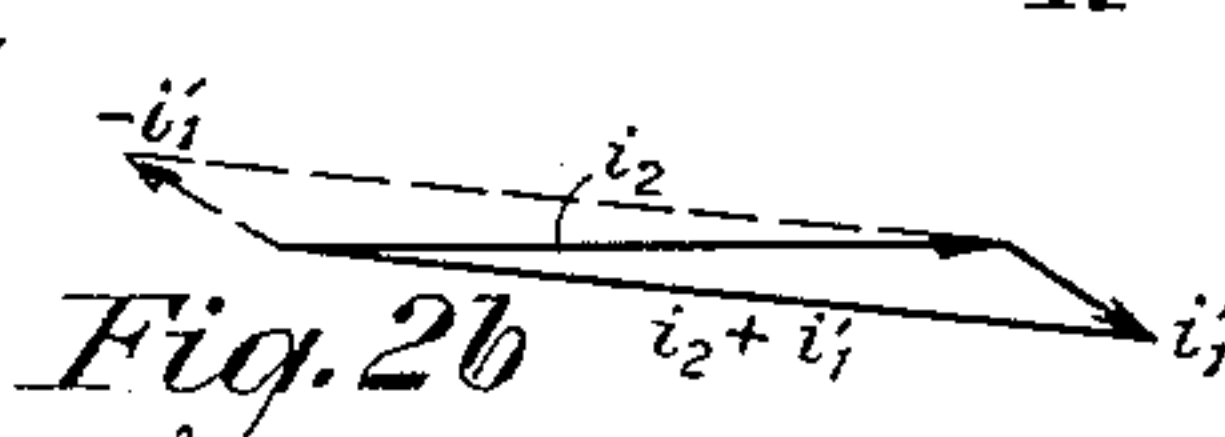
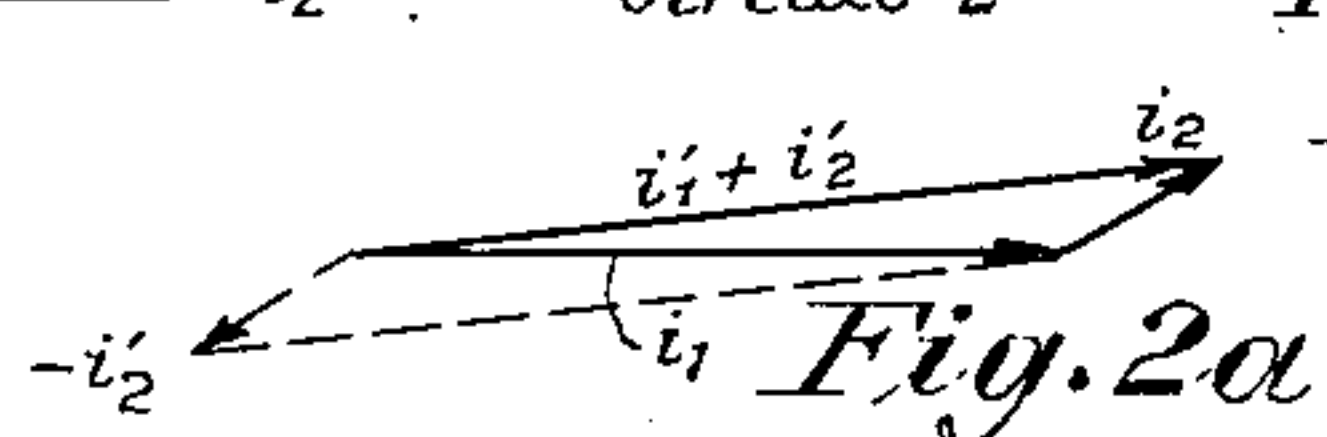
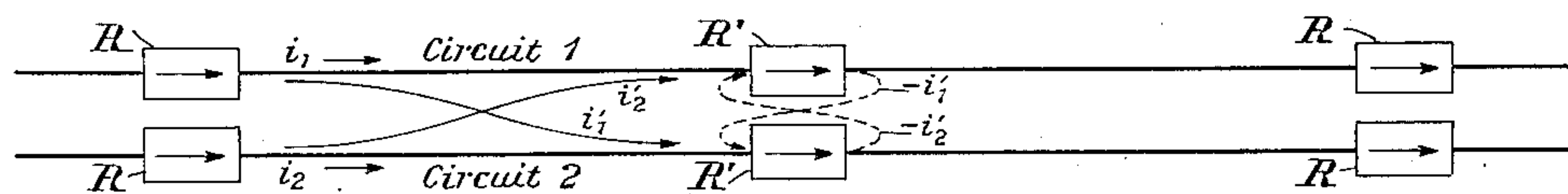
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CROSSTALK REDUCTION IN COMMUNICATION SYSTEMS

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CROSSTALK REDUCTION IN COMMUNICATION SYSTEMS

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This invention relates to crosstalk reduction and more particularly, to crosstalk reduction in a plurality of transmission lines used for communication purposes. Still further, it relates to such reduction in a cable of a plurality of coaxial conductors.

Its purpose is to reduce or eliminate the crosstalk on a line due to a plurality of other lines by positively introducing in the line or circuit a component of signal of appropriate magnitude and phase. A further purpose is to reduce such crosstalk in each and all of a plurality of cross-talking lines.

The invention will be better understood by reference to the following specification and the accompanying drawing in which Figure 1 shows a scheme for crosstalk reduction in the case of two pairs of adjacent wires and is given for illustrative purposes; Figs. 2a and 2b are explanatory vector diagrams; Fig. 3 shows my invention as applied to three pairs of transmission lines; Fig. 4 gives a circuit arrangement for seven pairs of such lines; and Fig. 5 shows a splicing diagram by which the crosstalk exposure for each of the seven coaxial conductor pairs in the cable of Fig. 4 is brought to the same value.

Referring to Fig. 1, there is shown a scheme for the reduction of crosstalk in a pair of transmission lines such as may occur in open-wire circuits or in a cable. In this figure, transmission is indicated as being in the same direction for both circuits, the currents being respectively i_1 and i_2 . If the line is of considerable length, as would ordinarily be the case, repeaters would be introduced at suitable points such as indicated. In view of their proximity to each other, there would be a certain amount of crosstalk from circuit 1 to circuit 2 and also from circuit 2 to circuit 1. The magnitude and phase of the crosstalk from circuit 1 to circuit 2 at the input of repeater R' may be indicated by i_1' and that from circuit 2 to circuit 1 by i_2' , the amount depending upon the degree of coupling between the two circuits. If, now, mutual admittances, having proper value, are connected between these circuits and current of the appropriate magnitude and phase is fed through these admittances, then it is possible to balance out the crosstalk from each circuit to the other. In the figure, this is indicated by the feeding of power from the output of repeater R' in circuit 1 to the input of repeater R' in circuit 2, and similarly, from the output of repeater of circuit 2 to the input of repeater of circuit 1.

This is made more evident by reference to the

vector diagram of Fig. 2a in which the direct transmission current i_1 of circuit 1 is represented by the vector i_1 . Due to the direct transmission current of i_2 , a small component of this current, represented by the curved arrow i_2' of Fig. 1, will crosstalk from circuit 2 to circuit 1 and is shown in Fig. 2a by vector i_2' . The resultant current which enters the repeater in this circuit thus becomes the vector sum of i_1 and i_2' and the original current i_1 has now been changed in magnitude and phase. In order to correct this condition, a small part of the output current, indicated by $-i_2'$, is withdrawn from the repeater in circuit 2 and is fed back 180° out of phase and thus exactly neutralizes the current i_2' which was originally induced from circuit 2 into circuit 1. Thus the vector diagram of Fig. 2a shows $-i_2'$ as 180° out of phase with i_2' and the resultant current of i_1 in circuit 1 is unchanged in magnitude and phase. Fig. 2b shows an exactly analogous vector diagram for the circuit 2.

It is apparent that in an open pole line system or in a cable having a great many circuits, either of the ordinary twisted pair or the coaxial conductor type, there are a large number of couplings between any one circuit and all the remaining circuits, the magnitude of the respective couplings depending upon the exposure of the one circuit with respect to the others. In order to carry into effect, then, the idea described in connection with Fig. 1, it is evident that a large number of mutual admittances would be required. The situation would be much simplified if one mutual admittance or mixing circuit could be used for all instead of one for each circuit, and this becomes possible provided the crosstalk from any one pair to any other has the same magnitude irrespective of the combination chosen. It is possible to accomplish this by splicing successive reel lengths in such a manner that along a repeater section each circuit within the cable has a total equal exposure to every other circuit, and that each exposure results in the same amount of crosstalk whenever it occurs. This situation may be obtained in an open-wire, pole line system or in a cable with twisted pairs, although in general it would be with difficulty. It is more readily obtained in the type of crosstalk which occurs between parallel coaxial conductors because of the use of shielding to reduce the crosstalk. This results in a crosstalk which is very uniform and symmetrical and does not depend largely upon the geometrical perfection of the arrangement of the conductors which can be reached in manufacture but is determined by

the primary dimensions and arrangements of these conductors and is substantially independent of any small deviations in them. While my invention is applicable to any of the three types of circuits mentioned, it is peculiarly adapted to coaxial conductors for the reasons given above, and I find that they will permit the use of one mixing circuit for the purpose of feeding back currents such that they will balance out the crosstalk in the various circuits.

As explanatory of my invention, whether applied to one type of transmission line or another, there is shown in Fig. 3 the currents when three circuits are employed. In this case, if the circuits have been designed or adjusted for equal exposure between repeater stations, then there will be equal components of crosstalk current from circuit 1 to circuits 2 and 3. Equal components also crosstalk from circuit 2 to circuits 1 and 3, and a similar condition occurs due to the current in circuit 3. With the proper splicing arrangement, so as to give equal exposure, the crosstalk in all three circuits will then have equal magnitudes and in order to compensate for this crosstalk, equal amounts of currents are fed through a mixing device A to the input side of the repeaters in such a manner that they will be 180° out of phase and, consequently, balance out the crosstalk in each circuit. This incidentally results in feeding back a small amount of main transmission in reverse phase but this simply reduces the repeater gain somewhat and is, therefore, of minor importance.

In Fig. 4 there is shown a repeater station at some intermediate point in a cable, the two sheath ends of which are shown at s. The cable is indicated as carrying seven conductor pairs although the number may be greater and, in this particular instance, these pairs are coaxial conductors as indicated by means of the circles C. Each coaxial pair as it comes out of one cable section passes through a repeater and then on into the next cable section. From the output of the repeaters of each of the coaxial pairs numbered 1 to 7, there are derived circuits which are connected in parallel to the input of an equalizer E, the circuit from which then continues to a phase corrector H and a repeater R₁. From the output of the repeater, the circuit divides with a branch going to the input of each of the repeaters.

On the assumption that, previous to going to the repeater station, the various sections have been so spliced that each one of the circuits 1 to 7 has the same exposure to each of the other circuits, crosstalk coupling to each circuit will be identically the same. Under these circumstances, the feed-back of power from the output of each of the repeaters into the mixing repeater R₁ and from there to the input of each of the repeaters will bring about the neutralization of crosstalk, all in a manner described in connection with Figs. 1 to 3.

It is, of course, important that there shall be no appreciable reaction directly from the output of one circuit such as 2 to the output of another circuit such as 1. For this reason, there is introduced in the derived circuit from the output of each repeater an artificial line or attenuator A₁. Attenuation in these should be sufficient to make the coupling between these output circuits negligible. The equalizer E is for the purpose of allowing for variations with frequency of the original crosstalk currents. In the event that the invention is used in connection with twisted pairs in cable, it is noted that the crosstalk increases with

increase in frequency. On the other hand, for the coaxial construction of conductors it decreases with an increase in frequency. In either event, some device is required which will permit the correct amount of current to be fed back at all frequencies and the equalizer E is given such frequency characteristics as to bring this about.

Following the equalizer, the currents pass through a phase corrector H, the purpose of which is to allow for the original phase shift in the crosstalk and to correct any phase shift introduced by the equalizer and amplifier so that the total shift in phase with respect to crosstalk will be 180°. The necessity of the amplifier R₁ depends upon the values which must be assigned to the artificial lines or attenuators and upon the amount of crosstalk existing. It is, however, a desirable device in itself in this connection because of its inherent unilateral properties. From the output of the repeater, which automatically reverses the phase 180°, the currents are fed through other artificial lines A₂, the purpose of which has already been explained, back to the input side of the various repeaters in direct phase opposition to the original disturbing currents, thus balancing out the crosstalk.

The matter of obtaining the same exposure for each transmission line from one repeater station to the next repeater station obviously becomes of importance in the carrying out of this invention. In the case where seven conductor pairs are used and these are not symmetrically located with respect to each other, it can be readily shown that there would be 21 different coupling coefficients, and to obtain equalization 21 transpositions or splicing arrangements will have to be used. If there is any symmetry, then this number will, of course, be reduced. Thus, in a cable sheath carrying seven coaxial conductors, one centrally located and the other six circularly spaced around this central one, the different kinds of couplings will be reduced to four, indicated by the letters a, b, c and d of Fig. 5. The coupling from 1 to 6 will be the same as from 1 to 2 and from 1 to 5 the same as from 1 to 3. In this case, it can be shown that equality of exposure can be obtained with as few as seven transpositions or splicing arrangements. These splicing arrangements are shown in Fig. 5, in which the successive rings, denoted I, II . . . indicate successive splicing sections in the cable. The positions of the circuits in the cross-section of the cable in the successive splicing sections are indicated by the letters A to G, it being understood that the circuit for that letter which does not appear in the circle of one splicing section occupies the center of the cable for that section. An inspection of this arrangement will show that if the transmission line between two points at which the feed-back arrangement is to be applied, is divided into seven sections with transposition at the splicing points as indicated by the successive rings, there will then be equal crosstalk exposure for each conductor pair from all of the others.

What is claimed is:

1. In a plurality of more than two transmission lines each giving crosstalk to the others and containing repeaters, the method of eliminating crosstalk which consists in rendering the exposure of each line to the others the same for each line and supplying to each line at the input of a repeater a definite amount of power from the output of the repeaters of all the other lines of such magnitude and such phase relationship as to neutralize crosstalk therein from the other lines.

2. In a communication system, a plurality of more than two pairs of transmission lines subject to crosstalk from each other and adjusted so that each line has the same crosstalk exposure to all the other lines, a repeater in each line at a given point, circuits for withdrawing power from the output of each repeater, bringing these circuits to a common mixing circuit and supplying power from the output of the mixing circuit to the input of each repeater of such magnitude and such phase as to neutralize the crosstalk.

3. In a communication system, a plurality of more than two pairs of transmission lines subject to crosstalk from each other and adjusted so that each line has the same crosstalk exposure to all the other lines, means for withdrawing power from each line to a common mixing point, and means for supplying power from the common mixing point from all the lines to each line of such magnitude and such phase relationship as to neutralize the crosstalk.

4. In a communication system, a plurality of more than two pairs of transmission lines subject to crosstalk from each other and adjusted so that each line has the same crosstalk exposure to all the other lines, a mixing circuit, a derived circuit from each line at a given point bringing power from each line to the input of the mixing circuit, a circuit from the output of the mixing circuit to each line and associated therewith to supply power to each line from all the other lines of magnitude and phase to neutralize crosstalk in the lines.

5. In a communication system, a plurality of more than two pairs of transmission lines sub-

ject to crosstalk from each other and adjusted so that each line has the same crosstalk exposure to all the other lines, a unilateral repeater, a derived circuit from each line to the input of the repeater acting as a mixing circuit, a circuit from the output of the repeater to each line and associated therewith to supply power to each line from all the other lines of magnitude and phase to neutralize crosstalk in the lines.

6. The combination of claim 4 characterized by the fact that there is a phase corrector in series in the mixing circuit.

7. The combination of claim 4 characterized by the fact that there is a phase corrector and an equalizer in series with the mixing circuit.

8. The combination of claim 4 characterized by the fact that there are attenuating means in each circuit from the lines to the mixing circuit.

9. The combination of claim 4 characterized by the fact that there are attenuating means in each circuit from the lines to the mixing circuit and from the mixing circuit to the lines.

10. The combination of claim 5 characterized by the fact that there are attenuating means in each derived circuit from the lines to the mixing circuit and from the mixing circuit to the lines.

11. The combination of claim 5 characterized by the fact that there are attenuating means in each circuit from the lines to the mixing circuit and from the mixing circuit to the lines and that the mixing circuit itself includes a phase corrector and an equalizer.

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