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RADIO SIGNALING SYSTEM

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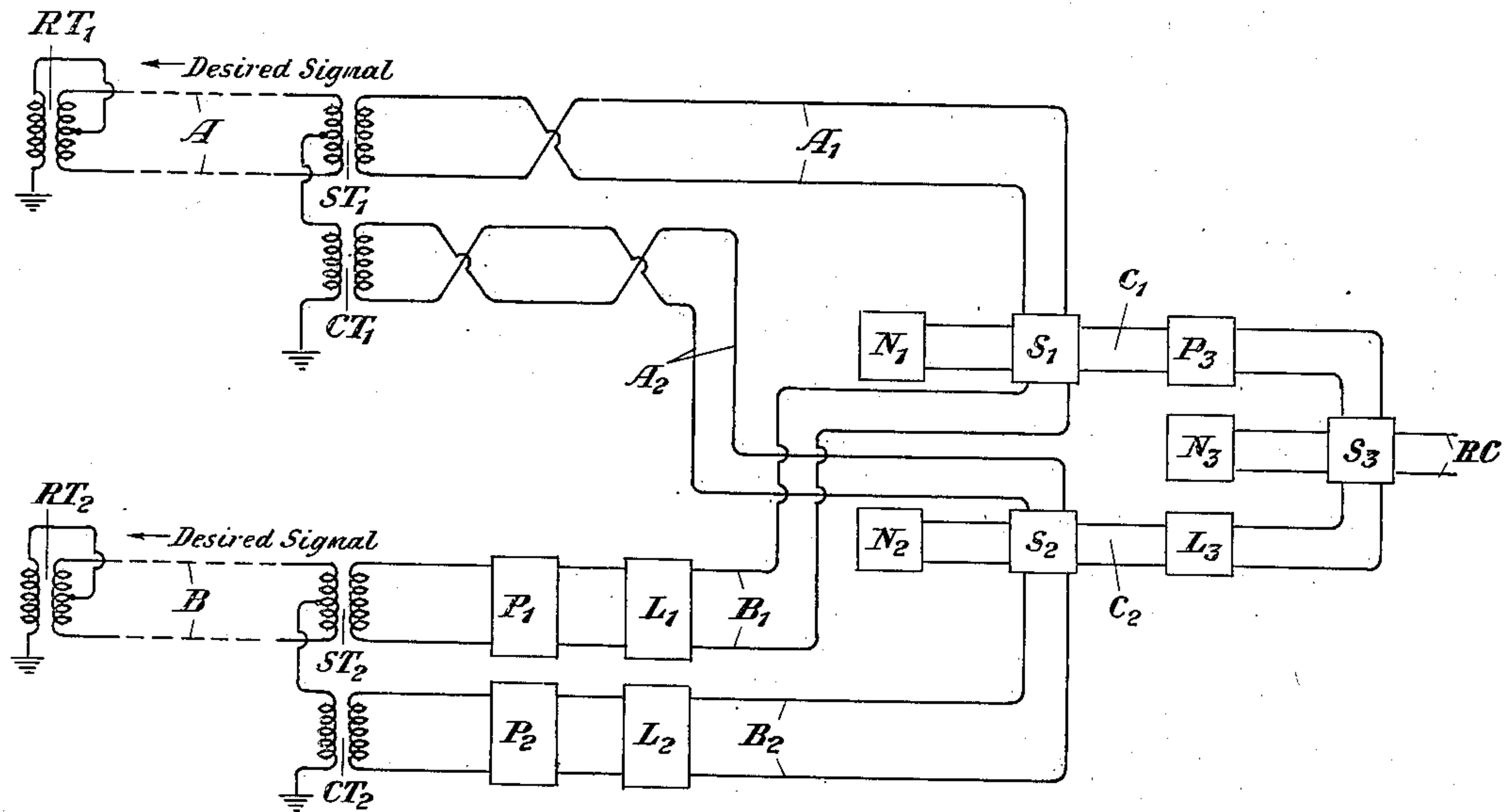


Fig. 1

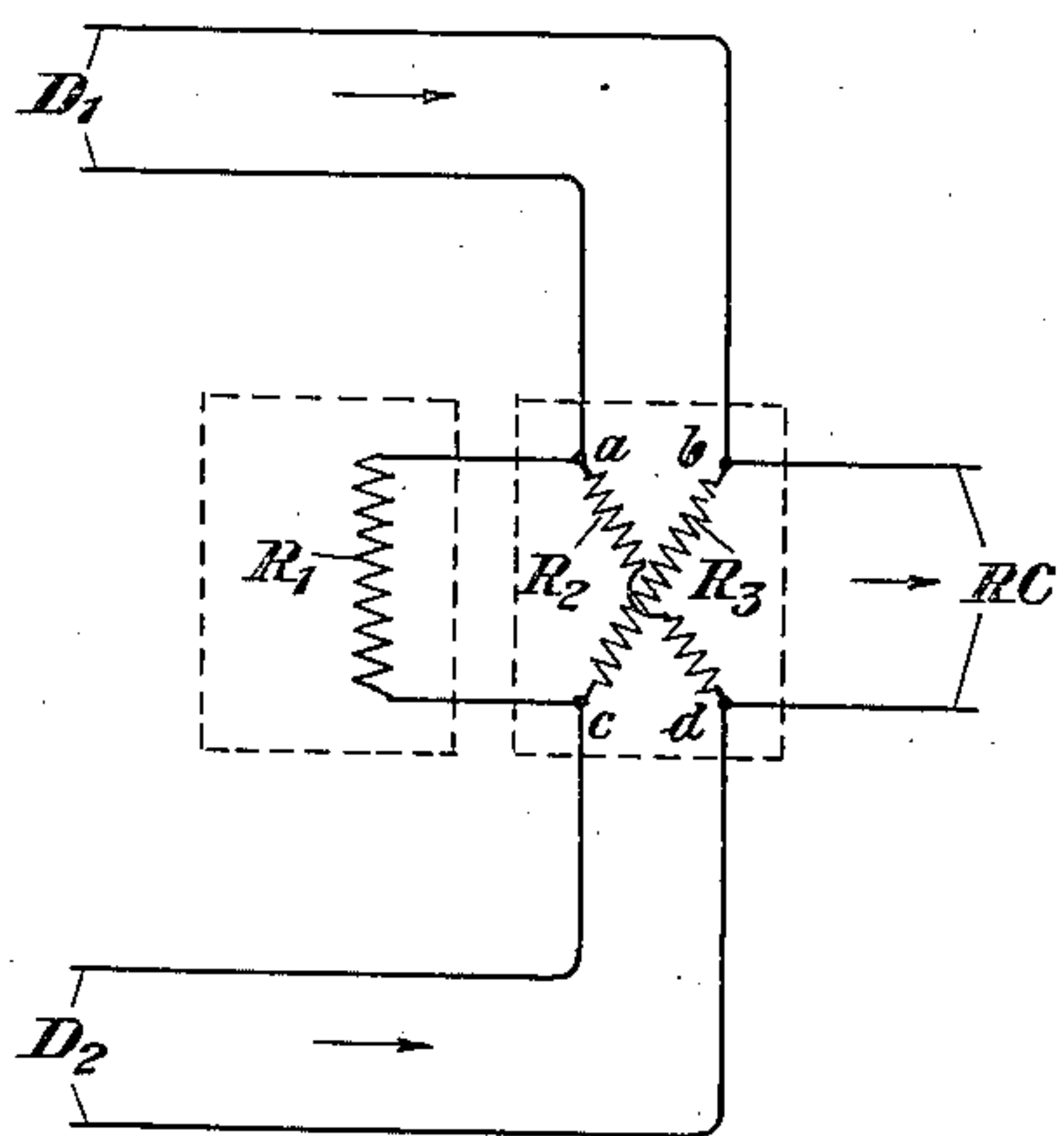


Fig. 2

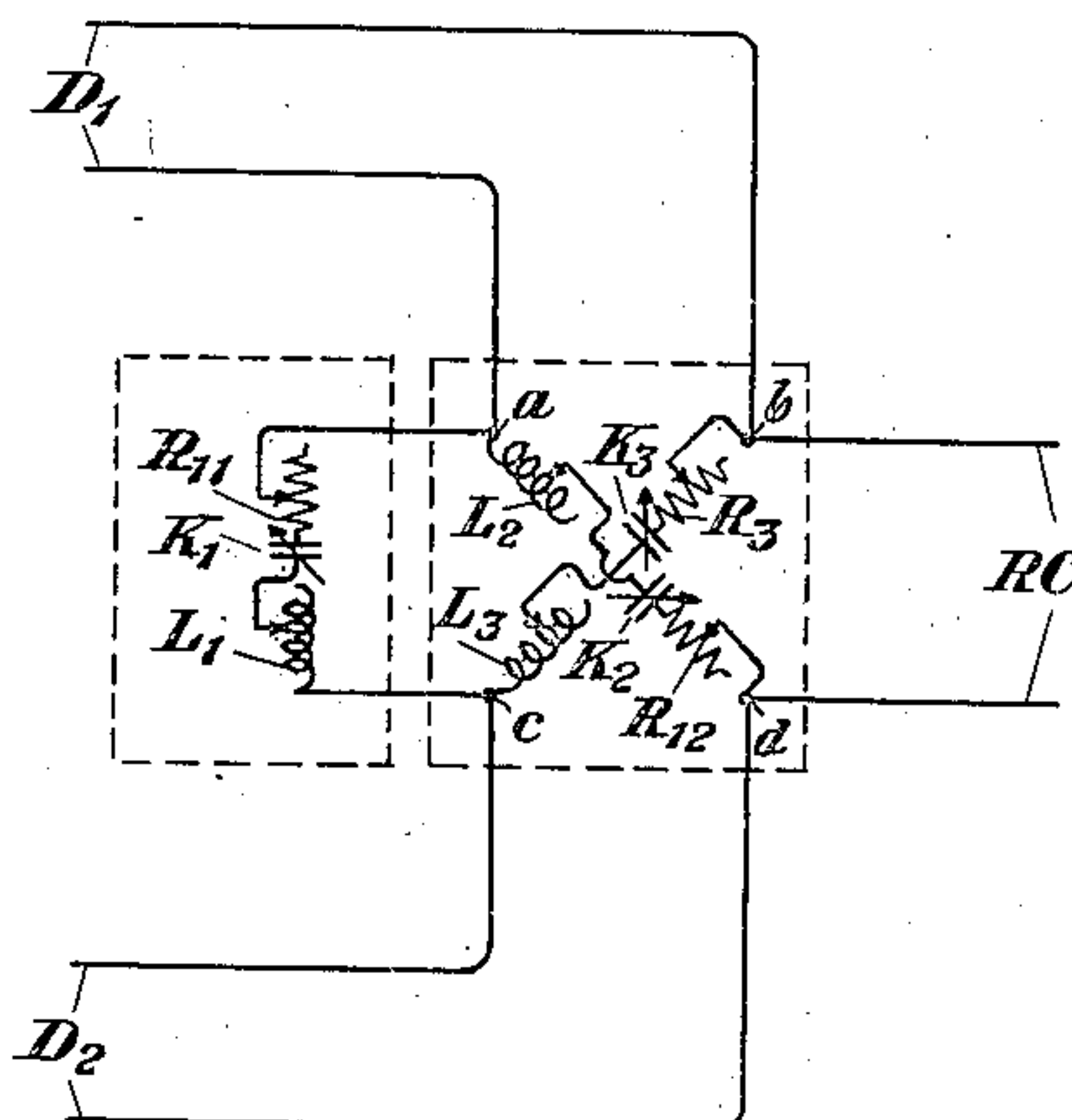


Fig. 3

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RADIO SIGNALING SYSTEM

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This invention relates to radio transmission systems and particularly to arrangements in such systems for combining the outputs of two or more circuits.

5 In radio receiving systems in which it is necessary to maintain a high degree of selectivity in reception, highly directive antenna systems are particularly desirable. Directive antenna systems are usually obtained by
10 combining the outputs of several antennæ which may or may not be themselves directive. Such systems of antennæ are usually known in the art as antenna arrays. This invention particularly relates to a means for
15 combining the outputs of such an array and equally well for combining two or more output circuits derived from a single antenna.

One form of antenna which has been found to be highly successful in practice is known
20 in the art as the "wave antenna". While this invention will be disclosed with particular reference to its use in connection with a wave antenna or an array of wave antennæ, it will be apparent that it is applicable to
25 any antenna array.

In an ordinary use of wave antennæ, as is well known in the art, a small fraction of the interference or noise voltages developed in the surge resistance of a wave antenna
30 may be used to balance out undesired interference and noise received by the antenna from a direction different from that of the desired signal. This process of neutralization is termed "compensation" and may
35 serve in effect to produce zero or negligible reception at any desired angle, i. e., at any angle different from the angle of the desired signal.

The directivity of a receiving system may
40 be increased by the use of parallel wave antennæ spaced apart a certain fraction of a wave length in a direction at right angles to that of the desired signal, each wave antenna, however, being substantially parallel to the
45 line of travel of the desired signal. Such an arrangement is often referred to as a "broadside wave antenna system" and its effect, in general, is to increase the directivity or rather the discrimination against
50 signals or noise coming from other than the

desired direction. In such a system, compensation may also be employed to reduce the reception of interference or noise to a considerable extent.

In accordance with the present invention, 55 it is proposed to bring to a common point not only the desired signals impressed upon two or more wave antennæ but also voltages representing undesired signals or interferences which may be set up in antennæ by
60 waves or disturbances in space. The signals which may be brought to the common point from the wave antennæ may be combined under suitable conditions of phase and amplitude and similarly the voltages represent- 65 ing undesired signals or interferences may also be combined under similar conditions of phase and amplitude. The latter voltages may then be utilized to balance out noise and interference coincident with the desired sig- 70 nals in the terminal circuit of the said wave antennæ.

In order to accomplish the object of this invention, means may be provided for combining the outputs of the wave antennæ so 75 that there will be a somewhat additive effect for the desired signals in the output of the combining means and so that there may be zero or negligible interaction between the input circuits of the combining means. In 80 other words, it is intended to provide means whereby the currents flowing in the input circuits may be mutually independent and non-reactive and still these currents may become suitably combined by the combining means. 85 One form of combining means which will be described hereinafter comprises a number of impedance elements, interconnecting an output circuit which may lead to a radio receiver and two input circuits over which the cur- 90 rents to be combined may flow. In the particular form of combining network to be described hereinafter, the impedance of each of these elements is preferably equal to the impedance leading into the output or receiv- 95 ing circuit. Moreover, currents impressed upon one of the input circuits by one or more of the wave antennæ cannot become impressed upon the other of the input circuits similarly connected to one or more of the 100

wave antennæ, and vice versa. Also, if the desired signals impressed upon the respective input circuits are brought into phase equality, the output or receiving circuit may receive the energy of the desired signals, some of this energy in the input circuits being, however, lost in the impedance elements by virtue of the resistance components of these elements.

While this invention will be pointed out with particularity in the appended claims, the invention will, nevertheless, be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawing in which Figure 1 shows one form of receiving system to which this invention has been applied, the system comprising two antennæ connected in broadside, Fig. 2 represents a network composed of elements of resistance forming a combining circuit, and Fig. 3 represents a network composed of elements of reactance as well as of resistance to form a combining circuit.

Referring to Fig. 1 of the drawing, two wave antennæ A and B are shown, each consisting of two or more parallel wires extending across the country substantially parallel to the direction of travel of the signals to be received. It is to be distinctly understood, however, that the principles of this invention may be applied to any number of wave antennæ or other antennæ constituting an array. Assuming that each antenna extends, for example, from east to west, then a signal which comes from the east gradually builds up by increments, reaching its maximum value at the west end of the antenna. In other words, the current in the antenna will gradually grow in amplitude as the signaling wave travels along its surface. Yet, if it is desired to receive the signaling wave which approaches the antenna from the eastern direction, the amplitude of the current set up by the signaling wave at the eastern terminal of the antenna will be extremely small, if not negligible. While, at the western terminal, the amplitude of the current will be considerably larger and a maximum.

It may sometimes be necessary to locate the receiving apparatus near the eastern terminal of the antenna. In order to permit such a location, the antenna is terminated at the western terminal in a reflection transformer such as RT_1 , so that the antenna conductors serve not only to pick up the waves in space but also may be employed as a transmission line for transmitting from the western terminal to the eastern terminal, the currents resulting from the voltages built up in the antennæ. The midpoint of the secondary winding of the reflection transformer RT_1 is connected through the primary winding of that transformer to ground. By means of these connections, the current flows

to ground through the primary winding of the reflection transformer RT_1 and the voltage created thereby across the winding bridging the conductors of the antenna A causes the flow of current over the conductors as a metallic circuit. At the eastern terminal of the antenna another transformer ST_1 is located, the midpoint of the primary winding of which is connected to ground through the primary winding of another transformer CT_1 , which is so constructed that with its attached circuits, it serves to properly terminate the antenna. The resistance thus interposed between the eastern terminal of the antenna A and ground is often spoken of as the "surge resistance." The transformer ST_1 associates the metallic circuit of the antenna A with a transmission line A_1 , this line leading to a receiver by way of apparatus to be subsequently described. The voltage resulting from an undesired signal builds up in each conductor of antenna A in the opposite direction, i. e., from west to east along the antenna and substantially equal currents resulting therefrom will flow through the halves of the primary winding of transformer ST_1 oppositely to ground (by virtue of the connection to ground of the midpoint of the primary winding of transformer ST_1) thence through the primary winding of the transformer CT_1 . No effects will be produced in the secondary winding of the transformer ST_1 and accordingly the local line A_1 will be substantially unaffected by such currents.

A wave antenna of the type described exhibits considerable directional selectivity, receiving signals flowing from east to west with high efficiency. Since this wave antenna is not purely unidirectional in its characteristic as discussed hereinabove, signals approaching at angles substantially different from the angle of desired signals may also be received. While the energy level of such signals may be relatively low, the level may be sufficient, however, to cause the introduction of noise and interference into the receiving circuits. The amount of noise or interference introduced by signals different from the desired signals will depend upon the direction from which they are coming. Signals coming, for example, from the north and from the south i. e., perpendicularly to the antennæ, will hardly be received, if at all. Yet, it may be important to compensate or balance out the noise or interference derived from signals coming from still other directions.

So far, the apparatus has been described with respect to a single wave antenna. When a plurality of antennæ are employed (only two of which are shown herein for illustrative purposes), each may be provided with equipment similar to that described in connection with antenna A. A signal moving in the direction from east to west impressed upon the antenna B will be trans-

mitted to reflection transformer RT_2 and back over the conductors of the antenna to a local circuit B_1 . The current of undesired signals picked up by antenna B will be substantially non-effective in the local circuit B_1 connected to the secondary winding of the transformer ST_2 , only a small and perhaps negligible fraction of the said undesired signals being superposed upon the desired signals in the circuit B_1 .

The desired signal components from the antennæ A and B flowing in the local circuits A_1 and B_1 may be combined in a common circuit C_1 by means of a network S_1 , the details of certain forms of which are shown in Figs. 2 and 3 of the drawing. It is, of course, necessary for a suitable combination of these signaling components that they be impressed upon the network S_1 in phase with each other. It may also be necessary, in practice, that the signaling components from the antennæ A and B be impressed upon the network S_1 at the same or substantially the same amplitudes. These results may ordinarily be obtained by making circuits A_1 and B_1 of substantially equal length. Yet, if the geographical situation is such that these lines may not be of substantially equal length, they may be made of the same length by providing indirect routes between the network S_1 and the eastern terminals of the antennæ. As an alternative, the shorter line may be made electrically of the same length as the longer line by interposing in the shorter line an artificial line section which may consist of a phase shifter P_1 and an attenuator L_1 , introducing phase shift and loss equivalent to the difference between these lines.

In a similar manner, the noise or interference currents flowing through the primary windings of transformers CT_1 and CT_2 related to the antennæ A and B, respectively, may be transmitted to another network S_2 over lines A_2 and B_2 , respectively, and there arranged for suitable combination in a circuit C_2 . It will be understood that the network S_2 may be of the same general type as network S_1 , which will be more fully described hereinafter. Here, again, it may be necessary that the components taken from the respective antennæ be impressed upon the network S_2 in the same phase with each other and at equal amplitudes. The lines A_2 and B_2 may be of substantially equal length or may be electrically of substantially equal length as described hereinabove. A phase shifter P_2 and an attenuator L_2 , both of which are well known in the art, may be included in one of the lines such as B_2 . Obviously, the phase shifter P_2 serves the purpose of adjusting the phase of a compensating current coming through transformer CT_2 to equal the phase of the compensating current coming through transformer CT_1 , phase equality being necessary to a suitable additive combina-

tion of the respective currents. Similarly, the attenuation adjuster or attenuator L_2 may, if desired, be varied so that the current flowing in the local circuits B_2 is substantially equal in magnitude to the current flowing in the local circuit A_2 .

The networks S_1 and S_2 are connected to networks N_1 and N_2 , respectively. Networks N_1 and N_2 preferably comprise elements of resistance, as will be described in connection with Fig. 2, or elements of resistance and reactance, as will be described in connection with Fig. 3. The networks N_1 and N_2 may terminate the networks S_1 and S_2 in impedances substantially equal to the impedances looking into the lines C_1 and C_2 from the networks S_1 and S_2 , respectively.

As described hereinabove, the signaling currents are combined in the common circuit C_1 together with such noise and interference currents resulting from undesired signals or disturbances as may be picked up by the wave antennæ A and B. The compensating noise and interference currents brought together by circuits A_2 and B_2 are combined in a common circuit C_2 . In order to free the signaling currents from the noise and the interference currents superimposed thereon, the compensating noise currents from the circuit C_2 may be impressed on the circuit RC together with all currents from the circuit C_1 through the medium of the network S_3 which is preferably of the same general type as networks S_1 and S_2 . It may be, of course, necessary that the compensating current and noise or interference current to be compensated shall be of substantially equal amplitudes and 180 degrees out of phase. Accordingly, a phase shifter P_3 and an attenuation adjuster L_3 are interposed between the network S_3 and the networks S_1 and S_2 , respectively. The phase shifter may be manipulated to bring about a 180 degree phase variation necessary to properly combine the current in the circuit C_1 to be compensated with the compensating current in the circuit C_2 for effective neutralization. The attenuation adjuster L_3 may serve to render the magnitude of the compensating current in the circuit C_2 the same as that of the current to be compensated in the circuit C_1 , this being a condition which also must be fulfilled for effecting neutralization of these combining currents. A network N_3 which may be similar in character to the networks N_1 and N_2 is connected to the network S_3 , network N_3 having an impedance substantially equal to the impedance of the circuit RC. After the adjustments above mentioned shall have been made for the phase and magnitude of the compensating currents as well as for the currents to be compensated, the receiving circuit RC will receive the desired signals substantially free from the effects of the noise or interfering currents.

In using the system of this invention, the

adjustments required for the combination of currents flowing in the circuits may be made with a minimum of effort. The adjustment necessary for the proper combination of the signal currents derived from the various antennæ as well as the adjustments necessary for the proper combination of the compensating currents of these antennæ are relatively stable and fixed in their nature, requiring only slight changes with time. Due to the varied conditions brought about by the impression of signals from various angles on the wave antennæ, it may be necessary, at intervals, to readjust the phase shifters and attenuators representing the compensating apparatus, in order to preserve the required degree of balance against these waves.

In Fig. 2 of the drawing, there is shown a network arrangement for combining the currents flowing in two separate circuits. The form of arrangement represented in this figure comprises a number of resistances, each of which may be equal in magnitude to the resistance of the output or receiving circuit RC. One input circuit such as D_1 may be connected to terminals a and b , while another input circuit may be connected to terminals c and d , terminals a, b, c and d constituting the terminals of an arrangement such as anyone of the networks S_1, S_2 and S_3 of Fig. 1 may be. A resistance unit R_1 may comprise a network which may fulfill the requirements of anyone of the networks N_1, N_2 and N_3 of Fig. 1. Resistance R_1 is connected between terminals a and c . Resistances R_2 and R_3 are connected between terminals a and d and terminals b and c , respectively. Each of the resistances R_1, R_2 and R_3 may preferably be of a magnitude corresponding to the magnitude of resistance in the output of receiving circuit RC.

It will be apparent that resistances R_1, R_2 and R_3 compose three of the arms of a Wheatstone bridge arrangement, the fourth arm of which is the output or receiving circuit RC. The input circuit D_1 is connected to one of the diagonals of the bridge, the terminals of which are formed by resistances R_1 and R_2 and resistance R_3 and the output or receiving circuit RC, respectively. The other input circuit D_2 is connected to the other of the diagonals of the bridge, the terminals of which are formed by resistances R_1 and R_3 and the resistance R_2 and the output or receiving circuit RC, respectively. Since the elements R_1, R_2 and R_3 may be designed to have magnitudes of resistance equal to the resistance of the output or receiving circuit RC, the bridge will be balanced and the current flowing in one of the input circuits will cause no potential drop in the other of the input circuits, and vice versa. Consequently, the currents flowing in these input circuits will be mutually independent and non-reactive. The output or receiving circuit RC

will receive the energy of these input circuits, suitable allowance being made for losses due to the flow of currents through these resistance elements. Thus, the output or receiving circuit RC will receive only part of the energy of the input circuits D_1 and D_2 .

In Fig. 3 of the drawing, there is shown another arrangement for combining the currents flowing in two separate circuits. A Wheatstone bridge arrangement is provided here also, an arrangement similar to the one described in connection with Fig. 2 of the drawing. In this Wheatstone bridge arrangement, however, each of the arms of the bridge may be composed of adjustable elements of inductance, capacitance and resistance. Three of the arms of the bridge may include adjustable resistances R_{11}, R_{12} and R_{13} , variable condensers K_1, K_2 and K_3 and three windings L_1, L_2 and L_3 adjustable in inductance values, respectively. The fourth arm of the bridge is formed by the output or receiving circuit RC. As in Fig. 2 of the drawing, the input circuits D_1 and D_2 are connected to the diagonals of the bridge.

The three arms of the bridge of which the output or receiving circuit RC is the fourth arm may be adjusted to have components of resistance, capacitance and inductance each equal to the corresponding compounds in the output or receiving circuit RC. When such an adjustment is effected, the bridge arrangement becomes balanced so that the input circuits D_1 and D_2 are mutually independent and non-reactive, i. e., the flow of current through one of these circuits causes no flow of current in the other of these circuits and vice versa. The output or receiving circuit RC receives all of the energy in the input circuits D_1 and D_2 minus the energy dissipated in the resistance elements of the other arms of the bridge.

While this invention has been disclosed in connection with two wave antennæ, it will be apparent that it is applicable to any number of antennæ. Thus, for example, if a broadcast antenna system employing three antennæ were used, the outermost antennæ could be connected with a network or networks for the combination of their signaling currents in the manner shown in Fig. 1. Such combined currents could then be applied to another network or networks together with the signaling current from the middle antenna to produce a resultant representing the combination of all said currents. In like manner, the compensating currents from the three antennæ could be combined by bringing together the interference from the outer antennæ and combining the resultant with interference from the inner antenna. These compensating currents could then be combined with the resultant signaling currents (upon which noise or interference may

be superposed) so as to effectively neutralize such noise or interference.

It is desirable to point out that the transpositions in the transmission lines A_1 and A_2 connected with the antenna A (see Fig. 1) are for the purpose of preventing cross-talk or other interference between these currents flowing over these lines.

While this invention has been pointed out in certain particular embodiments merely for the purpose of illustration, it will be clearly understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. The combination with a broadside antenna system of a combining circuit having a resistance network to combine radio frequency currents representing signals and interference superposed thereon, a resistance network to combine radio frequency interference currents, and a resistance network to oppose the currents of said first resistance network against those of said second resistance network to eliminate the effect of said interference in a receiving circuit.

2. The combination with a broadside antenna system of a combining circuit having means to combine radio frequency currents representing signals and interference superposed thereon, means to combine radio frequency interference currents, and means including a conjugate network to oppose the currents of said first combining means against those of said second combining means to eliminate the effect of said interference in a receiving circuit.

In testimony whereof, I have signed my name to this specification this 5th day of December, 1927.

AUSTIN BAILEY.