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RADIO SIGNALING SYSTEM

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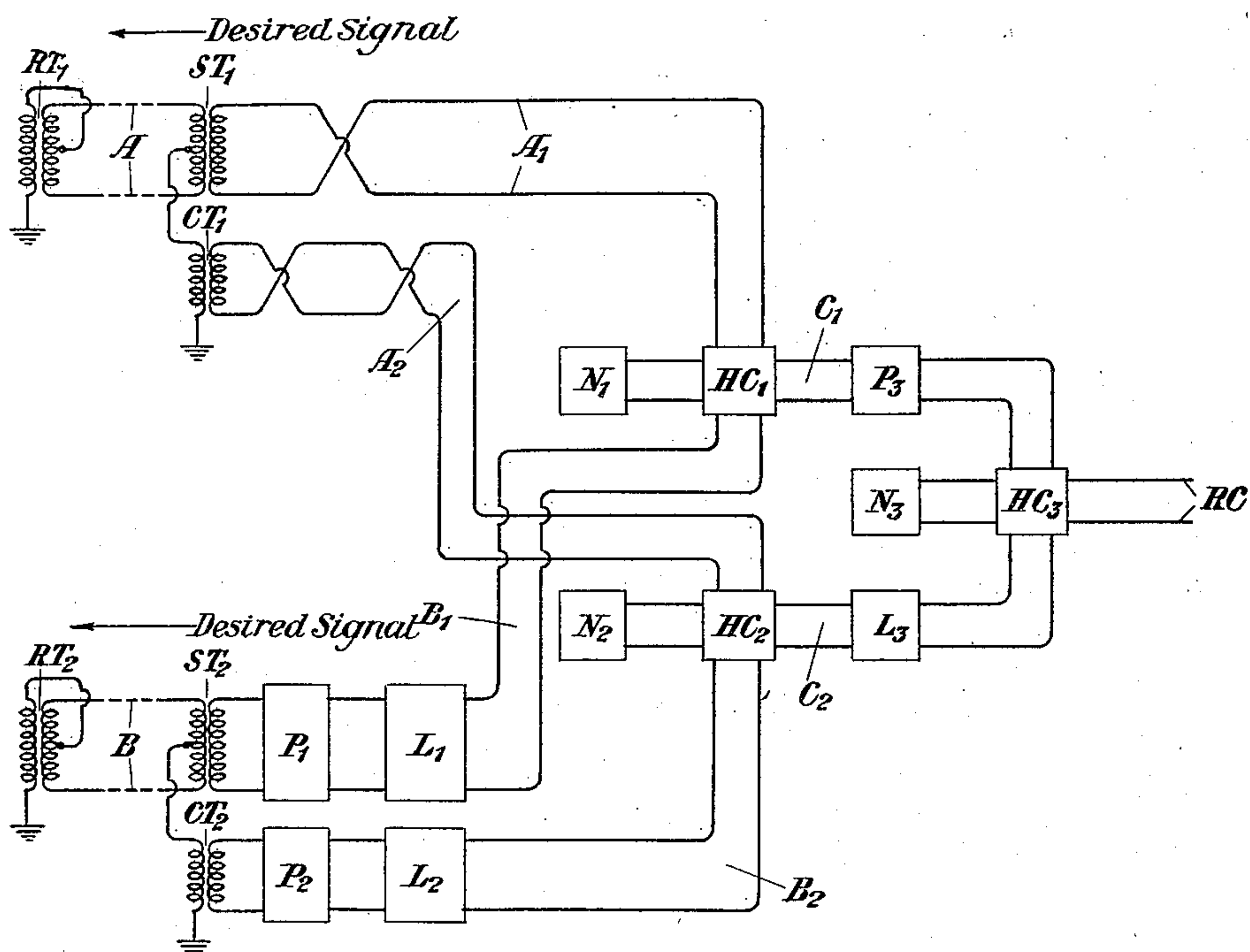


Fig. 1

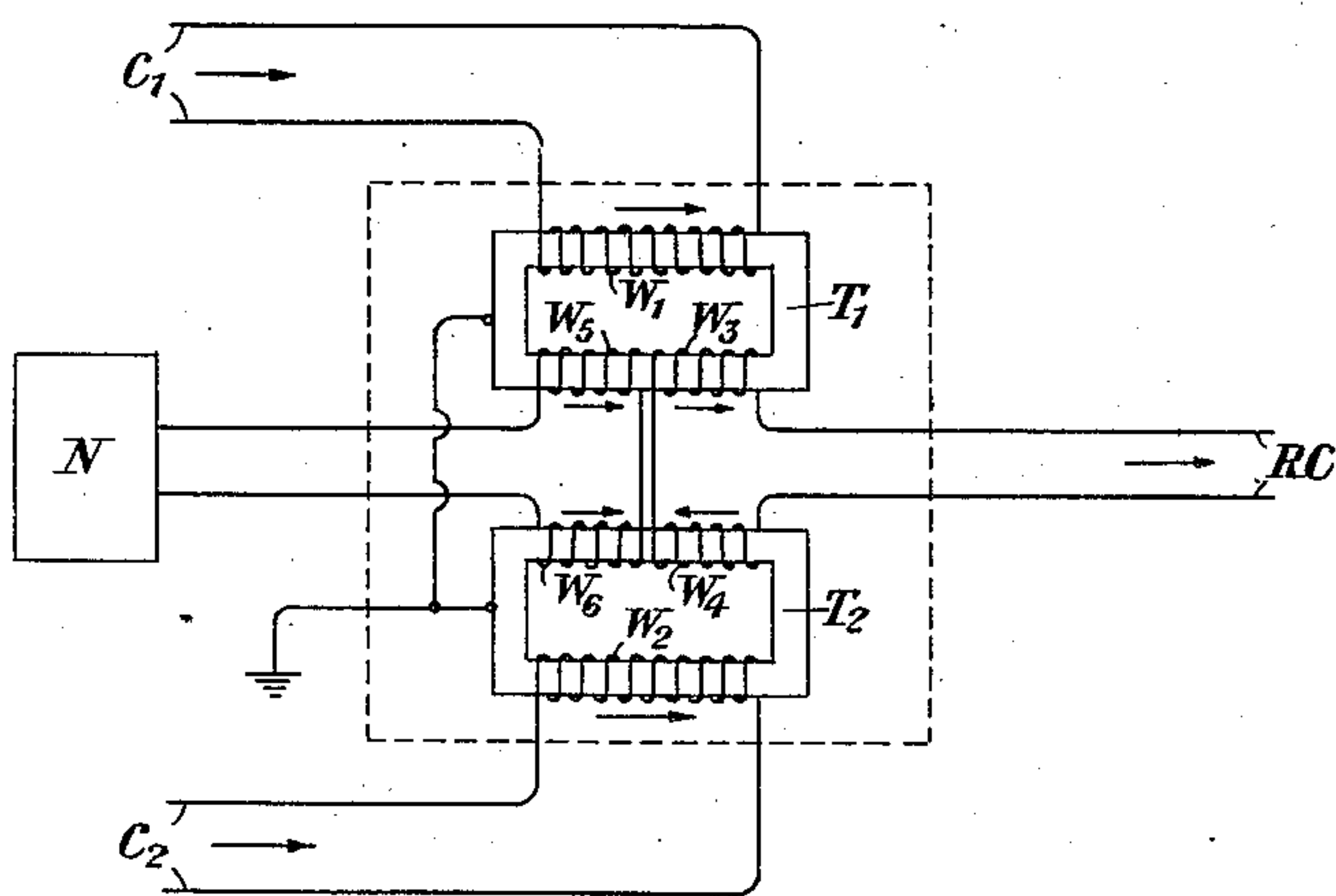


Fig. 2

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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 known in the art as antenna arrays. This invention particularly relates to a means for combining
15 the outputs of several antennæ constituting the component parts 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
20 to be highly successful in practice is known 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
25 will be apparent that it is applicable to any antenna array.

In the ordinary use of wave antennæ, as is well known in the art, a small fraction of the interference or noise voltages developed in
30 the surge resistance of a wave antenna is 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
35 "compensation" and serves in effect to produce zero or negligible reception at any desired angle, that is, at any angle different from the angle of the desired signal.

The directivity of a receiving system will
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
45 to the 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 signals
50 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 are set up in the antennæ by
60 waves or disturbances in space. The signals which are brought to the common point from the wave antennæ will be combined under suitable conditions of phase and amplitude, and similarly, the voltages representing un- 65 desired signals or interference will be also combined under similar conditions of phase and amplitude. The latter voltages will then be utilized to balance out noise and interference coexistent with the desired signals 70 in the terminal circuit of the said wave antennæ.

In order to accomplish the object of this invention, means will be provided for combining the outputs of the wave antennæ so
75 that there will be an additive effect for the desired signals in the output of the combining means, though there will be zero or negligible interaction between the input circuits of the combining means. In other words, the
80 currents flowing in the input circuits will be mutually independent and non-reactive, and still these currents will be combined additively by the combining means. One form of combining means, which will be described 85 hereinafter, comprises a hybrid coil having a plurality of windings, one of which is utilized to receive desired signals impressed upon one wave antenna, another of which is utilized to receive desired signals impressed
90 upon another wave antenna, one or more of which are connected to a balancing network of a well-known type and another one or more of which are connected to an output circuit which may lead to a radio receiver. 95 In the particular form of hybrid coil to be described hereinafter, the balancing network has an impedance which substantially equals the impedance looking into the output or receiving circuit. Moreover, desired signals 100

impressed upon one of the windings by one of the wave antennæ cannot be transferred to another of the windings upon which are impressed similar desired signals by another of the wave antennæ, and vice versa. Also, if the desired signals impressed upon the respective windings of the hybrid coil are equal in amplitude and in phase, the output or receiving circuit of the hybrid coil will receive the entire energy of the desired signals.

While this invention will be pointed out with particularity in the appended claims, the invention will nevertheless be better understood from the detailed description herein-after 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 wave antennæ connected in broadside, and Fig. 2 represents a hybrid coil forming one element of 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 definitely 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 is sometimes 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 voltage 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 antenna current flows to ground through the primary winding of the reflection transformer RT_1 and the voltage created thereby across the winding bridged across the conduc-

tors of the antenna A causes a flow of current over the conductors as a metallic circuit. At the eastern terminal of the antenna, such as A, 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 the 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 current resulting therefrom will flow through the halves of the primary winding of the transformer ST_1 oppositely to ground (by virtue of the connection to ground of the midpoint of the primary winding of the 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 the desired signals will be received. While the energy level of such signals is relatively low, it is sufficient, however, to introduce 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 the south, i. e., perpendicular to the antennæ, will hardly be received, if at all. Yet, it is 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 will 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 transmitted to the 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 fraction of the said undesired signals will be superposed upon the desired signals in the circuit B_1 .

The desired signal components from the antennae 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 hybrid coil HC_1 , the details of one form of which are shown in Fig. 2 of the drawing. It is, of course, necessary for a proper combination of these signal components that they be impressed upon the hybrid coil HC_1 in phase with each other. It is also necessary in practice that the signal components from the antennae A and B be impressed upon the hybrid coil HC_1 at substantially the same amplitude. These results may ordinarily be obtained by making the circuits A_1 and B_1 of substantially equal length. Yet, if the geographical situation is such that these lines may not normally be of substantially equal length, they may be made of the same length by providing indirect routes between the hybrid coil HC_1 and the external terminals of the antennae. 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 in length between these lines.

In a similar manner, the noise or interference currents flowing through the primary windings of the transformers CT_1 and CT_2 of the antennae A and B , respectively, may be transmitted to a hybrid coil HC_2 over lines A_2 and B_2 respectively, and combined in a circuit C_2 by means of a similar hybrid coil HC_2 . Here again, the components taken from the respective antennae must be impressed upon the hybrid coil HC_2 in the same phase and equal amplitude with each other. Moreover, the lines A_2 and B_2 should be of substantially equal length or should be made electrically of substantially equal length, as described hereinabove. A phase adjuster 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 adjuster P_2 serves the purpose of adjusting the phase of the compensating current coming through the transformer CT_2 to equal the phase of the compensating current coming through the transformer CT_1 , phase equality being necessary to a suitable additive combination 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 circuit B_2 is substantially equal in magnitude to the current flowing in the local circuit A_2 .

The hybrid coils HC_1 and HC_2 are connected to balancing networks N_1 and N_2 , respectively, these balancing networks comprising preferably series and shunt resistive and reactive elements, as is well known in the art. These balancing networks N_1 and N_2 terminate the hybrid coils in impedances substantially equal to the impedances looking into the lines C_1 and C_2 from the hybrid coils HC_1 and HC_2 respectively.

As described hereinbefore, the signal currents are combined in the common circuit C_1 , together with noise and interference currents resulting from undesired signals or disturbances picked up by the wave antennae 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 signal currents from the noise and interference currents superimposed thereon, the compensating noise currents from the circuit C_2 are impressed on the circuit RC together with all currents from the circuit C_1 through the medium of the hybrid coil HC_3 , which is preferably of the same general type as hybrid coils HC_1 and HC_2 . It is, of course, necessary that the compensating current and noise or interference current to be compensated shall be of substantially equal amplitude and 180° out of phase. Accordingly, a phase shifter P_3 and an attenuation adjuster L_3 are interposed between the hybrid coil HC_3 and the hybrid coils HC_1 and HC_2 respectively. The phase adjuster is manipulated to bring about the required 180° 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 serves 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 must also be fulfilled for effecting neutralization of these combining currents. A balancing network N_3 , similar in character to balancing networks N_1 and N_2 , is connected to the hybrid coil HC_3 , this balancing network having an impedance substantially equal to the impedance of the circuit RC connected to the hybrid coil. After the adjustments above mentioned 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 combination of currents flowing to circuits may be made with a minimum of effort. The adjustments necessary for the proper combination of the signal currents derived from the various antennae, 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 upon the wave antennæ, it is necessary at intervals to re-adjust 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 hybrid coil arrangement for combining the currents flowing in two separate circuits. The form of arrangement represented in the figure comprises two transformers, each of which has, upon its core, three windings each wound in a definite direction. The winding W_1 of transformer T_1 is connected to the input circuit C_1 , and the winding W_2 of transformer T_2 to an input circuit C_2 . The windings W_3 and W_4 of transformers T_1 and T_2 , respectively, are connected to the output or receiving circuit RC, while windings W_5 and W_6 of the respective transformers are in series with a balancing network N.

The windings of the transformers T_1 and T_2 are symmetrical, the corresponding windings of these transformers having the same values. Moreover, a balanced condition exists between the balancing network N and the receiving circuit RC. The transformer arrangement shown herein constitutes in effect a combining circuit which is adapted to combine currents flowing in circuits C_1 and C_2 for transmission to the circuit RC.

Having in mind the foregoing description of the transformer arrangement, the manner in which it functions to combine the currents of two separate circuits will be better understood from the following description. Let it be assumed that energy is to be transmitted over the circuits C_1 and C_2 to the output or receiving circuit RC. Accordingly, the flow of currents in the windings W_1 and W_2 of transformers T_1 and T_2 may be assumed to be in the directions indicated by the arrows adjacent thereto. These currents in windings W_1 and W_2 will induce potentials upon windings W_3 and W_5 and W_4 and W_6 , respectively, which will tend to cause the flow of currents therethrough. The windings W_3 and W_4 are so arranged that the flow of currents therethrough due to the normal flow of currents in circuits C_1 and C_2 as indicated, will aid each other, whereas windings W_5 and W_6 are differently arranged so that the flow of currents therethrough will normally oppose each other under the same circumstances. The arrows adjacent to these windings represent the polarity of the potentials normally impressed across these windings. If the currents flowing in circuits C_1 and C_2 are of equal amplitudes and of the same phase, equal voltages will be induced in

windings W_5 and W_6 which are oppositely directed so that there is no resultant effect in the circuit of the network N. Under the same conditions, the output or receiving circuit RC will receive all the energy from the circuits C_1 and C_2 . If, however, the current flowing in the circuit C_1 is greater or less than the current flowing in the circuit C_2 , then the magnitudes of the potentials impressed across the windings W_5 and W_6 will be unequal, and current will flow through the balancing network N of an amount proportional to the difference between the potentials impressed across these windings. Furthermore, if the currents flowing in circuits C_1 and C_2 were of equal amplitudes and of opposite phases, the potentials set up across the terminals of windings W_5 and W_6 will still be of equal magnitudes, and yet these currents would become substantially neutralized by virtue of their presence in the output or receiving circuit RC in phase opposition. In this case the entire energy from circuits C_1 and C_2 will be dissipated in the network N. This property of the hybrid coil is made use of when undesired signal or interference currents are combined in phase opposition, as in the compensating circuit described hereinabove. Furthermore, if the impedance of the network N is substantially equal to that presented by the receiving circuit RC, currents flowing in circuit C_1 will not be transmitted to circuit C_2 , and vice versa. Therefore there is no interaction between circuits C_1 and C_2 .

The symmetrical transformers T_1 and T_2 , each containing three windings, constitute the means for combining the energy present in two separate circuits. The invention is not, however, limited to the particular arrangement shown, since it will be apparent to those skilled in the art that a different rearrangement of the elements shown, or of equivalent elements, might be employed to produce a similar combining circuit.

While the 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 broadside antenna system employing three antennæ were used, the outermost antennæ could be connected with a hybrid coil for the combining of their signal currents in the manner shown in Fig. 1. Such combined currents could then be applied to another hybrid coil, together with the signal current from the middle antenna to produce a resultant representing the combination of all of the 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 antennæ. These compensating currents could then be combined with the re-

sultant signal current (upon which noise or interference is superimposed) by a coil such as HC_3 so as to effectively neutralize such noise or interference.

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

10 While this invention has been shown and described in a certain particular embodiment, 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:

20 1. In a signaling system, the combination with a plurality of antennæ, constituting an array, of a common receiving circuit, a transformer arrangement comprising a plurality of windings, a plurality of transmission paths, one transmission path extending from each antenna to a corresponding winding of the transformer arrangement, and a balancing network connected to certain of the windings of the transformer arrangement, said balancing network exhibiting an impedance substantially equal to the impedance of the common receiving circuit, said common receiving circuit being also connected to certain of the windings of the transformer arrangement.

25 2. In a signaling system, the combination with a plurality of substantially parallel wave antennæ, separated a predetermined distance and constituting an array, the longitudinal axis of which may or may not be substantially parallel to the line of travel of desired signals, of a common receiving circuit, a transformer arrangement comprising a plurality of windings, a plurality of transmission paths, one or more transmission paths extending from each wave antenna to corresponding windings of the transformer arrangement, and a balancing network connected to certain of the windings of the transformer arrangement, said balancing network exhibiting an impedance substantially equal to the impedance of the common receiving circuit, said common receiving circuit being also connected to certain of the windings of the transformer arrangement.

55 3. In a signaling system, the combination of a pair of wave antennæ placed side by side a predetermined distance apart, each being substantially parallel to the line of travel of desired signals, a transformer arrangement comprising a plurality of windings, a pair of transmission paths, one extending from each wave antenna to a corresponding winding of the transformer arrangement, a common receiving circuit connected to other

of the windings of the transformer arrangement, and a balancing network connected to the remaining windings of the transformer arrangement, said balancing network exhibiting an impedance substantially equal to the impedance of the common receiving circuit.

4. In a signaling system, the combination of a pair of input circuits, an output circuit, a balancing network, and a transformer arrangement to which said input circuits are symmetrically connected, said transformer arrangement being also connected to said output circuit and being adapted to permit the free transmission of signals from said input circuits to said output circuit without interference of interaction between said input circuits.

5. A system for combining the currents flowing in a pair of circuits so that the currents in either of the circuits will not be impressed upon the other circuit, comprising a transformer arrangement having a plurality of windings, one of which is connected to each of said circuits, said circuits being connected symmetrically with respect to the corresponding windings of the transformer arrangement, a receiving circuit connected to certain of the windings of said transformer arrangement, and a balancing network connected to the rest of the windings of said transformer arrangement.

6. The combination of a pair of transformers, each including three windings, two input circuits each connected to a corresponding winding of one of the transformers, a receiving circuit connected serially with respect to a pair of said windings, one corresponding to each transformer, and a balancing network connected serially between the remaining two windings, one also corresponding to each transformer.

7. The combination of two transformers, each transformer including three windings arranged on a common core, each winding in one transformer being similar in all respects to a corresponding winding in the other transformer, an output circuit connected serially between a pair of similar windings of said transformers, a balancing network also connected serially between another pair of similar windings of said transformers, and two input circuits, each connected serially to the remaining winding of each transformer.

8. The combination of two transformers each having one primary winding and two secondary windings, two input circuits, one connected to each primary winding, an output circuit connected in series with a secondary winding of each transformer, and a balancing network simulating the impedance of said output circuit connected in series with the other secondary winding of each transformer.

In testimony whereof I have signed my name to this specification this 31st day of March, 1927.

SAMUEL WINTHROP DEAN.

5 In testimony whereof I have signed my name to this specification this 31st day of March, 1927.

AUSTIN BAILEY.

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