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A. G. CHAPMAN

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RADIO SIGNALING SYSTEM

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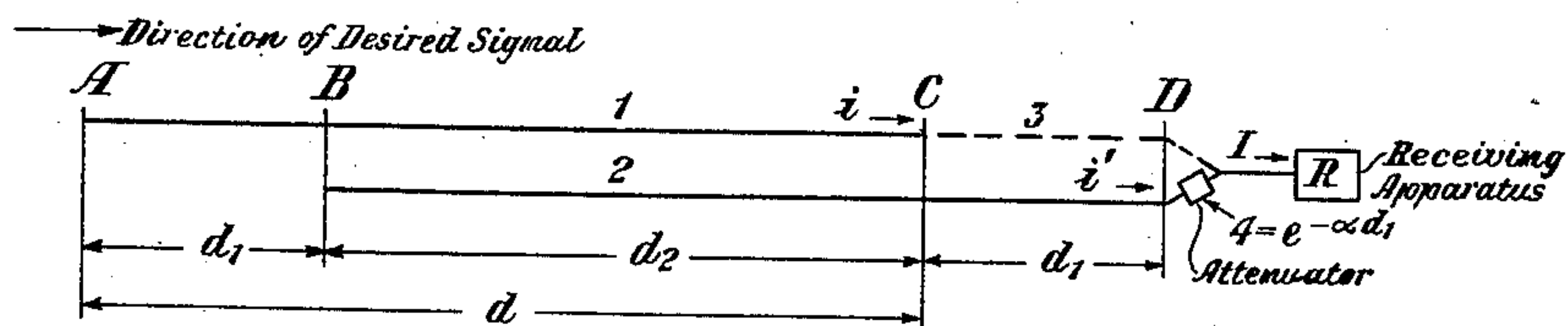


Fig. 1

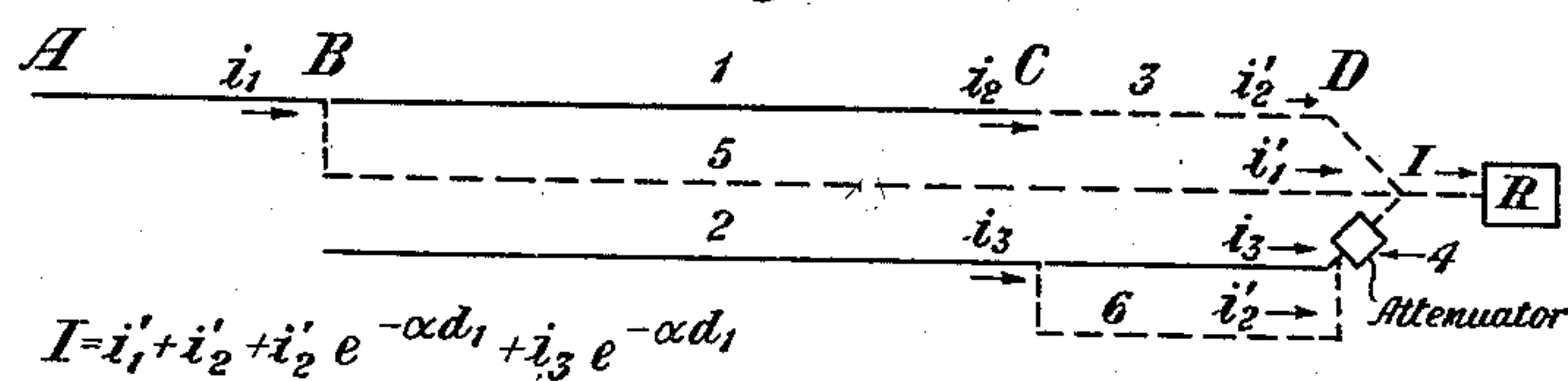


Fig. 2

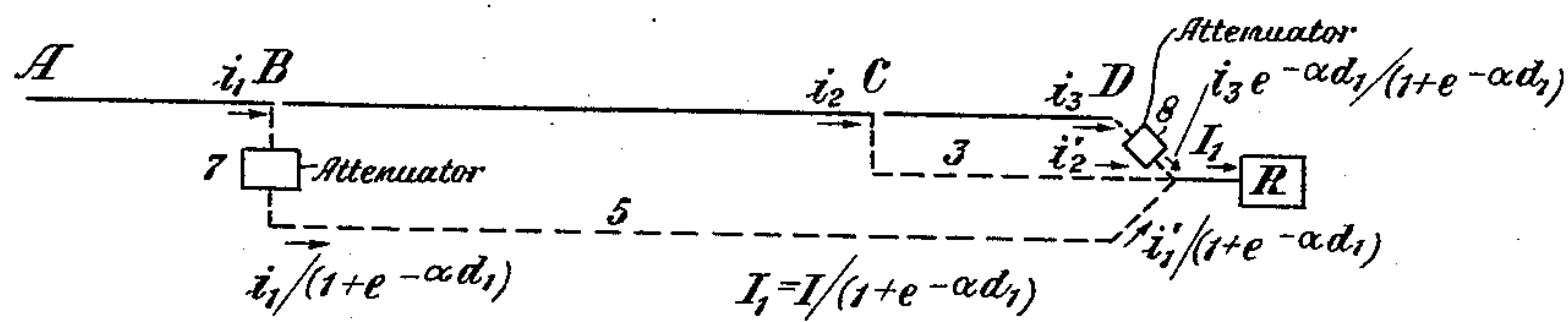


Fig. 3

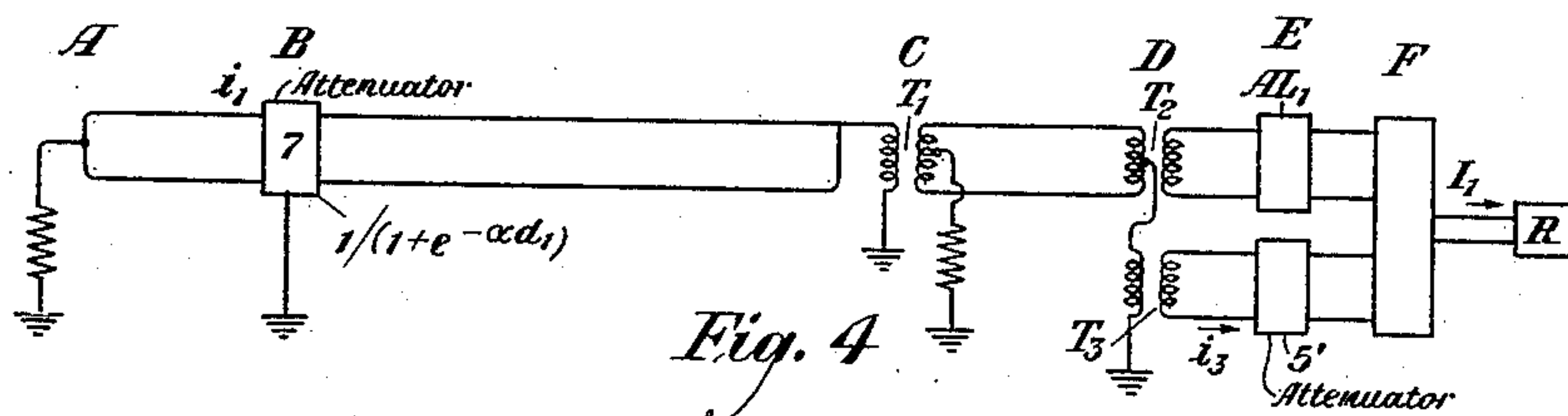


Fig. 4

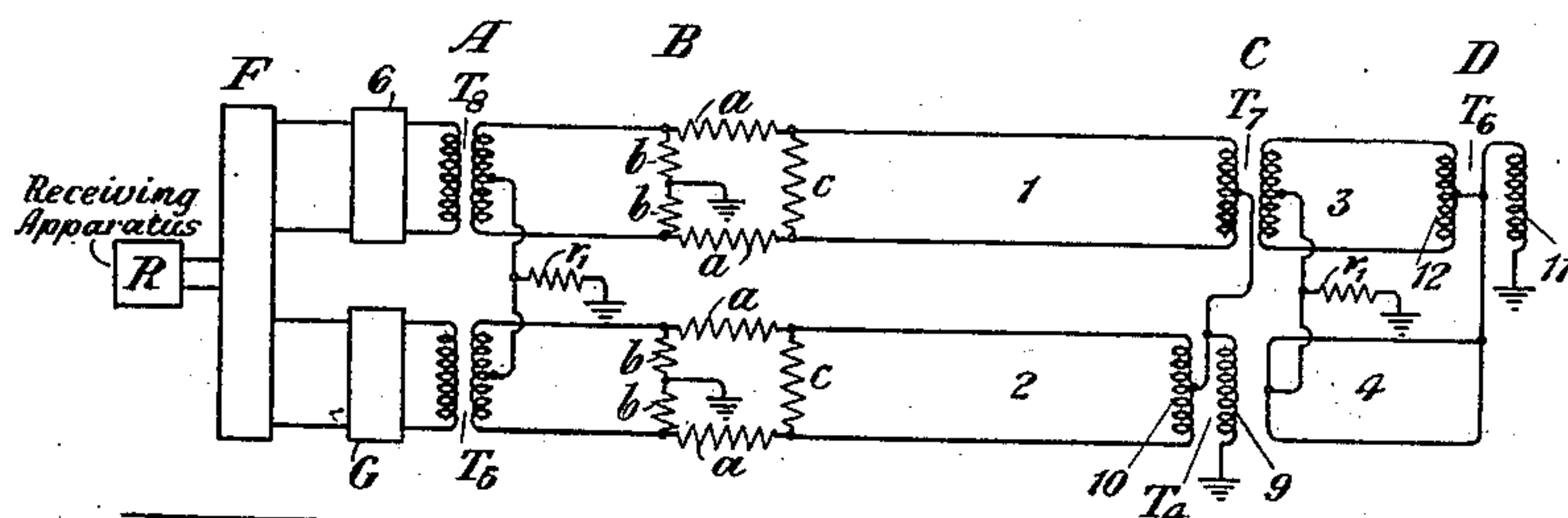


Fig. 5

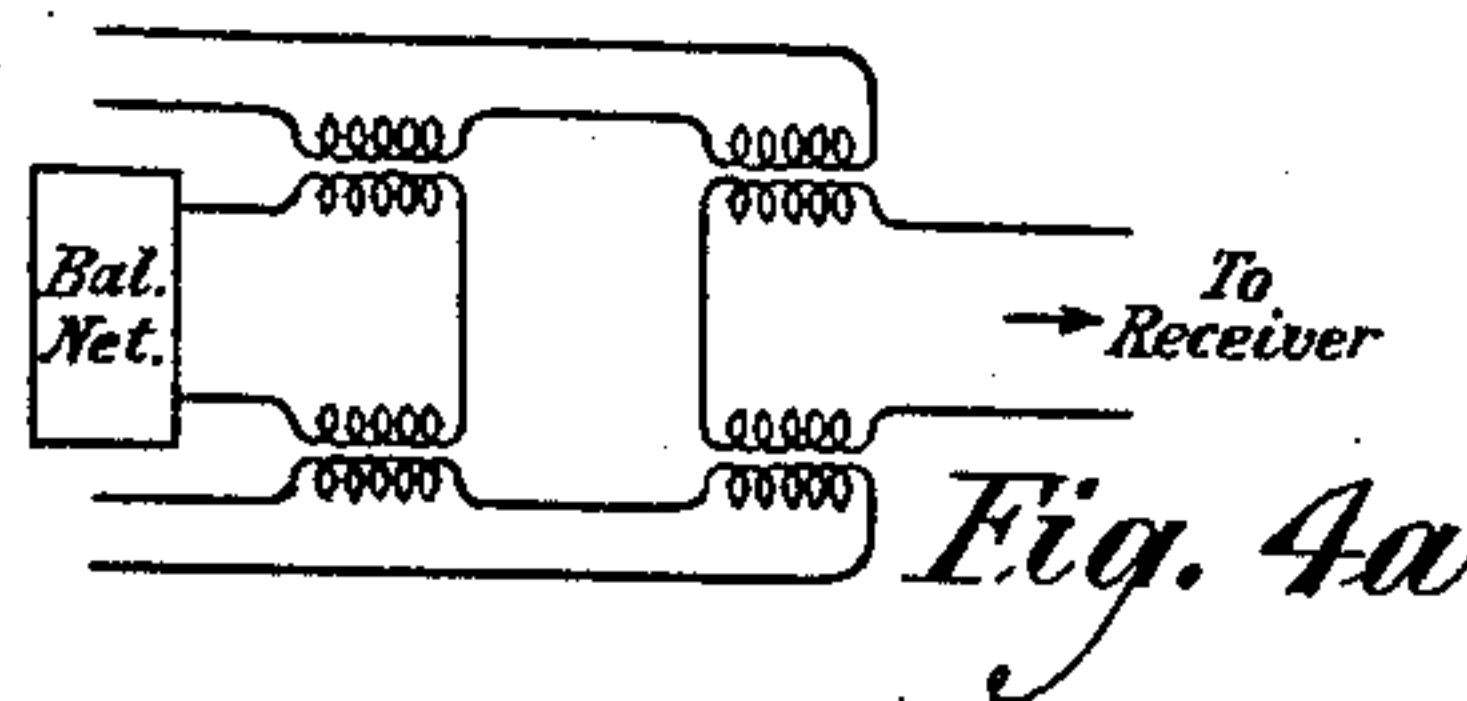


Fig. 4a

Alternative Arrangement for Network at B

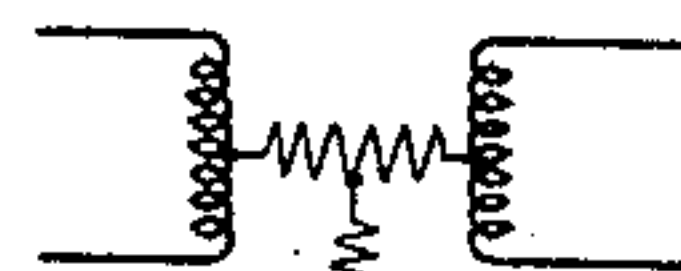


Fig. 5a

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RADIO SIGNALING SYSTEM

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This invention relates to radio receiving systems, and particularly to a wave antenna system employing a single pole line for the support of the antenna, which antenna system has the same directional characteristics as an array of staggered wave antennae of small lateral spacing.

Wave antennae are well known in the art, having been disclosed in the patents to Beverage and others, and in technical publications. A radio receiving system, consisting of two, parallel, like wave antennae separated by a fraction of a wave length and with one antenna displaced longitudinally a fraction of a wave length with respect to the other, has been called a staggered system. The antennae must be separated 1,000 to 1,200 feet apart to minimize crosstalk between them and each antenna requires a pole line for its support and a transmission line to bring the received currents to the radio receiver. Furthermore, the separation of the antennae produces a broadside effect, that is, the effect of space phase change from one antenna to the other in undesired waves received from points not in line with the antennae in either direction, which effect must be taken into consideration.

My invention resides in a wave antenna system having the same directional characteristic as a particular form of the staggered system of the prior art would have if the two antennae were placed on a single pole line, and if no cross-talk effects existed between them. My invention therefore requires only a single pole line, and no transmission lines for connection with the receiving station.

This invention will be readily understood from the following description, when read in connection with the attached drawing, of which Figure 1 illustrates schematically the staggered wave antennae of the prior art; Figs. 2 and 3 illustrate steps in the development of the invention; Fig. 4 illustrates schematically a simple form of the invention; Fig. 4^a shows a desirable method for connecting the antenna conductors to the receiver; Fig. 5 shows the embodiment of the invention in a more practical form; and Fig. 5^a is a detail of Fig. 5.

Fig. 1 shows schematically the particular staggered antenna system of the prior art to which my invention is equivalent in directional characteristic. The antennae 1 and 2 are parallel and equal in length, but shifted lengthwise a distance d_1 . This requires a transmission line 3 to bring the current i from the terminal C of antenna 1 to the radio receiver R at the right of the point D. A radio current i is received at terminal C of antenna 1 and a current i' is received at terminal D of antenna 2. These currents are equal in magnitude but out of phase. The current i leads the current i' by the phase angle $\beta_0 d_1 \cos \theta$ where $\beta_0 d_1$ is the space phase change in length d_1 at any particular frequency and θ is the angle of incidence for any particular radio signal (for the desired signal $\theta=0$). The current i is retarded in phase by the angle βd_1 in being propagated from C to D and is reduced by the attenuation factor $e^{-\alpha d_1}$. The current i' is also attenuated by the factor $e^{-\alpha d_1}$ in passing through the attenuator 4. Thus, there are two currents entering the receiver R of equal magnitude but one current leading by the angle $(\beta_0 d_1 \cos \theta - \beta d_1)$. The two currents combine to form the resultant current I which is about twice i for $\theta=0$, becomes a smaller part of i as θ increases and vanishes for a value of θ which makes the relative angle equal to 180 degrees. In order to simplify the description of the principle underlying this invention, the transmission line 3 is assumed to have the same phase change βd_1 as the section CD of the wave antenna 2. It is also assumed, for the sake of simplification, that the transmission line has the same attenuation factor $e^{-\alpha d_1}$ as the wave antenna for the length d_1 . The actual attenuation factor of the transmission line has no effect on the directional characteristic since the attenuation is compensated for. The transmission line would actually have less phase change than βd_1 and if the arrangement of Fig. 1 were actually built an artificial line would be connected in series with 3 to increase the phase change. The artificial line could be so adjusted to cause the total phase change between C and D to be different from

βd_1 or the artificial line could be placed in series with antenna 2 but it is the staggered system having a phase change of βd_1 between C and D for antenna 1 to which my invention is equivalent in its directional characteristic. In Fig. 1 the overhanging portions AB and CD have the length d_1 , and the overlapping portion BC has the length d_2 . The total length of each antenna is indicated by d . It is desirable to point out that throughout all of the figures the correspondingly designated sections have the same lengths as in Fig. 1.

In Fig. 2 is illustrated a staggered wave antenna system in which the separate antennae are divided into sections and the current set up in each section is brought to the common receiver R over separate transmission lines. Thus, the section AB of antenna 1 is connected by the transmission line 5 with the receiver R, and the section BC of that same antenna is connected by the transmission line 3 with the receiver. The section BC of antenna 2 is connected by the transmission line 6 with the receiver R, the connection including the attenuator 4, to which is also connected the section CD of antenna 2. In the arrangement shown in Fig. 2, the left-hand end of each part is assumed to be connected to ground through a resistance that equals the characteristic impedance of a wave antenna. The right-hand end of each section is connected to its transmission line through a transformer of suitable ratio to avoid reflection effects at the junction of the grounded and the metallic circuits. If the transmission lines have the same attenuation and phase change as corresponding lengths of the wave antennae, it will be seen that the total received current at the point D is the same as in Fig. 1, although at any other point upon the system the currents for either of the two antennae are not the same as in Fig. 1. The attenuator 4 has the same attenuation factor as in Fig. 1. The currents i'_1 and i'_2 indicate the values which i_1 and i_2 will have after propagation to the point D.

Fig. 3 shows a system in which the separate antennae of Fig. 2 have been replaced by a single antenna having the same directional characteristic as Figs. 1 and 2. It will be seen that the section BC of the antenna system of Fig. 2 supplies two components of the total current I at the point D of the system. One of these components is i'_2 , and the other is i'_2 attenuated by the action of the attenuator 4, that is to say, $i'_2 e^{-\alpha d_1}$. The section BC of Fig. 3 supplies only one component i'_2 and the total contribution of the section is reduced by the ratio of $1/(1 + e^{-\alpha d_1})$ or about one-half. This reduction is compensated for by similarly reducing the contributions of the other sections, namely, AB and CD, by means of the attenuators 7 and 8 inserted in the transmission lines of those sec-

tions. The result is that the total received current I_1 of the arrangement shown in Fig. 3 is about one-half that of the arrangement of Fig. 2, but the important thing is that the two currents have the same directional characteristic. The attenuator 8 not only accomplishes the reduction for the section CD but also performs the function of the attenuator 4 of the preceding figures. It is to be understood that the sections of the antenna of Fig. 3 have their left-hand ends terminated by resistance and their right-hand ends coupled with the transmission lines by suitable transformers. The arrangement shown in Fig. 3 requires only a single pole line for the support of the antenna system, but it is apparent that the transmission lines extending from the right-hand ends of the sections must be supported and therefore the system as thus disclosed, is not an improvement over the multi-antennae systems of the prior art, such as shown in Fig. 1. The transmission lines 3 and 5 of Fig. 3 could not practically be carried upon the same pole line as the antenna because a circuit composed of the two wires of a transmission line with ground return would pick up radio signals and these would induce unwanted radio signals in the paralleling wave antenna. This difficulty, however, is overcome by the arrangements shown in Figs. 4 and 5.

In Fig. 4 is disclosed a two-wire system in which the two wires act in parallel to ground as an antenna and, at the same time, serve as a metallic circuit for the transmission of the antenna currents from the various sections to the receiver R. The current i_1 , which is set up in the section AB comprising the two wires in parallel to ground, is transmitted through the attenuator 7 and is propagated over the section BC to the point C where it combines with the current i_2 which has been set up in the section BC. The resulting current, flowing to ground through the transformer T_1 , is transmitted over the section CD metallically, and is, in turn, impressed by the transformer T_2 upon that branch of the receiving circuit which includes the artificial line AL_1 . This artificial line compensates for the difference in the phase change between the metallic circuit and the ground circuit for the section CD which in length equals d_1 . The metallic circuit CD and the artificial line AL_1 provide the same total phase change as the line 3 of Fig. 3. At the point F is a coupling net work similar to a four-wire terminating set for the purpose of coupling the various circuits with the common receiver without producing interaction between the various circuits. Fig. 4^a shows a schematic wiring diagram of a 4-wire terminating set. The section CD serves as a grounded circuit to intercept the radio signals, the currents of which flow through a winding of the transformer T_3 . This current i_3 is impressed by the transformer T_3 upon

the attenuator 5', which has the same functions as 8 in Fig. 3. The latter attenuator has the attenuation factor $e^{-\alpha d_1}/(1 + e^{-\alpha d_1})$. The numerator differs from unity because of the necessity for compensating for the attenuation factor of the transmission line 3 of Figs. 1 to 3. This factor was assumed to be $e^{-\alpha d_1}$ to simplify the discussion. The attenuation factor of the attenuator 5' should be $k/(1 + e^{-\alpha d_1})$ where k is the factor for the metallic circuit CD and for the artificial line AL₁ at E. The factors for attenuators 7 and 5' of Fig. 4 involve d_1 , that is, the staggering distance, and α the attenuation constant of the two-wire ground return circuit. This arises from the fact that the system shown in Fig. 1 requires that equal currents propagated from the point C to the receiver R over the two paths differ after reaching R by the attenuation factor of the ground-return circuit CD. For the sake of simplicity it has been assumed that the transformers T₁, T₂, and T₃ are perfect, but actually such transformers will introduce undesired phase and magnitude differences in the currents delivered to the combining network at the point F, and such differences will have to be corrected by suitable modification of the networks AL₁ and 5'. It may be stated that practically the network at E would be an adjustable artificial line of low attenuation and that at 5' would be an adjustable attenuator and artificial line providing separate adjustments for phase and magnitude. By means of such adjustments, the directional diagram of the system shown in Fig. 4 may be varied to give the best result for a particular location.

The practical arrangement of the invention is shown in schematic form in Fig. 5. As is well known, it is customary in wave antenna systems to have the receiver at that end of the wave antenna which is nearer the transmitting station. This is accomplished by transmitting the signal current back from the more distant end of the antenna to the said end that is nearer the transmitter. The same idea has been incorporated in the arrangement shown in Fig. 5 in which the direction of transmission of the wave in space is from left to right. In order to accomplish this, the antenna comprises a four-wire line. The four wires in parallel to ground serve as interceptors of radiant energy, and at the same time the two pairs of conductors as metallic circuits serve for the propagation of the currents back from the distant end to the end at which the receiver is located. The four wires in parallel to ground between the points A and B serve to intercept the signals, the currents of which are attenuated by the networks shown at the point B. The currents, as thus attenuated, combine with the currents set up in the section BC acting as an antenna to intercept the space wave. The combined currents flow to ground through the winding

9 of the transformer T₄. This current therefore produces a voltage across the winding 10 of this same transformer and the current is propagated over the metallic circuit 2 to the receiver R at the left-hand end, the connection including the transformer T₅, the network G and the combining network F. The current that is produced by the radiant energy in the section CD, comprising the four conductors in parallel to ground, flows to ground through the winding 11 of transformer T₆. This current creates a voltage across the winding 12 of the same transformer, and the resultant current is transmitted through the transformer T₇ to the metallic circuit 1 and thence through the transformer T₈ to the receiver 8, the connection including the attenuator 6 and the network F. The phase-changing network G compensates for the fact that the current, produced in the section AC by the interception of radiant energy, does not have to traverse the section CD before it is transmitted to the receiver R. This will be apparent when it is realized that the current resulting from the interception of the radiant energy by the section CD, when reflected by the transformer T₆, must traverse not only the metallic circuit 1, which equals in length the metallic circuit 2, but also must traverse the metallic circuit 3. The attenuation factor of the network G is $e^{-j\beta_c d_1} e^{-j\beta_m d_1}$. The subscripts m and g refer to the two-wire metallic and four-wire grounded circuits, respectively. The attenuator 6 performs the same function as attenuator 5' in Fig. 4. The attenuation factor of 6 should be

$$\frac{k_1}{(1 + e^{-\alpha_g d_1}) e^{-\alpha_m d_1}},$$

where k_1 compensates for the attenuation factor of the network G. The factor $e^{-\alpha_m d_1}$ in the denominator compensates for the extra attenuation of the current from the antenna section CD in the metallic circuit 3. The other factor in the denominator occurs for the same reason that $1 + e^{-\alpha_g d_1}$ occurs in the denominator of the attenuation factors of attenuators 8 and 5'. The attenuators at B in Fig. 5 perform the same function as attenuator 7 in Fig. 4, that is, they reduce the current from the four-wire antenna section AB by the factor $1/(1 + e^{-\alpha_g d_1})$. The attenuator and the phase-changing network at the receiver should be adjustable.

The attenuation network at B in the four-wire circuit of Fig. 5 consists of five resistances designated a , b , b , a , and c . For practical convenience a should equal 600 ohms, b 1200 ohms, and c 1170 ohms, approximately. With those constants, the loss introduced in each metallic circuit is about 10 TU. The large losses in the metallic circuits may be avoided by a transformer arrangement having a T-network, as shown in Fig. 5^a. Such an arrangement might tend to introduce un-

desired phase changes in the four-wire antenna circuit, due to the inductance of the transformer windings, but such could probably be corrected by special transformer design.

The arrangements shown in Figs. 4 and 5 disclose schematically a directional receiving system involving a single wave antenna having the directional characteristics of a staggered wave antenna system and in which the separate antenna sections serve not only to intercept radiant energy but also to transmit metallicly to the radio receiver the currents set up in the preceding antenna sections. Since the arrangements disclosed require only a single pole line, they are much more economical in construction than those of the prior art. They furthermore do not require separate pole lines for the transmission circuits, and therefore, avoid the defect in the system shown in Fig. 3.

While the invention has been disclosed as embodied in particular forms, it is to be understood, of course, that those forms are merely illustrative of the invention. The invention is not to be construed as thus limited, but has the scope of the appended claims. What is claimed is:

1. In a wave antenna system for directional signaling the combination with a wave antenna comprising a plurality of sections, of means to render certain sections interceptors of radiant energy and as transmission lines for the currents produced in other sections by intercepted energy, a terminal circuit including means to vary the phase and the attenuation of currents in certain sections, means to combine the currents as thus varied and means to receive the combined currents.
2. In a wave antenna system for directional signaling the combination with a wave antenna comprising a plurality of sections each consisting of two pairs of conductors effectively connected in parallel to ground to constitute an interceptor of radiant energy, of means for impressing upon one of said pairs the voltage resulting from the combined current of all of said parallel conductors constituting one section of said antenna, means to impress upon the other of said pairs a voltage resulting from the combined current of all of the parallel conductors constituting another section of said antenna, and a terminal circuit having means to variably control either the phase or magnitude or both of the said currents impressed thereon by the said pairs of conductors, means to combine the said currents, and a receiving device upon which the combined currents are impressed.
3. In an antenna system for signaling in a predetermined direction, the combination with an antenna made up of a plurality of sections, each of which serves as an interceptor of radiant energy and as a conductor for the transmission of currents resulting

therefrom, of connecting means between the adjacent sections to impress upon each subsequent section the currents flowing in the preceding section for transmission thereover, and means to receive the combined currents.

4. In an antenna system for signaling in a predetermined direction, the combination with an antenna made up of a plurality of sections, each of which consists of a pair of conductors, of means to couple the said pairs of adjacent sections so as to constitute a plurality of coupled metallic circuits for the transmission of currents, the said coupling means being so connected to ground that the wires of each section serve in parallel as interceptors of radiant energy.

5. In a wave antenna system for directional signaling the combination with an antenna comprising a plurality of sections whose longitudinal axes lie approximately in the same straight line, of means connected with the sections of the said antenna to render each section a collector of radiant energy and to join the adjacent sections so that each acts as a transmission line for the conveyance of currents resulting from the energy collected by the preceding one, and a receiving device upon which the currents of all sections are combinedly impressed.

6. In a wave antenna system for directional signaling the combination with a wave antenna comprising a plurality of sections each consisting of two pairs of conductors effectively connected in parallel to ground to constitute a collector of radiant energy, of means for impressing upon one of said pairs the voltage resulting from the combined current of all of said parallel conductors constituting one section of said antenna, means to impress upon the other of said pairs a voltage resulting from the combined current of all of the parallel conductors constituting another section of the said antenna, and a terminal circuit upon which are impressed the currents transmitted over both pairs of conductors.

In testimony whereof, I have signed my name to this specification this 21st day of November, 1927.

ARTHUR G. CHAPMAN.