Aug. 14, 1928. 1,680,363

R. BOWN

DIRECTIVE ANTENNA

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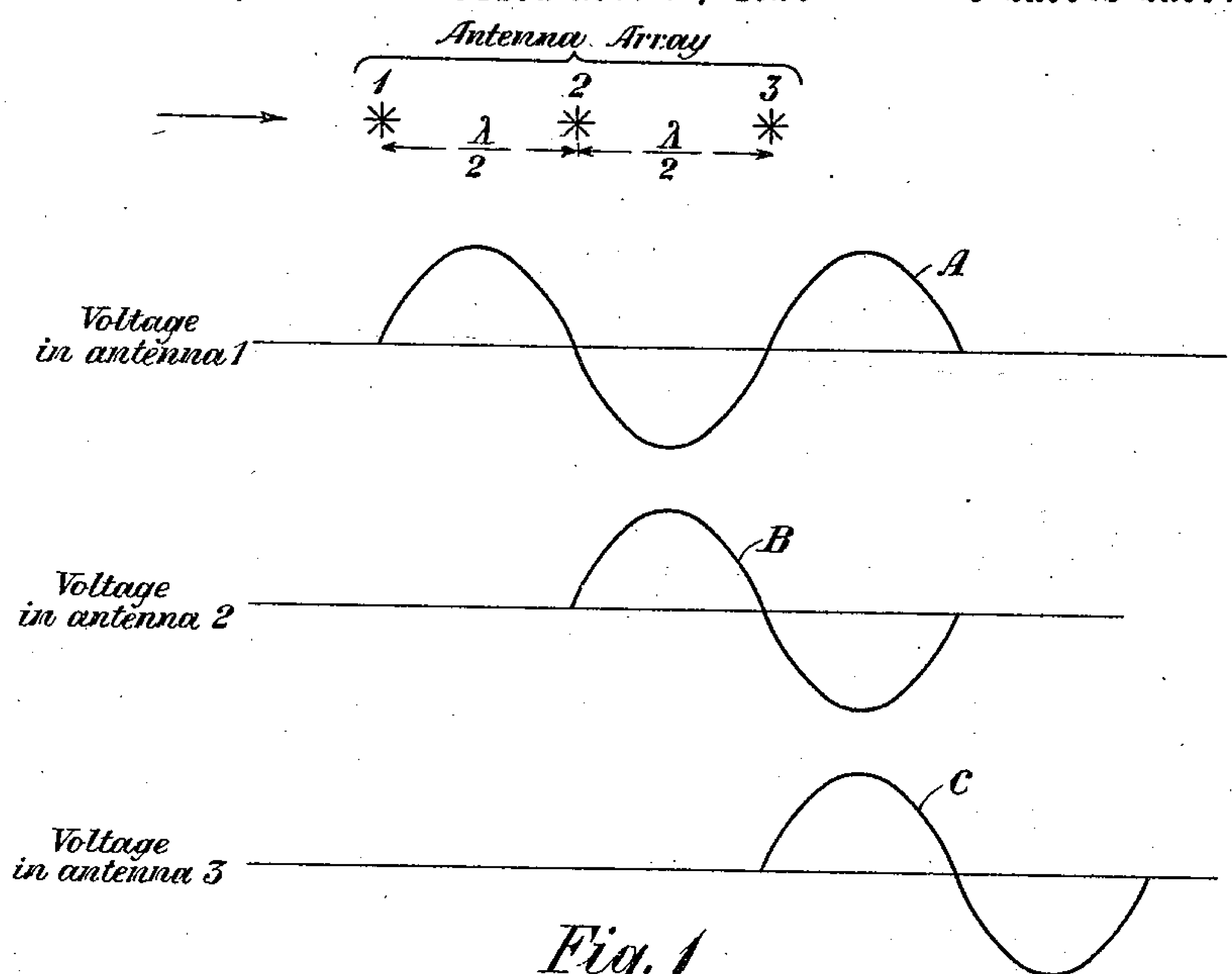

Fig. 1

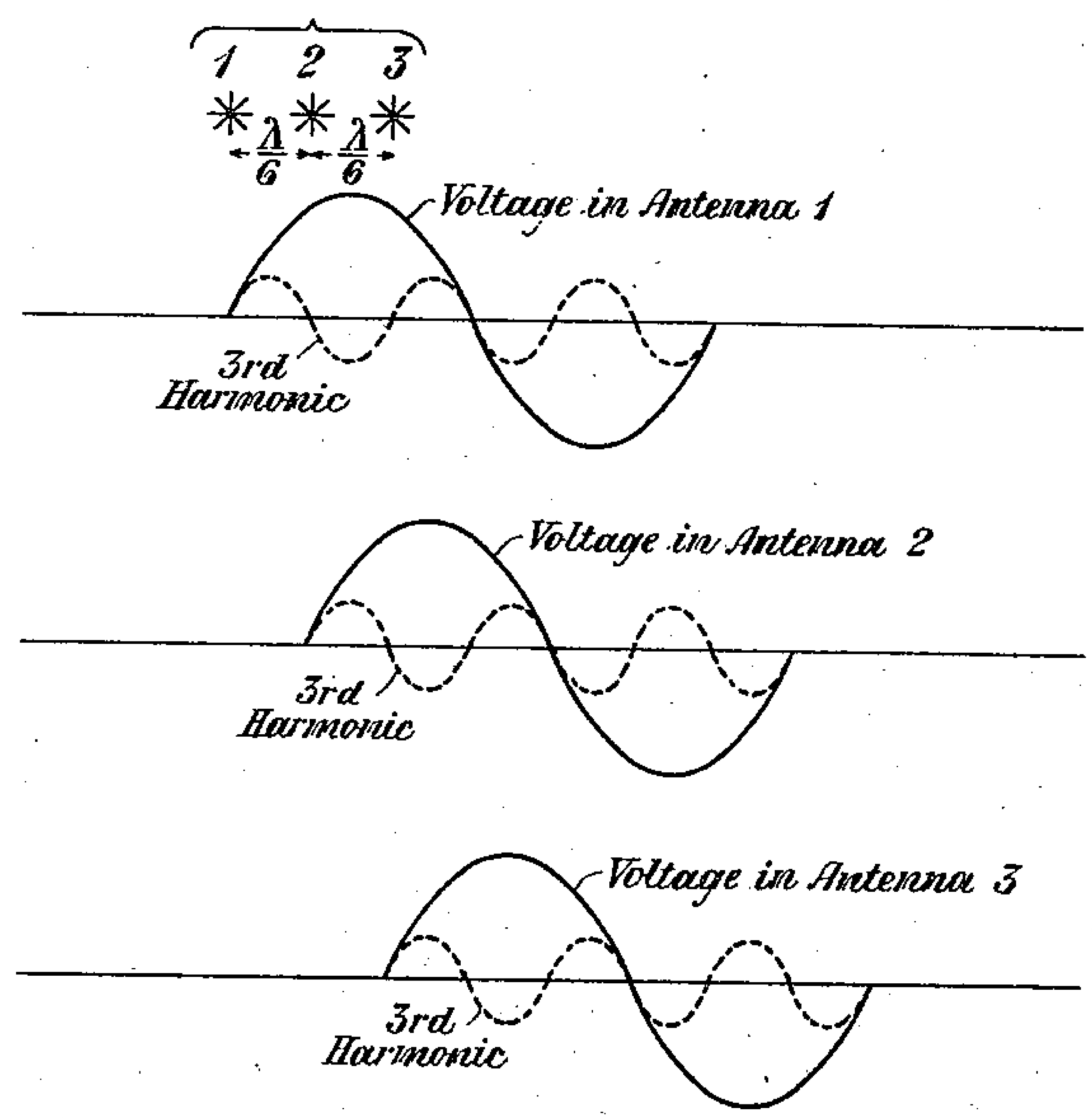

Fig. 2

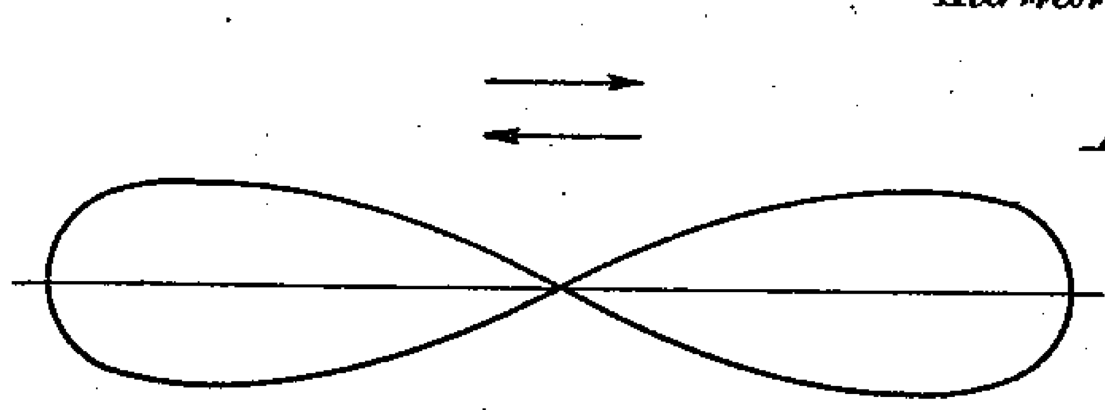

Fig. 3

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DIRECTIVE ANTENNA

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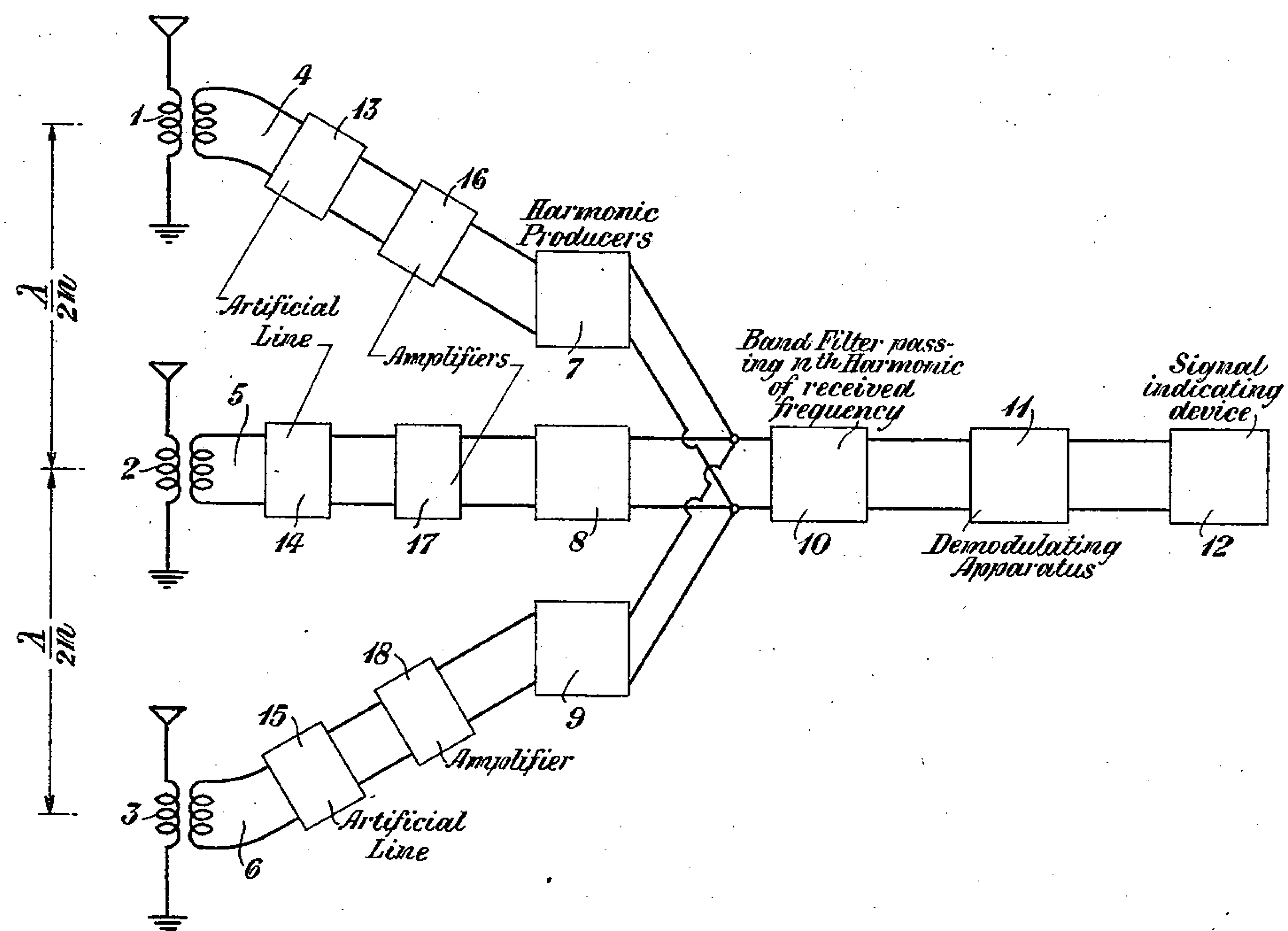

Fig. 4

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DIRECTIVE ANTENNA

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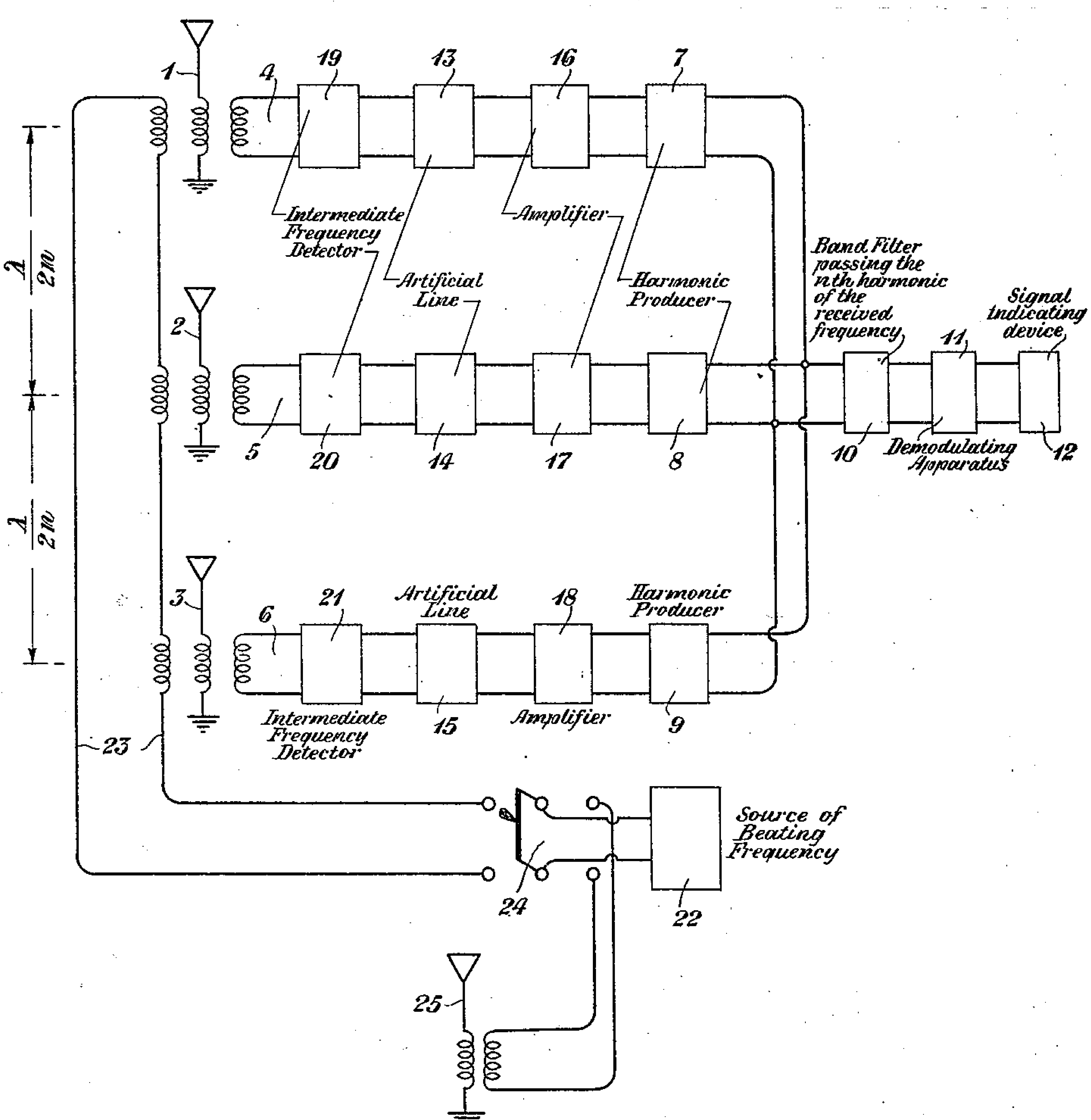

Fig. 5

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UNITED STATES PATENT OFFICE.

RALPH BOWN, OF MAPLEWOOD, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

DIRECTIVE ANTENNA.

Application filed November 13, 1924. Serial No. 749,799.

This invention relates to directive radio signaling systems, and particularly to means for altering the phase relations between a plurality of alternating currents set up in the antennæ of such systems.

In a directive radio signaling system such as is described in the copending application of Campbell, Serial No. 327,553, filed September 30, 1919, a plurality of antennæ are spaced apart at equal distances representing a common fraction or a multiple of a wave length, and each of the antennæ is connected with a common receiving circuit upon which is impressed the potentials set up in the antennæ of such system. One of the objections to an antenna array such as disclosed in the Campbell application arises from its space requirements when intended for use with long wave lengths such as are used in transoceanic radio operation. For example, if a rectilinear array of sixteen antennæ spaced one-half λ apart is used for the reception of waves whose length is 16 000 meters, the spacing between adjacent antenna is over four miles, and the total length of such an array would be in the neighborhood of sixty miles. From this it will, of course, be apparent that the space requirements of such a system impose a great handicap upon its use.

One of the objects of this invention is to provide a method and means rendering it practicable to carry out the principle set forth in the Campbell application by an antenna array in which the distance between the adjacent antennæ is but a fraction of that set forth in the Campbell application.

Other objects of this invention will be apparent from the following description when read in connection with the attached drawing of which Figures 1, 2 and 3 show graphically the principles upon which my invention rest; Fig. 4 shows a form of the circuit in which it is embodied; and Fig. 5 shows a variation involving intermediate frequency detection of the received waves.

In Fig. 1, three antennæ of an array are shown spaced apart by a distance equal to one-half of the received wave length. For the sake of brevity only three antennæ have been shown, but it is to be understood that the invention is applicable to an array comprising any number of antennæ and arranged in any form. As is well known, in such an array the distances between adjacent antennæ is a common fraction or a multiple of the wave length λ. Assume that this distance is $r\lambda$. The currents set up in the various antennæ due to the signaling waves have a phase difference determined by the value of r and the angle of approach of the wave. Assuming that the wave approaches the antenna array in the direction represented by the arrow of Fig. 1, the voltage set up in antenna 1 may be represented by curve A, that set up in antenna 2 by B, and that in antenna 3 by C. The phase relations at any instant may be determined from the curves. An array having a spacing equal to one-half of the received wave length so that the currents set up in the respective antennæ are one-half a period apart in phase has good bilateral reception quality. As mentioned heretofore, the spacing of the antenna one-half a wave length apart renders such a structure almost prohibitive. I have found that if the array is reduced in size to the point where the spacing distance is $1/n$th of its original value, that is, where the spacing distance equals $\frac{r\lambda}{n}$, the nth harmonics of the received voltages will duplicate the phase relations existing between the fundamental voltages received by the more widely spaced antenna. This is clearly shown in Fig. 2 in which the antennæ designated 1, 2 and 3 are shown spaced apart by $1/6$ of λ. With waves of the same length as shown in Fig. 1 impressed upon the antennæ of Fig. 2, the voltages in the respective antennæ will be $1/6$ of a wave length apart in phase, but the voltages representing the third harmonic of the received frequency will have the same phase relation as the fundamental frequency shown in Fig. 1.

My invention therefore consists broadly in shortening the spacing between the adjacent antennæ of a system by an amount equal to $\frac{r\lambda}{n}$ and then producing harmonics of the frequency set up in each antenna and selecting therefrom the nth harmonic for combination in the common receiving circuit in order to obtain the directional effect.

The manner in which this is done is shown in Fig. 4 in which the antennæ 1, 2 and 3 are shown spaced apart a distance equal to $\frac{\lambda}{2n}$. Each antenna is connected with a harmonic producer by means of the circuits 4, 5 and 6 which are of equal electrical length. This equality is maintained by means of the artificial lines 13, 14 and 15, and of amplifiers 16, 17 and 18 inserted in the connecting lines 4, 5 and 6 between the antennæ and the harmonic producers. Each of the harmonic producers 7, 8 and 9 is connected with the common receiving circuit which has therein as part of the equipment a band filter or other frequency selective device 10 for selecting the nth harmonic of the received frequency. If the nth harmonic is the third, the antennæ would be spaced apart a distance equal to $\frac{1}{6}$ of the received wave length, and the third harmonic of the received waves would be impressed upon the demodulating apparatus 11 the output of which would be detected by means of the signal indicating device 12. It will accordingly be seen from Fig. 2 that by spacing the antenna apart a distance equal to $\frac{1}{6}\lambda$ and by using the third harmonic of the voltages set up in each of the antennæ the system will have the same directional characteristic as an array in which the antennæ are spaced apart by $\frac{1}{2}\lambda$.

The arrangement shown in Fig. 5 is a modification of the circuit hereinbefore described, the modification consisting in beating the received frequency to a lower frequency before transmitting it over the connecting circuits to the common circuit in which the currents from all of the connecting circuits are combined. The same numerals indicate similar parts in Figs. 4 and 5. In the circuit shown in Fig. 5 the connecting circuits 4, 5 and 6 contain not only the apparatus shown in Fig. 4 but also intermediate frequency detectors 19, 20 and 21. A source of beating frequency 22, which preferably is located in the vicinity of the harmonic producers 7, 8 and 9 is arranged to supply the frequency necessary to beat the frequency received by the antennæ 1, 2 and 3 to a lower frequency. A switch 24 is provided in the output side of the source 22 to connect the source with the antennæ 1, 2 and 3 either by means of the wire line 23 or by means of the antenna 25.

In the operation of the system shown in Fig. 5 the received waves whose length is λ will be impressed upon the antennæ which are spaced apart at the distance $\frac{\lambda}{2n}$. Current of the frequency corresponding to λ will be set up in the connecting circuits 4, 5 and 6 together with current of the beating frequency from the source 22. The two frequencies will beat together in the detectors 19, 20 and 21, and currents of an intermediate frequency will be impressed upon the harmonic producers 7, 8 and 9. These currents will, of course, be equalized by the setting of the artificial lines and the amplifiers situated between the intermediate frequency detectors and the harmonic producers in each of the connecting circuits. Harmonics of the intermediate frequency currents would be produced by the devices 7, 8 and 9, and the nth harmonic would be passed by the filter 10 to the demodulating apparatus 11. The signal produced by the demodulating apparatus would be indicated by the device 12.

It will accordingly be seen that by means of my invention it is practicable to control the phases of received voltages set up in the antenna array and to attain the desired directional characteristic even though the voltages set up in the said antennæ by the received waves would not directly produce the same characteristic.

While this invention has been described as applied to a directive radio signaling system, it is to be understood that it is not so limited but is capable of application in other ways. And it is likewise capable of embodiment in other forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a system for changing phase differences by frequency conversion the combination with an antenna array for receiving waves of length λ the distance between adjacent antennæ being equal to $r\lambda$ of a plurality of connecting circuits individual to and connected with the said antennæ all of said circuits being of the same length electrically, an harmonic producer individual to and connected with each of said connecting circuits, and a common translating circuit connected with the said connecting circuits and having a frequency selecting device to transmit therethrough only a predetermined harmonic of those produced in each of said connecting circuits.

2. In a system for changing phase differences by frequency conversion, the combination with an antenna array for receiving waves of length λ, the distance between adjacent antennæ being equal to $r\lambda$, of plurality of connecting circuits individual to and connected with the said antennæ, each connecting circuit having adjusting means to render the electrical length thereof equal to that of the other circuits, a harmonic producer individual to and connected with each of the said connecting circuits, and a frequency selecting device common to all of said connecting circuits to transmit therethrough a predetermined harmonic of those produced in each of the said connecting circuits.

3. In a system for changing phase differences by frequency conversion, the com-

bination with an antenna array for receiving waves of length λ, the distance between adjacent antennæ being equal to $r\lambda$, of a plurality of connecting circuits individual to and connected with the said antennæ, each connecting circuit having an artificial line and an amplifier to render the electrical length thereof equal to that of the other circuits, a harmonic producer individual to and connected with each of the said connecting circuits, and a frequency selecting device common to all of said connecting circuits to transmit therethrough a predetermined harmonic of those produced in each of the said connecting circuits.

4. In a system for changing phase differences by frequency conversion, the combination with an antenna array for receiving waves of length λ, the distance between adjacent antennæ being equal to $r\lambda$, of a source of beating oscillations whose frequency differs from that of the received waves, a plurality of connecting circuits of the same electrical length individual to each of said antennæ, and also connected with said source of oscillations, each connecting circuit having means to beat the received waves with the beating oscillations to produce an intermediate frequency, and a harmonic producer likewise individual to each connecting circuit to create harmonics of the frequency produced by the said beating operation, and a common translating circuit having a frequency selecting device to transmit therethrough a predetermined harmonic of those produced in each of said connecting circuits.

5. In a system for changing phase differences by frequency conversion, the combination with a plurality of circuits of equal electrical length, of voltage producing means for impressing upon each of the said circuits voltages of the same frequency but differing in phase, the phase difference between successively adjacent circuits being the same, means connected with each of said circuits to produce harmonics of the frequency applied thereto, and a translating circuit common to all of said first mentioned circuits having means to select a predetermined harmonic of those produced in the said first mentioned circuits.

6. In a system for changing phase differences by frequency conversion, the combination with a plurality of circuits of equal electrical length, of voltage producing means for impressing upon each of the said circuits voltages of the same frequency but differing in phase, the phase difference between successively adjacent circuits being the same, a source of beating oscillations also connected with each of said circuits, the frequency of said oscillations differing from that of the voltage producing means, each of said circuits having means to beat together the said beating frequency and the frequency of the voltage impressed thereon by the voltage producing means to create an intermediate frequency, means connected with each of said circuits to produce harmonics of the said intermediate frequency, and means to select a predetermined harmonic of those created by the said harmonic producing means and a translating circuit upon which the selected harmonic is impressed.

In testimony whereof, I have signed my name to this specification this 11th day of November, 1924.

RALPH BOWN.