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DE LOSS K. MARTIN

RADIO SIGNALING SYSTEM

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Fig. 1

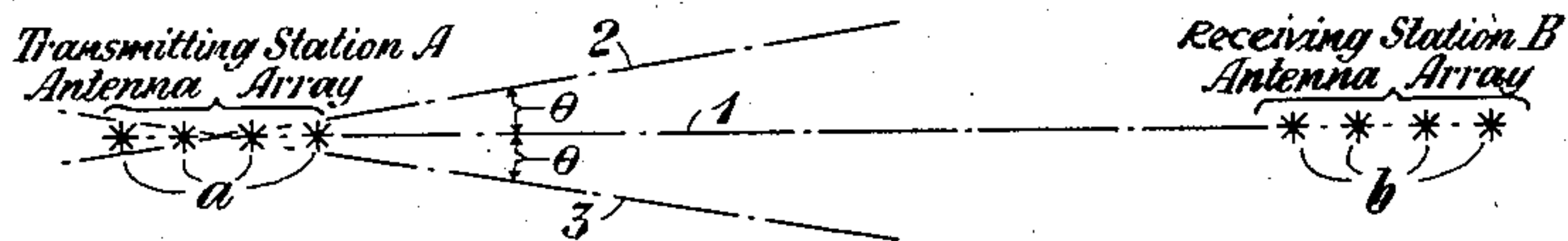


Fig. 3

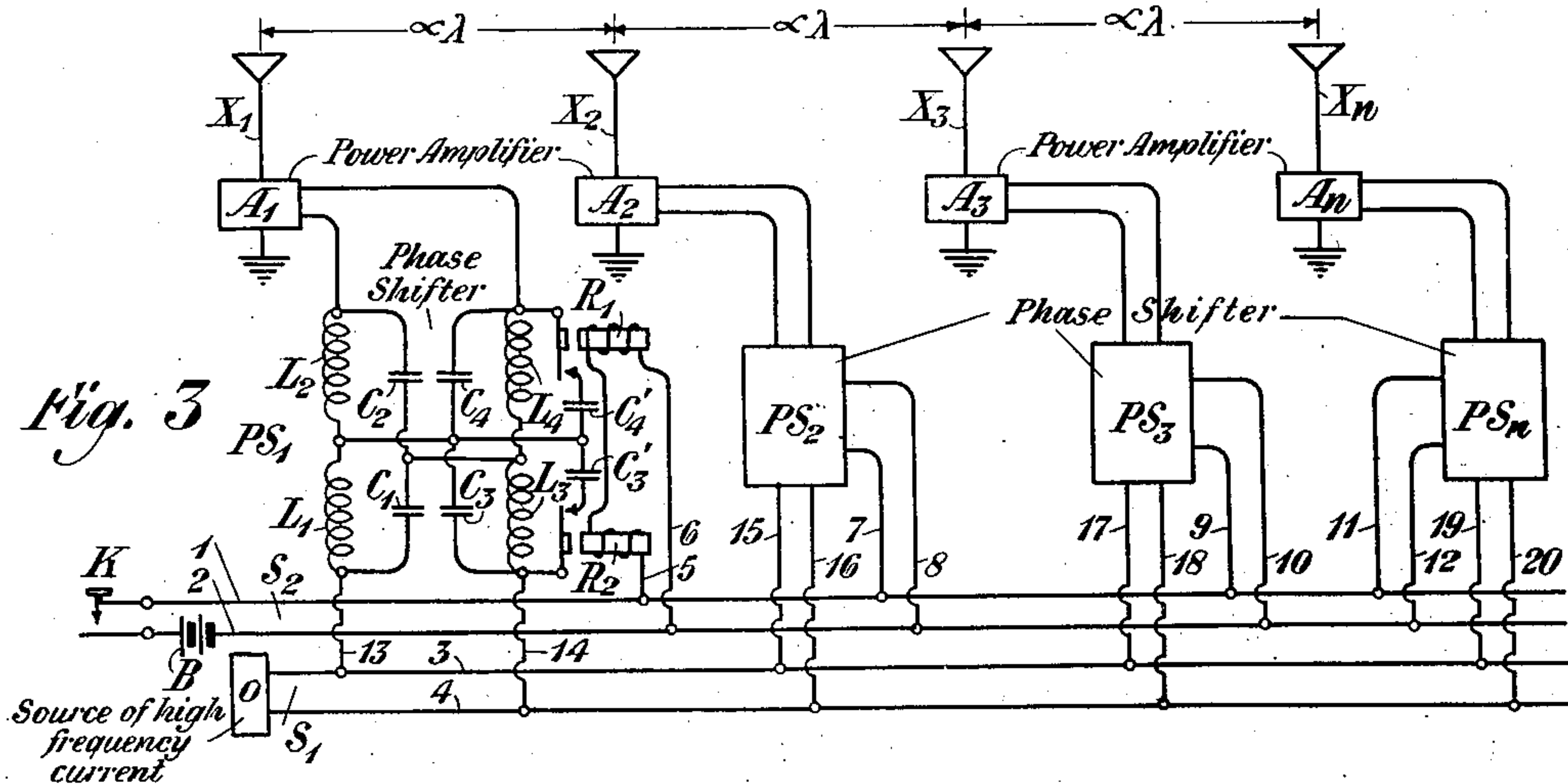


Fig. 4

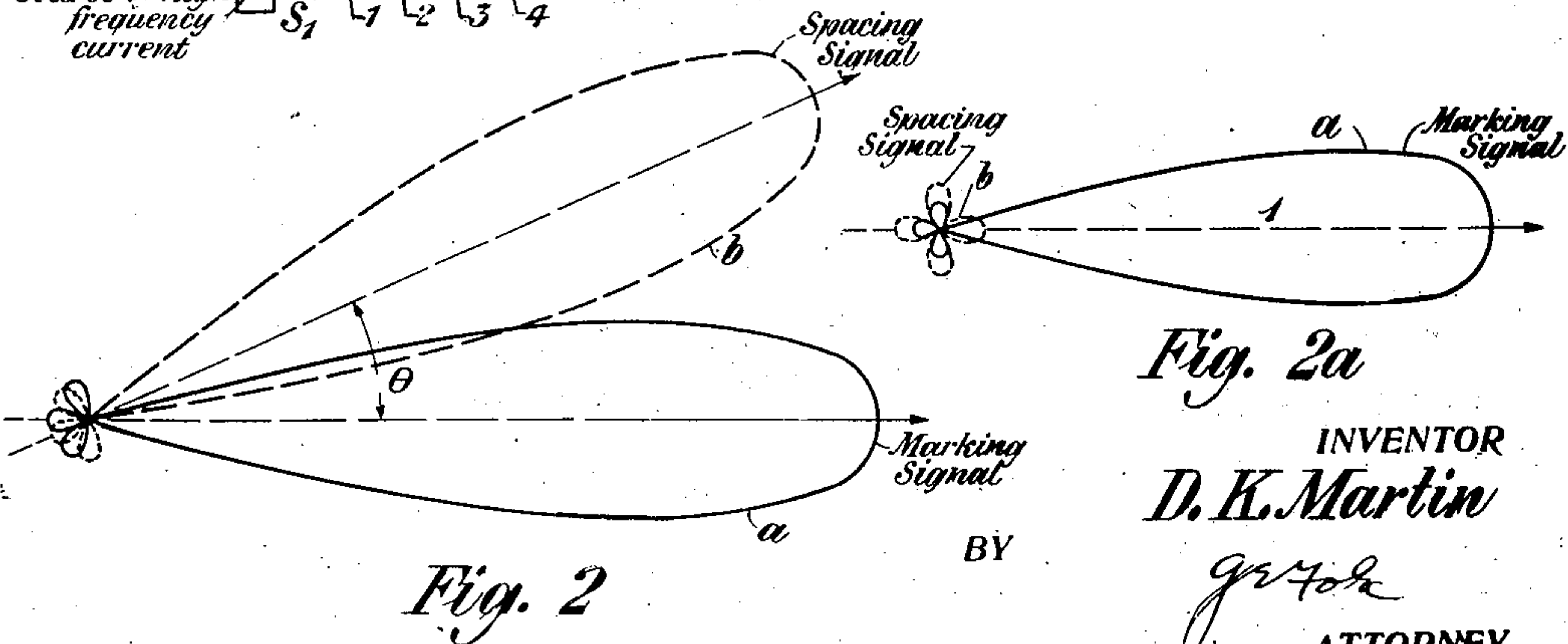
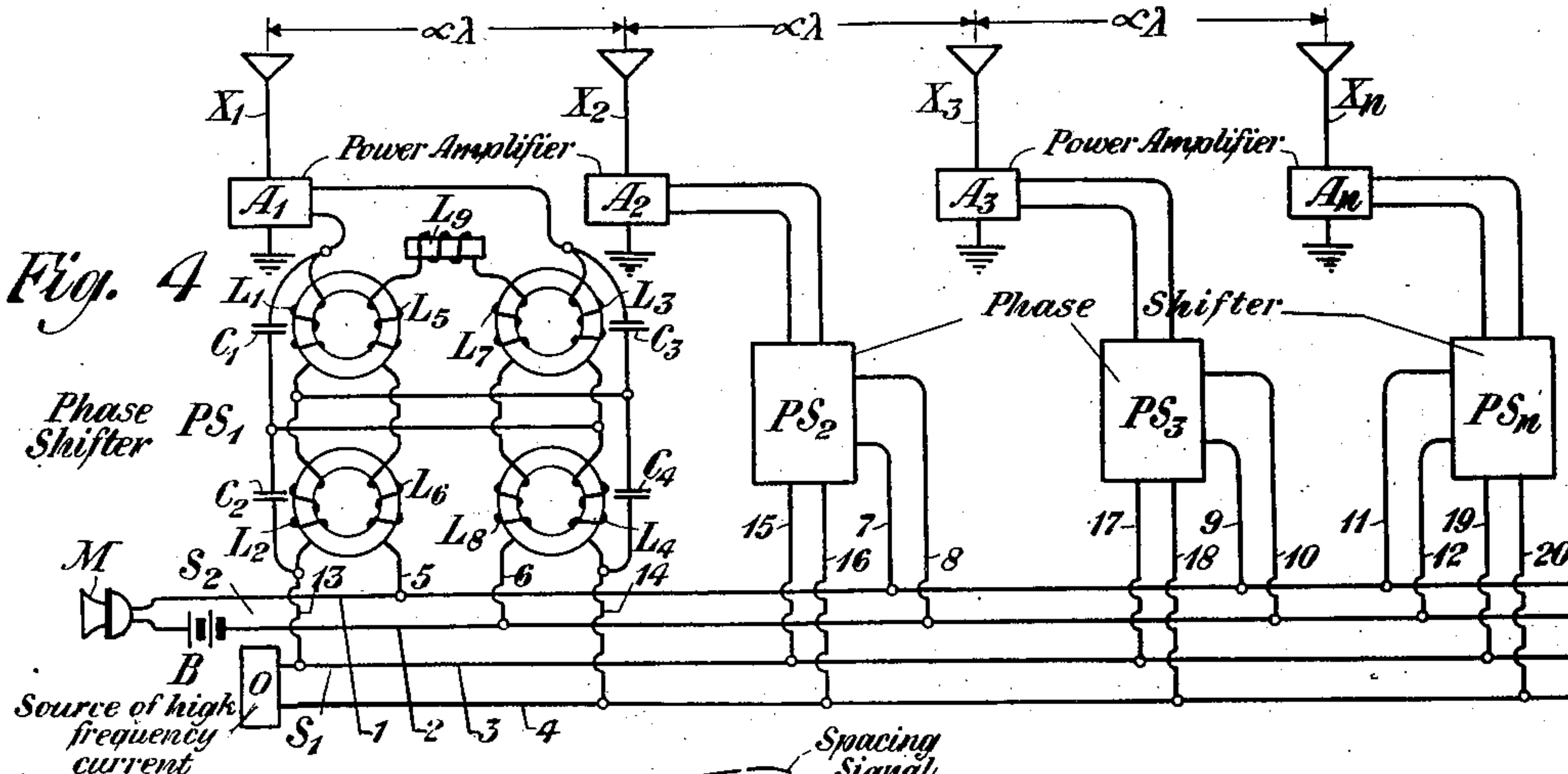


Fig. 2a

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RADIO SIGNALING SYSTEM.

Application filed January 11, 1923. Serial No. 612,030.

This invention relates to radio signaling systems and particularly to such systems in which the transmission and the reception of signals are effected by varying the direction of radiation of the transmitted high frequency waves.

The use of an antenna array to control the direction of radiation of high frequency waves is known to those skilled in the art of radio signaling. Such systems are disclosed in the copending application of George A. Campbell, Serial No. 327,553, dated September 30, 1919. By the proper spacing of the separate antenna structures constituting such an array and by the proper phasing of the currents impressed upon or received by such antenna structures, the directional characteristic of such structures for transmitting and receiving may be controlled. By such control we may effect maximum radiation or reception in a single direction or in two directions, either diametrically opposite or at a more acute angle to each other, or we may effect simultaneous radiation in many directions. These, however, are by no means the only ways in which radiation from an antenna array may be controlled but are simply illustrative of the directional flexibility of an antenna array.

My invention consists in the utilization of this inherent characteristic of an antenna array to effect the transmission of telegraph or telephone signals between two or more stations constituting a system.

This invention will be better understood from the following description when read in connection with the attached drawing, of which Figure 1 shows schematically two stations, each having an antenna array by means of which the method in which my invention is embodied may be carried out, Figs. 2 and 2^a show directional characteristics of a system in which my invention is embodied, Fig. 3 shows the circuit arrangement for a station adapted to transmit telegraph signals in accordance with the principles of my invention and Fig. 4 shows the circuit arrangement for a station adapted to transmit telephone signals.

In Fig. 1, A represents a transmitting station and B a receiving station, each having an antenna array, represented by a plurality of separate antenna structures, *a* at station A and *b* at station B. While I have

shown the use of an antenna array at the receiving station, it should be understood that an antenna array is not necessary at the receiving station in order to carry out the invention, since any type of receiving antenna may be used. Moreover, the invention is not limited to an antenna array of a particular type but may be embodied in any type of an array in which the directional characteristic may be readily changed by varying the phase angle of the currents applied to the separate antenna structures whereby the direction of radiation of the entire array may be readily changed. For the purpose of describing the principle of my invention the characteristic of the array shown at the transmitting station A of Fig. 1 is that represented by the solid line characteristic of Fig. 2. This characteristic designated *a* shows maximum radiation toward the right, and the zone of radiation is rather narrow. There is also a certain amount of radiation, but a relatively small amount, which is represented by the other solid line loops which radiate from the axial point of this characteristic. If the transmitting station A normally transmits along the line 1, the array connected with the receiving station B will be affected thereby to the maximum degree, assuming, of course, that the individual antenna structures at station B are so located and the phase controlling apparatus connected with the individual antenna and with the common receiving circuit are likewise so adjusted as to effect maximum receptivity along the line 1. If, however, the phase angles of the currents applied to the separate antenna structures at station A are so changed that the direction of transmission of the radiated wave is along the line 2 or 3, the antenna array at station B would be affected to a lesser degree than if the transmission had been along the line 1 and, by controlling the radiation characteristic, the effect upon the station B may be made substantially nil. From the foregoing brief description, it will be seen that the degree of receptivity of the antenna array at station B depends upon the direction of maximum radiation of the energy from station A.

I employ this principle for the transmission of telegraph signals by directing a high frequency impulse along the line 1 to repre-

sent the transmission of a marking signal and I alter the direction of radiation, that is to say, I direct it along the lines 2 or 3 to represent a spacing signal. The form of the radiation characteristic, and the direction of propagation for the marking and the spacing signals are shown in Fig. 2, wherein the solid line characteristic a represents a marking signal and the dotted line characteristic b represents a spacing signal.

Another method of transmitting marking and spacing signals consists in changing the radiation characteristic of the array instead of changing the directional characteristic. Thus, in Fig. 2^a the characteristic of the marking signal designated a is similar to that shown in Fig. 2. In order to send a spacing signal, the radiation characteristic is changed so as to effectively suppress radiation along the line 1, whereby substantially no energy reaches the distant receiving station along this line. This is shown by the dotted line characteristic designated b which shows substantially equal radiation in four directions but in which the amount of radiation in any direction is very small.

Having in mind the basic principle under which signals may be transmitted to a distant receiving station either by changing the line of direction of transmission of the antenna array as shown in Fig. 2 or by changing the directional characteristic of the array as shown in Fig. 2^a, I will now proceed to describe two transmitting circuits embodying the foregoing principles, one of which, Fig. 3, shows the means for transmitting telegraph signals and the other of which, Fig. 4, shows means for transmitting telephone signals.

In Fig. 3, X_1, X_2, X_3 and X_n represent a plurality of antenna structures spaced at a definite part of a wave length apart and, taken together, constituting the antenna array. Connected with each of the said antennae is a power amplifier designated A_1, A_2, A_3 and A_n . While these power amplifiers may be of any well known type it would probably be desirable to use the well known thermionic vacuum tube amplifiers. Connected with each of the said amplifiers through a plurality of phase shifting devices, PS_1, PS_2, PS_3 and PS_n is a source of high frequency current O , which is connected with the conductors 3 and 4 constituting a common high frequency transmission line. The phase shifting devices, which preferably are alike, consist of the inductances designated L_1, L_2, L_3 and L_n , in connection with PS_1 , which are connected in series with the conductors 3 and 4 of the high frequency transmission line by means of the conductors 13 and 14. The inductances have connected in parallel therewith condensers C_1, C_2, C_3 and C_4 so that the network comprising the inductances and

the condensers has a definite impedance Z_0 at the frequency of the current generated by the source O . Each of the said phase shifting devices has associated therewith supplemental condensers designated C_3' and C_4' , in connection with PS_1 , which normally are not connected effectively into the circuit of the network. The connection of the condensers C_3' and C_4' may, however, be effected by means of the relays R_1 and R_2 , which are controlled by the key K and the source of direct current B , and in similar manner similar supplemental condensers of other phase shifters may be controlled. The connection of these supplemental condensers into the phasing networks will, of course, change the impedance thereof to the value Z_0' .

High frequency oscillations will be impressed by the conductors 3 and 4 upon the conductors 13 and 14 and will be radiated by the antenna X_1 ; and in similar manner oscillations will be impressed upon the conductors 15 and 16, 17 and 18 and 19 and 20 and radiated by the antennae X_2, X_3 and X_n . Assuming that the key K is open, the phase angle which these oscillations will have when applied to the respective antennae will be determined by the impedance Z_0 of the networks PS_1, PS_2, PS_3 and PS_n , individual to their respective antennae. Let it be assumed that these oscillations are phased in such a manner that the direction of radiation is represented by the dotted line characteristic b of Fig. 2. This represents the transmission of a spacing signal to the distant receiving station, since the amount of energy received there may be made practically nil by making the angle θ sufficiently large. In order to transmit a marking signal, the key K is closed, which in turn operates the relays R_1 and R_2 of phase shifter PS_1 by the flow of current from the battery B over conductors 2 and 6, relays R_1 and R_2 , conductors 5 and 1 and through the key K . In similar manner, other relays connected with the phase shifters PS_2, PS_3 and PS_n would be controlled by the current from the battery B . The operation of relays R_1 and R_2 effectively connects into the network of the phase shifter PS_1 the condensers C_3' and C_4' , which changes the phase angle of the current flowing from the source O to the antenna X_1 because the impedance of the net work is changed from Z to Z' . In like manner, although not necessarily to the same degree, the phase angle of the current flowing from the same source to the other antennae of the array would be changed so that the directional characteristic of the array would be represented by a of Fig. 2. This results, therefore, in the transmission of a marking signal to the distant receiving station.

In carrying out the method of operating

this circuit in the manner represented by Fig. 2^a, the amount of radiation in any direction is practically nil when a spacing signal is being transmitted, while, on the other hand, the radiation is a maximum in the direction of the receiving station when a marking signal is to be transmitted. This may be effected in the arrangement shown in Fig. 3 by the proper adjustment of the networks of the various phase shifters to produce substantial neutralization of radiation when the key K is open as shown by *b* of Fig. 2^a, but, on the other hand, to effect maximum radiation along a predetermined line, as represented by *a* of Fig. 2^a, when a marking signal is to be transmitted.

The arrangement for transmitting telephone signals is shown in Fig. 4, in which the same reference numerals or letters as are used in Fig. 3 represent similar parts. In this figure, a type of antenna array similar to that shown in Fig. 3 is used. Each antenna of the array has connected therewith a power amplifier which is connected through a phase shifter with a source of high frequency current O. The phase shifter differs structurally, at least, from that shown in Fig. 3. Phase shifter PS₁, which is typical of all of these devices, comprises a plurality of iron core inductance coils, of which certain of the windings are connected with the high frequency source and other windings are connected with the low frequency microphone M, having a direct current source B connected therewith. The high frequency windings L₁, L₂, L₃ and L₄ have connected therewith condensers C₁, C₂, C₃ and C₄, which together constitute a network having a definite impedance Z₀ at the frequency of the source O, provided the permeability of the iron cores remains fixed. The phase angle of the current supplied to the antenna X₁, for example, may be changed by varying the permeability of the iron cores. This may be done by actuating the microphone M, which varies the flow of current from the battery B over a circuit comprising conductors 1 and 5, windings L₆, L₅, L₇ and L₈ and conductors 6 and 2. It will be readily seen that the permeability of the iron cores upon which the various windings are placed will be varied in accordance with the voice currents resulting from the actuation of the microphone M. These variations of the permeability of these cores will result in changing the value of the high frequency inductances which results in substantially immediate changes in the phase angle of the high frequency currents applied to the antenna X₁. It will, of course, be apparent that while these changes in the phase angle are occurring in the current applied to the antenna X₁, similar changes occur in the currents applied to the other antenna, by virtue of the operations of the phase shifters PS₂,

PS₃ and PS_n. If the phase shifters are so adjusted that when no variations of the direct current circuit are occurring, the phase of the high frequency current applied to the respective antennae is such as to produce, for example, a radiation characteristic similar to *a* of Fig. 2, then the variations of the phase angles of the high frequency currents resulting from the impression of sound waves upon the microphone M will result in a rapid shifting of the longitudinal axis of the radiation characteristic, as shown in Fig. 2, this shifting resulting from and being in accordance with the changes in the direct current circuit resulting from the voice waves. It will be apparent, therefore, that at a distant receiving station such as B of Fig. 1, having an antenna array which is adjusted to give maximum receptivity along the line 1, the receptivity would vary in accordance with variations of the angle θ representing the deviation of the radiation characteristic from this line, that is to say, the amount of current received at B would vary in accordance with the voice waves impressed upon the microphone M. It will be accordingly seen that the radiation characteristic *a* of Fig. 2, which represents the normal radiation of the antenna array of Fig. 4, when no voice waves are impinging upon the microphone M, may be shifted in accordance with the voice waves impressed upon the said microphone so that the angle θ which the longitudinal axis of the characteristic *a* makes with the line joining the transmitting and the receiving stations as, for example, the line 1 of Fig. 1, will vary in accordance with variations of the voice waves.

While no mention has been made heretofore of the arrangement of the receiving circuit of this system, it is to be understood that any well known type of receiving antenna may be used. If it be desired to use an antenna array at the receiving station, such a circuit is shown in Fig. 12 of the said application of George A. Campbell, Serial No. 327,533. It employs a plurality of antennae spaced a definite part of a wave length apart and having connected therewith and individual thereto a plurality of circuits, each having the necessary filters, amplifiers, and phase shifting devices, which circuits are connected with a common receiving circuit having a suitable local source of high frequency oscillations for the detection of the low frequency signals.

While this invention has been described as embodied in a particular form and arrangement of parts it is to be understood that it is capable of embodiment in other and different forms within the spirit and scope of the appended claims.

What is claimed is:

1. In a radio signaling system having a transmitting station comprising a transmit-

ting antenna array, a source of high frequency current, and signaling means for controlling the directional characteristic of the said array connected therewith, and a receiving station having receiving apparatus connected therewith, the method of signaling, which consists in producing a beam of high frequency oscillations, and varying the direction of radiation of the said beam from the said transmitting array by and in accordance with the signals being transmitted.

2. In a radio signaling system having a transmitting station comprising a transmitting antenna array, a source of high frequency current, and signaling means for controlling the directional characteristic of the said array connected therewith, and a receiving station having receiving apparatus connected therewith, the method of signaling which consists in varying the magnitude of radiation in a given direction only by and in accordance with the signals being transmitted.

3. In a radio signaling system having a transmitting station comprising a transmitting antenna array, a source of high frequency current, and signaling means for controlling the directional characteristic of the said array connected therewith, and a receiving station having receiving apparatus connected therewith, the method of signaling which consists in producing maximum radiation in a given direction only to effect the transmission of one type of signal and to produce substantial suppression of radiation to effect the transmission of a different type of signal.

4. In a radio signaling system having a transmitting station comprising a transmitting antenna array, a source of high frequency current, and signaling means for controlling the directional characteristic of the said array connected therewith, and a receiving station having receiving apparatus connected therewith, the method of signaling which consists in varying the phase of the high frequency currents by and in accordance with the signals being transmitted,

whereby the directional characteristic of the array may be varied.

5. In a radio signaling system comprising a transmitting station and a receiving station, each having an antenna array arranged for unilateral transmission and reception therebetween, the degree of receptivity varying with the changes in the directional characteristic of the transmitting array, the method of signaling which consists in producing such a directional characteristic of the transmitted wave as to effect maximum receptivity and varying the directional characteristic to vary the degree of receptivity by and in accordance with the signals being transmitted.

6. In a radio signaling system, the combination with an antenna array comprising a plurality of antennæ, of a source of high frequency current common to all of said antennæ, means individual to each antenna to control the phase of the current supplied thereto by the said common source of current, and means to simultaneously change the phase of the current supplied to each antenna whereby the array is caused to have a different directional characteristic.

7. In a radio signaling system, the combination with an antenna array comprising a plurality of antennæ substantially equally spaced apart, of a source of high frequency current common to the said antennæ, a phase shifter individual to each antenna and connected between the said source and each antenna, a source of signals also common to said antenna, and switching means individual to each phase shifter and controlled by said source of signals to change the constants of the said phase shifter whereby the phase angle of the currents supplied to the antennæ is changed and the axis of the beam of energy radiated by the said array is shifted.

In testimony whereof, I have signed my name to this specification this 10th day of January, 1923.

DE LOSS K. MARTIN.