

March 29, 1927.

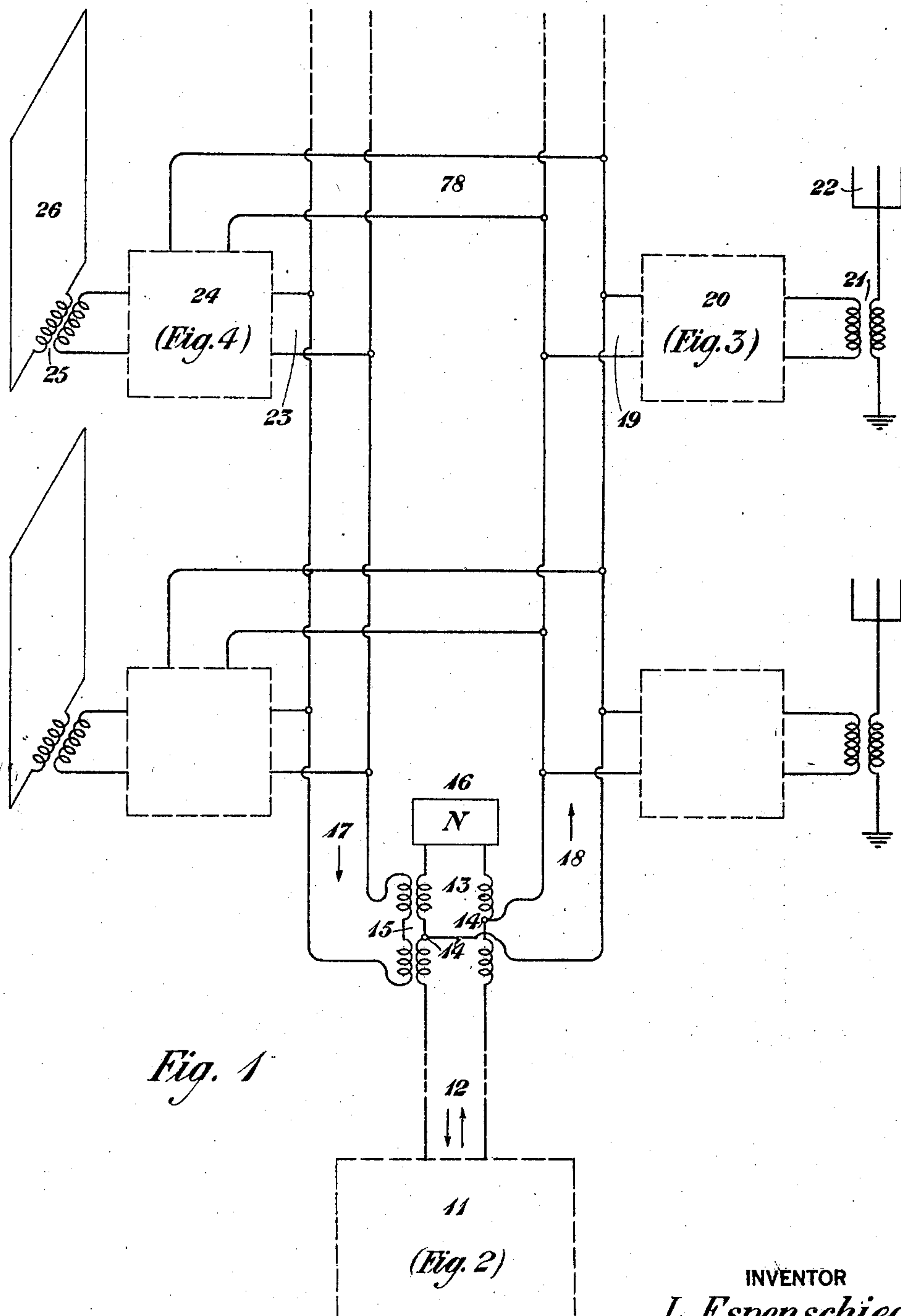
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MULTIPLE ANTENNA SYSTEM FOR RADIOCOMMUNICATION

Filed Sept. 3, 1921

3 Sheets-Sheet 1



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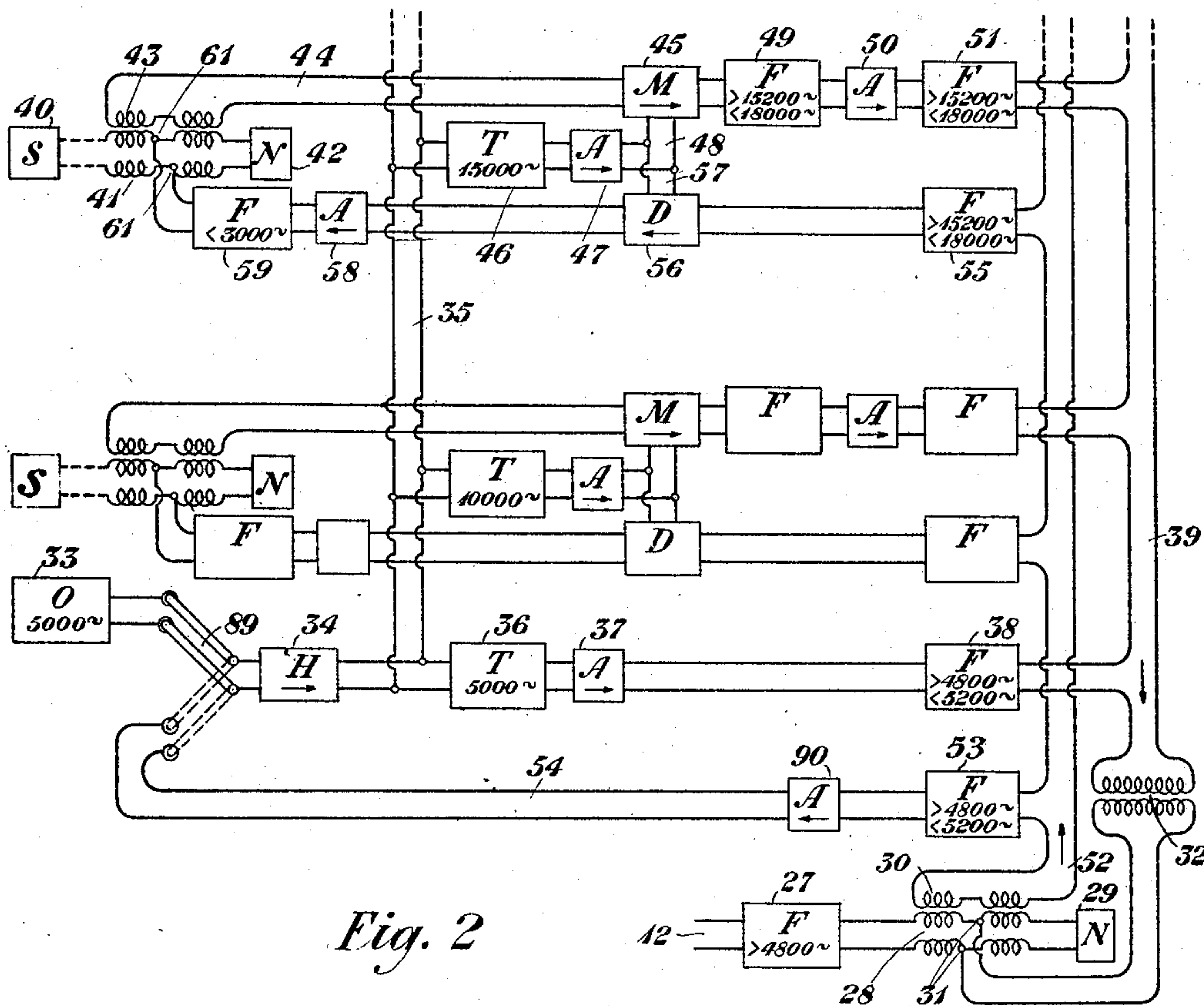
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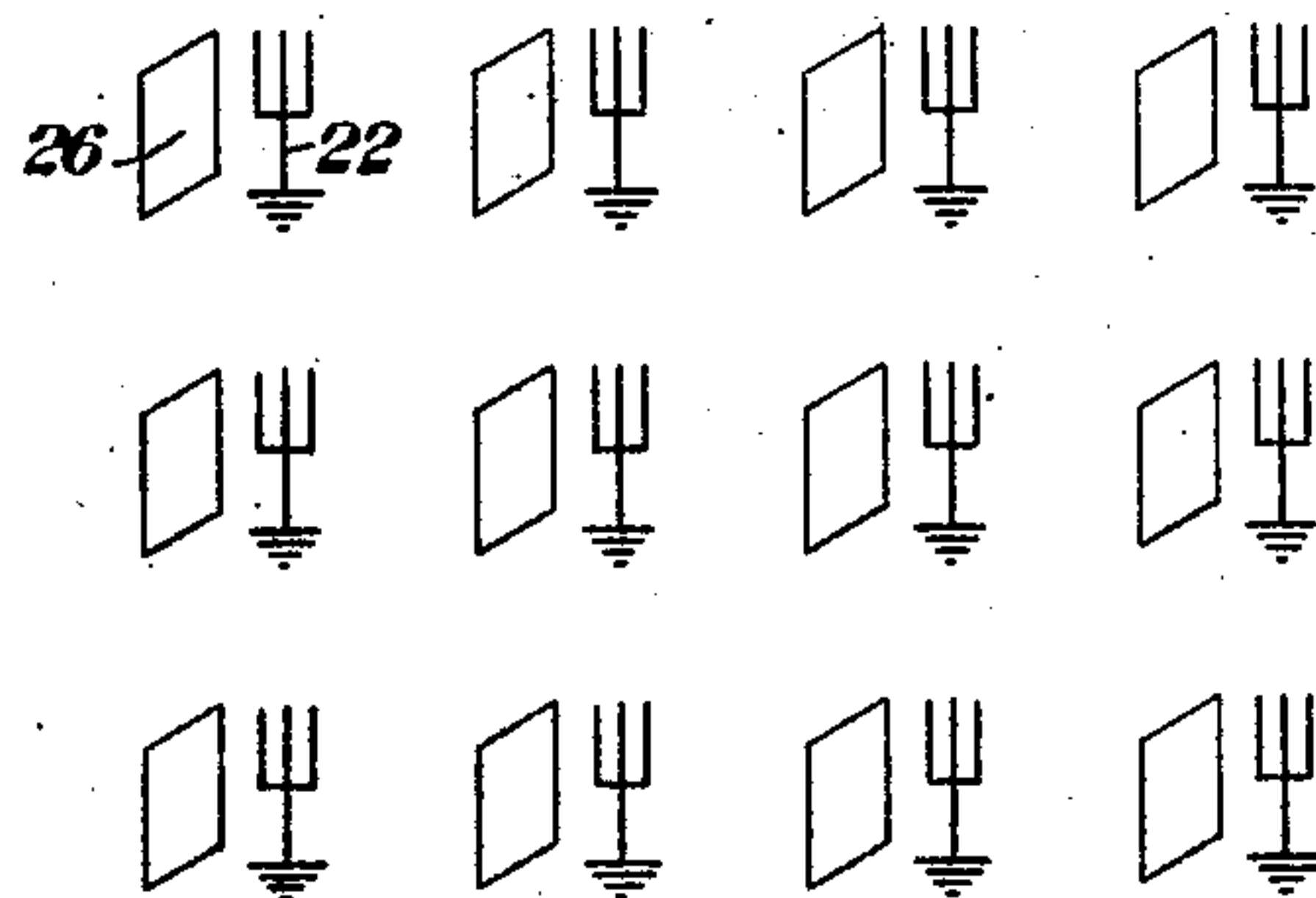
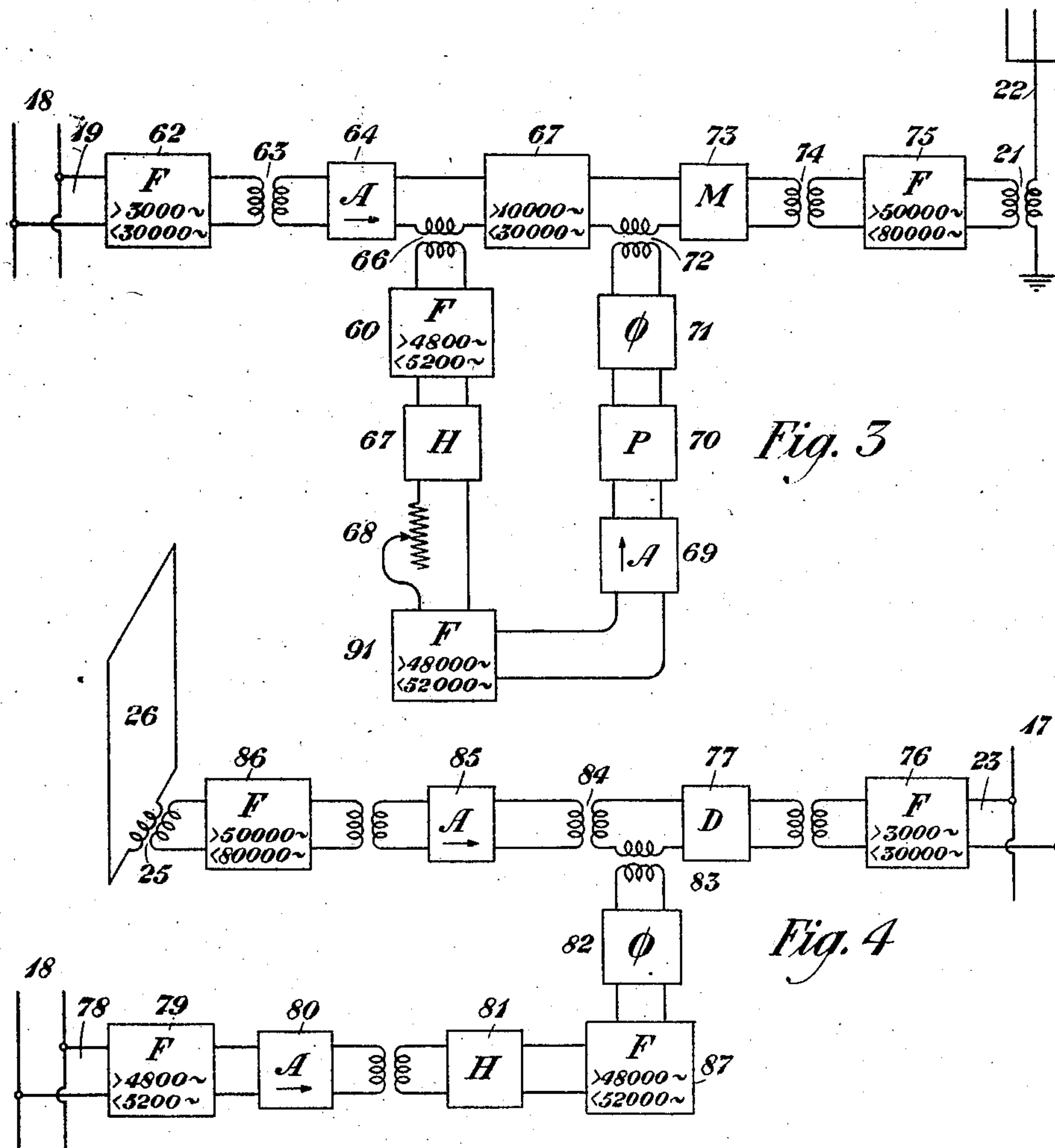
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UNITED STATES PATENT OFFICE.

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MULTIPLE-ANTENNA SYSTEM FOR RADIOCOMMUNICATION.

Application filed September 3, 1921. Serial No. 498,187.

The principal object of my invention is to provide means for the unitary operation of a radio antenna array. Another object of my invention is to provide means to operate a plurality of antennæ at a central station in proper amplitude relation and phase relation to secure effective conjoint action of these elements. In certain aspects my invention involves multiplex carrier current operation of an antenna array in connection with a central station.

In the accompanying drawings I have shown diagrammatically a specific embodiment of my invention and I now proceed to describe this with the understanding that it is by way of example and that the invention is defined in the appended claims. In these drawings, Figure 1 is a diagram showing the general arrangement of the apparatus at one multiple antenna station. Fig. 2 is a diagram of the central station apparatus for an antenna array. Fig. 3 is a diagram showing the apparatus associated with a single transmitting antenna. Fig. 4 is a diagram showing the apparatus associated with a single receiving antenna and Fig. 5 is a diagram showing how the transmitting and receiving antennæ may be disposed in an array.

In Figs. 2, 3 and 4 I have indicated certain elements of apparatus diagrammatically by rectangles with suggestive initials, A for amplifier, F for filter, M for modulator, D for demodulator, T for tuned circuit, O for oscillation generator, N for artificial line or network, P for power tube and ϕ for phase shifter. These elements of apparatus are well known and are described in various publications, for example in Blackwell & Colpitts, A. I. E. E. paper of April, May and June, 1921.

Referring to Fig. 1, the central station 11 is connected by a pair of conductors 12 with the hybrid transformer secondary 13 from whose middle points 14 a pair of conductors 18 goes to the transmitting antennæ. There is a branch 19 for each antenna 22 and the respective transmitting apparatus 20 is connected to the antenna through a transformer 21.

The receiving antennæ 26 are connected through transformers 25, receiving apparatus 24, and branch conductors 23 to the receiving line 17, which leads to the transformer primary winding 15 associated with

the secondary winding 13. The line 12 is balanced by the network or artificial line 16.

The central station 11 is shown in Fig. 2. The line 12 and high pass filter 27 are balanced at the central station by the network or artificial line 29 and between them is the primary winding 28 of a hybrid transformer, whose secondary 30 is connected to a receiving circuit 52. The middle points 31 of the windings 28 are connected through a transformer or repeating coil 32 to the transmitting line 39.

The oscillation generator 33 generates alternating current of a frequency of 5,000 cycles per second. The current of this frequency is delivered to the harmonic producer 34 which acts by distortion to produce currents of higher frequencies, harmonics of the fundamental, all of which are superposed in the output circuit 35. From this output circuit 35, one branch leads through a tuned circuit 36 (tuned to 5,000 cycles per second) and an amplifier 37, then a band filter 38 to the transmitting circuit 39. Other branches from the circuit 35 take off higher frequencies delivered by the harmonic producer 34. One of these branches leads through the tuned circuit 46, tuned to 15,000 cycles per second, thence through the amplifier 47 to the branch circuits 48 and 57.

At 40 is an ordinary subscriber's telephone set for transmitting and receiving, connected by a line through the hybrid transformer primary 41 to the artificial line or network 42. The transformer secondary 43 is connected by the circuit 44 to the input of the modulator 45. This modulator 45, of the balanced carrier suppression type, receives current of frequency 15,000 through the conductors 48 from the amplifier 47, and the input voice frequency currents over the conductors 44 modulate this 15,000 frequency current and the modulated current is delivered from the modulator 45 to the filter 49, thence to the amplifier 50 and thence through the band filter 51 to the transmitting line 39. The filters 49 and 51 pass the upper side band with respect to the carrier frequency of 15,000.

It is contemplated that all of the radio stations in communication with the one now being described shall have impressed upon them a fundamental frequency determined by the oscillation generator 33. Accordingly such other stations will be like the one now

being described, except that they will have the switch 89 thrown to the dotted line position. Among the frequencies received from the distant station in any such case will be
 5 5,000 in the circuit 52, and this will be taken through the filter 53 and amplifier 90 and delivered to the harmonic generator 34.

The received current in the circuit 52 passes in series to the band filter such as 55, and from each of these the current that is
 10 passed by such filter goes to a corresponding demodulator 56. The filter 55 passes the upper side band with respect to the carrier frequency 15,000. The particular demodulator designated 56 in Fig. 2 receives cur-
 15 rent of a frequency 15,000 cycles per second through the conductors 57 and the output current of voice frequency goes through the amplifier 58 and filter 59 to the middle points 61 of the hybrid transformer primary winding 41.

The transmitting apparatus between the line 18 of Fig. 1 and the individual transmitting antenna 22 is shown in Fig. 3. The
 25 branch conductors 19 from the transmitting line 18 receive the currents of frequency 5,000 and the upper side band based on 10,000, 15,000, etc., as modulated by the respective voice currents. All these super-
 30 posed currents go through the band filter 62, the repeating coil or transformer 63, and amplifier 64 to the filter 67, which connects with the modulator 73. In series with filter 67 is the primary of a transformer 66 whose
 35 secondary is connected through a filter 60 which passes 5,000 frequency to the input of the harmonic distorter 67, from which the output goes through the rheostat or potentiometer 68 to the filter 91 which passes
 40 frequency 50,000 through the amplifier 69 to the power tube 70. The 50,000 frequency output from power tube 70 goes through the phase shifter 71, and by means of the transformer 72 this output is put in series in the
 45 output side of the filter 67. Thus the modulator 73 modulates the current of 50,000 frequency from the phase shifter 71 by means of the current belonging to the upper side bands of frequencies based on 10,000, 15,000,
 50 etc., which come through the filter 67. The modulated output current from the modulator 73 goes through the transformer 74 and through the band filter 75, and transformer 21 to antenna 22. This band filter 75 passes
 55 frequencies greater than 50,000 and less than 80,000 cycles, comprising the upper side band of the modulator 73.

Referring to Fig. 4, the receiving antenna 26 is connected through the filter 86, amplifier
 60 85 and transformer 84 to the demodulator 77. The branch circuit 78 from the transmitting circuit 18 leads through the filter 79 which passes only current of the fundamental frequency 5,000. This is amplified
 65 in the amplifier 80 and delivered to the dis-

torter 81, thence through the filter 87, which passes current of frequency 50,000 to the phase shifter 82 from which the current is impressed by means of the transformer 83 on the demodulator 77, which receives the
 70 filtered and amplified current through the transformer 84 from the receiving antenna 26. The demodulated output current from the device 77 goes through the filter 76 to the line 17. 75

The system heretofore described is adapted to deliver currents in any desired proper relation of amplitude and phase to the respective antennæ of a transmitting array, such as the antennæ 22, which may be ar-
 80 ranged as shown in Fig. 5. The system is also adapted to receive currents over the receiving antennæ 26, which may be arranged as shown in Fig. 5 and deliver current to the central station in proper amplitude relation
 85 and phase relation based on the current received in the antennæ 26.

Voice currents coming from the telephone station 40 go through the hybrid coil trans-
 90 former 41—43, the secondary circuit 44 and modulator 45 where they modulate the currents of frequency 15,000 received from the amplifier 47. The filters 49 and 51 pass the upper side band, that is, the currents of a
 95 frequency range from 15,200 up to 18,000 which includes the highest essential voice frequency. These currents go over the circuit 39 to the points 31, then through the high-pass filter 27 to the line 12. Other
 100 side bands lying in other frequency ranges may be impressed similarly and at the same time from other input branches upon the circuit 39 and thence upon the circuit 12.

All these carrier currents in the circuit 12 are delivered through the midpoints 14 of
 105 the hybrid transformer 13—15, to the circuit 18 connected with which are the branches 19. The particular branch designated 19 in Fig. 3 has its band filter 62 tuned to take all the frequency side bands desired to be
 110 transmitted over circuit 12. In the apparatus shown in Fig. 3 a basic carrier frequency of 50,000 cycles per second is developed and this is modulated by the complex current re-
 115 ceived from the circuit 18 and the side band based on the carrier current 50,000 is radiated from the antennæ 22.

Each antenna is given the proper amplitude of current in relation to that of other antennæ by means of the rheostat 68, and
 120 the proper phase relation by means of the phase adjuster 71.

Such a complex current as has been described as radiated from the antennæ 22 may be received on the antennæ 26. The ap-
 125 paratus shown in Fig. 4 combines this complex current with a basic frequency of 50,000 cycles per second and demodulates it, giving output currents lying in the various upper side bands of frequency from 3,000 to
 130

30,000. These are superposed on the receiving circuit 17 and delivered over the apparatus described to the circuit 52. The band filters 55 are selective to the respective side bands involved. For example, the filter designated 55 in Fig. 2 passes the side band lying between 15,200 and 18,000 which includes the highest essential voice frequency. This side band of current is combined in the demodulator 56 with current of basic frequency 15,000 and the resulting output current of simple voice frequency is amplified in the amplifier 58 and goes over the telephone line to the subscriber's set 40.

It will be understood that it is practically difficult to transmit over wires of any considerable length currents of a proper frequency to be radiated from or received by the antennæ. Hence it will be seen that my system provides for working with moderate frequencies on the lines 12, 39 and 52, but using these currents of a moderate frequency to modulate currents of much higher frequency for transmitting, or to obtain such moderate frequency currents by demodulation from high frequency received currents.

For the operation of an antenna array it is essential that the currents in the respective antennæ and at the central station shall have a precise phase relation and in certain antenna arrays it is moreover desirable that there should be a graded amplitude relation among the currents. It will be seen that I have accomplished these ends by basing all the currents on a single oscillation generator of frequency 5,000 cycles per second in the particular case described. All of the carrier currents can be made to have a definite frequency ratio thereto and a definite phase relation so that all parts of the system can be kept in step for effective concurrent operation.

By means of antenna arrays it is known to be practicable to attain high selectivity of transmission or receiving in a particular direction; but to accomplish this purpose it is essential that the proper phase and amplitude relations should be secured as I have just stated, and my system is adapted for that purpose.

I claim:

1. A plurality of antennæ assembled to constitute an array for directional operation, a low frequency central station, low frequency conductors extending therefrom to the respective antennæ of the array, frequency changing means at the respective antennæ for co-operation between said low frequency conductors and said antennæ operating at high frequency, and means to adjust the currents for phase and amplitude at each of the antennæ.

2. A plurality of transmitting antennæ assembled in orderly arrangement to constitute an array for unitary directional

transmission, a plurality of receiving antennæ assembled in orderly arrangement to constitute an antenna array for unitary directional reception, high frequency modulators at the transmitting antennæ adapted to deliver their output currents to said antennæ, high frequency demodulators at the receiving antennæ, and a low frequency central station operatively connected for transmission to all said transmitting antennæ and for reception to all said receiving antennæ.

3. A multiple antenna directional transmitting array, a multiple antenna directional receiving array, a central station connected to all the antennæ of both arrays, and means at each antenna to generate carrier currents and to modulate them for sending at the transmitting antennæ and to apply them for demodulation at the receiving antennæ.

4. A plurality of antennæ constituting a unitary co-ordinate array for directional transmission, a central station, means to generate several carrier currents at the central station, means to modulate them at the central station with currents of signaling frequency, circuits to transmit them thence to the antennæ, means controlled over such circuits from the central station to generate radio frequency currents at the respective antennæ, means at the antennæ to modulate such radio frequency currents by the once modulated currents from the central station, and means to apply the modulated radio frequency currents to be radiated from the antennæ.

5. A plurality of antennæ constituting a unitary co-ordinate array for directional reception, a central station, a circuit connecting said antennæ and said station, means to receive multiplex modulated radio frequency carrier currents at the antennæ, means there to demodulate them and to deliver modulated low frequency carrier currents over said circuit to said station, means at the station to separate and demodulate such currents and deliver demodulated signal currents, and respective indicators therefor.

6. A plurality of antennæ, part of them constituting a unitary co-ordinate array for directional transmission and part of them constituting a similar array for reception, a low frequency central station, low frequency conductive means connecting said central station with said antennæ, and apparatus at each antenna operatively connecting it with said conductive means for high frequency operation of the antenna and low frequency operation of the said conductive means.

7. A plurality of antennæ, part of them constituting a unitary co-ordinate array for directional transmission and part of them constituting a similar array for reception, a low frequency central station, low frequency conductive means connecting said central sta-

tion with said antennæ, apparatus at each antenna operatively connecting it with said conductive means for high frequency operation of the antenna and low frequency operation of the said conductive means, and phase shifting and amplitude adjusting means at each antenna by which their co-ordinate operation for directivity may be secured.

8. A plurality of antennæ constituting a unitary co-ordinate array for directional transmission and reception, a central station, means to generate several carrier currents at the central station, means to modulate them at the central station with currents of signaling frequency, a circuit to transmit them thence to the antennæ, means controlled over such circuits from the central station to generate radio frequency currents at the antennæ, means at the antennæ to

modulate such radio frequency currents by the once modulated currents from the central station, means to apply the modulated radio frequency currents to be radiated from the transmitting antennæ, means also at the antennæ to apply the said generated radio frequency currents to demodulate received modulated high frequency currents on the receiving antennæ and deliver modulated low frequency carrier currents to said central station, and means at the station to separate and demodulate such currents and deliver demodulated signal currents, and respective indicators therefor.

In testimony whereof, I have signed my name to this specification this 30th day of August, 1921.

LLOYD ESPENSCHIED.