

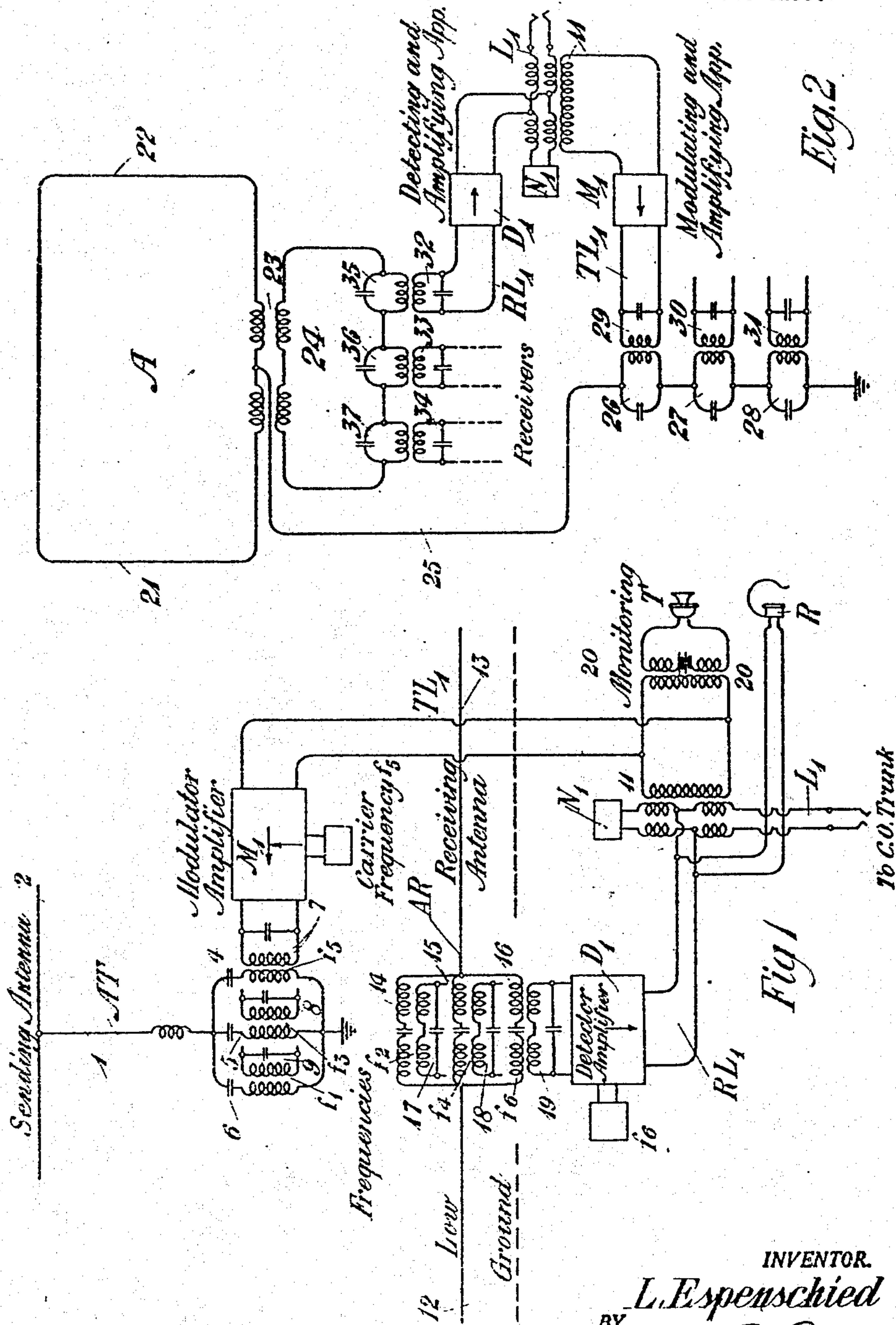
April 15, 1924.

1,490,165

L. ESPENSCHIED
BALANCED ANTENNA SYSTEM

Filed Sept. 30, 1919

3 Sheets-Sheet 1



INVENTOR.
L. Espenschied
BY *C. C. Rame*
ATTORNEY.

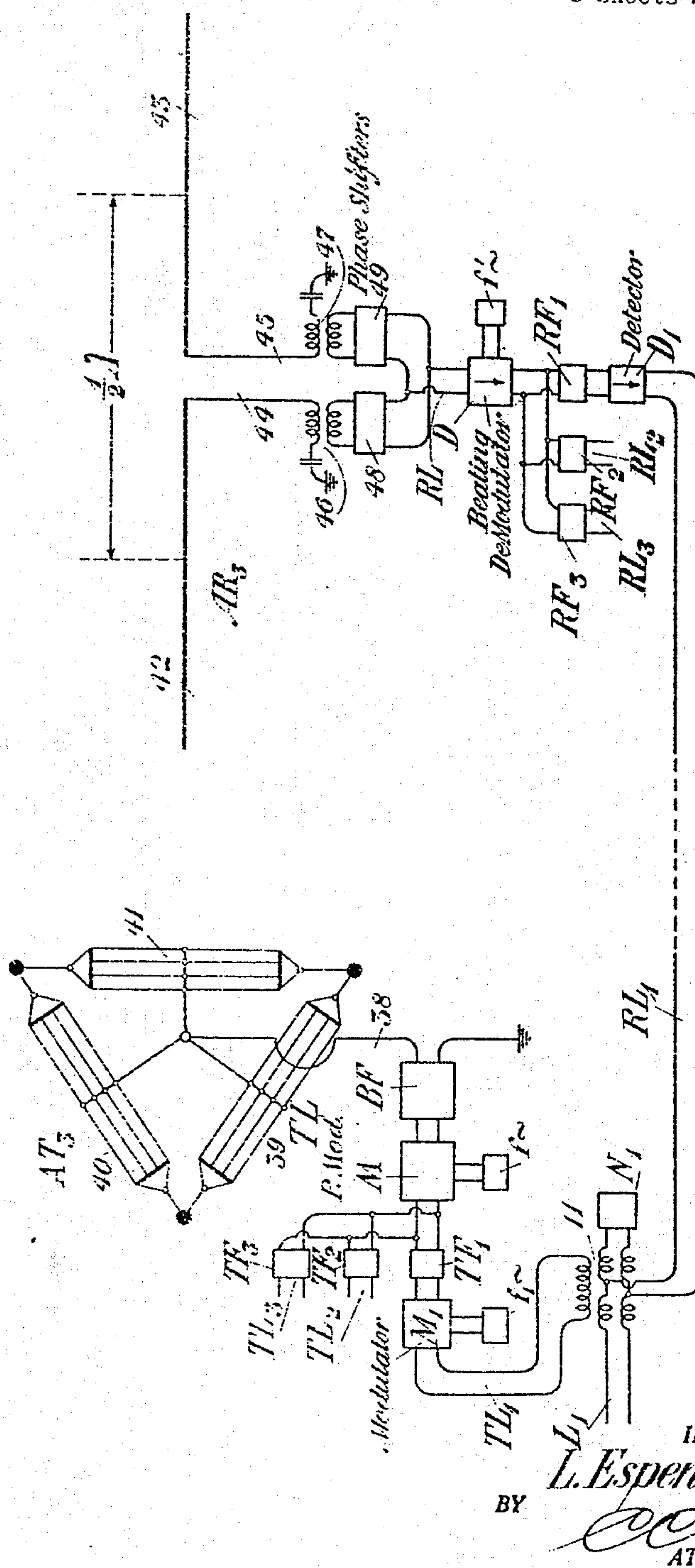
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Fig. 3



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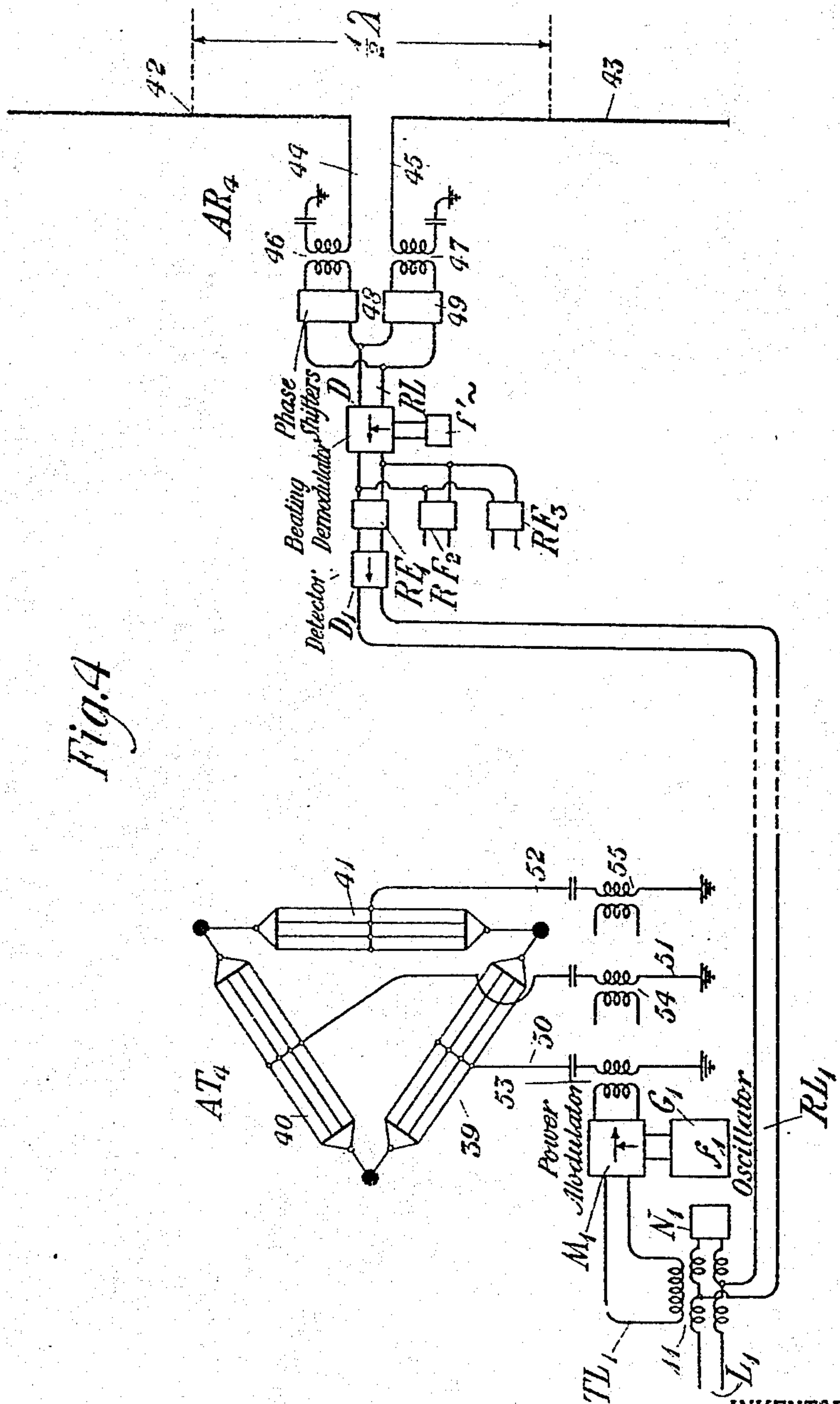
L. ESPENSCHIED

BALANCED ANTENNA SYSTEM

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Fig. 4



INVENTOR.
L. Espenschied
BY *C. Rose*
ATTORNEY

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UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF HOLLIS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

BALANCED ANTENNA SYSTEM.

Application filed September 30, 1919. Serial No. 327,502.

To all whom it may concern:

Be it known that I, LLOYD ESPENSCHIED, residing at Hollis, in the county of Queens and State of New York, have invented certain Improvements in Balanced Antenna Systems, of which the following is a specification.

This invention relates to radio signaling and more particularly to arrangements for preventing interference between oppositely directed radio transmissions.

One of the features of the invention relates to a directive receiving antenna so arranged that it will produce a maximum effect upon the receiving apparatus in response to oscillations received in a given direction, but will produce practically no effect upon the receiving apparatus in response to radiations received from the local sending antenna.

Another feature of the invention relates to a directive receiving antenna so arranged that its direction of maximum absorbing effect may be rotated at will, without affecting its faculty of producing substantially no effect upon the receiving apparatus in response to radiations transmitted from the local sending antenna.

Still another feature of the invention relates to a multiplex radio system in which a condition of balance obtains between oppositely directed channels, both at high and low frequency.

Still another feature of the invention relates to a multiplex radio system having balanced conditions such as just described and further characterized by the fact that oppositely directed transmissions are separated in frequency.

These features, as well as other features more fully appearing hereinafter, are realized in an arrangement in which the receiving antenna comprises a pair of symmetrical absorbing members so related to the receiving apparatus that energy absorbed from radiations transmitted in a given direction will produce a maximum cumulative effect upon the receiving apparatus. Where it is not desired to change the direction of maximum receiving efficiency, the sending antenna may be located at one side of the receiving antenna, so that substantially equal and opposite effects will be produced upon the two absorbing members of the receiving

antenna, thereby preventing any substantial effect being produced upon the receiving apparatus. Where, however, it is desired to vary the line of maximum absorbing effect, the receiving antenna may be arranged so that it may be rotated and the sending antenna located above the receiving antenna in a fixed position, so that equal and opposite effects will be produced in the two members of the receiving antenna, regardless of its radial position. Instead of rotating the receiving antenna for the purpose of changing its line of maximum directive effect, the same result may be secured by the provision of phase changing elements, whereby the energy absorbed by the two halves of the antenna will produce maximum cumulative effect upon the receiving apparatus when receiving in any desired direction.

In order that the antenna structure above described may be used for multiplex signaling, each of a plurality of low frequency lines may be connected to the sending antenna and the receiving antenna, by means of transmitting and receiving channels, respectively, said channels including the necessary means for translating low frequency signals into radio frequencies and vice versa. These channels may be rendered conjugate with respect to low frequencies by balancing the signaling lines in the usual manner, while the antenna arrangement above described constitutes a balance between the channels at radio frequencies. By assigning different frequencies to the transmitting and receiving channels and providing suitable tuning or filtering means, the selectivity between oppositely directed channels which is afforded by balance, may be supplemented by frequency selectivity.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, Figures 1, 2, 3 and 4 of which constitute circuit diagrams of different embodiments of the invention.

Referring to Figure 1, AT designates a sending antenna structure comprising a vertical member 1 and an aerial member 2, of usual construction. The vertical member is provided with a plurality of tuned branches 4, 5 and 6, each of which is coupled with corresponding tuned elements, 7, 8 and 9.

The tuning elements 7, 8 and 9 are each connected with a suitable transmitting channel, of which only the channel TL_1 associated with the tuning element 7, is illustrated. Each pair of coupled tuning elements is tuned to the same frequency and different frequencies are assigned to each pair. Thus the frequency f_1 is assigned to the tuning elements 6 and 9, the frequency f_3 to the tuning elements 5 and 8, and the frequency f_5 to tuning elements 4 and 7. The transmitting channel TL_1 , associated with the tuning element 7, is connected at its opposite end with low frequency signaling circuit L_1 through a balanced transformer arrangement 11. The receiving channel RL_1 is also associated with said transmission line L_1 by being connected to the midpoints of the windings of the transformer 11 and the line L_1 is balanced by an artificial line or network N_1 , in order to render the channels TL_1 and RL_1 substantially conjugate with respect to each other.

The receiving antenna, as illustrated, consists of two low horizontal members 12 and 13, said members being unconnected to ground, but being connected together through tuned elements 14, 15 and 16. These tuned elements have coupled therewith other tuned elements 17, 18 and 19, these three elements being associated with corresponding receiving channels, of which only the channel RL_1 associated with the tuned element 19, is illustrated. The tuned elements associated with the receiving antenna like those described in connection with the transmitting antenna, are tuned together in pairs, each pair having a different frequency. These frequencies may correspond to the frequencies of the transmitting channels, but in any radio system it is usually desirable, because of the comparatively large amount of unbalanced energy absorbed by the receiving apparatus, to use a different frequency for receiving from that used for transmitting purposes. Where such is the case, the frequencies of the tuned elements associated with the receiving antenna should be different from those associated with the transmitting antenna, consequently, as indicated, the elements 14 and 17 are tuned to the frequency f_2 , the elements 15 and 18 to frequency f_4 and elements 16 and 19 to frequency f_6 .

The transmitting channel TL_1 is provided with suitable modulating and amplifying apparatus schematically indicated at M_1 . This modulating and amplifying apparatus may be of any well-known character and is arranged to translate the low frequency signals into radio frequencies, by modulating a carrier frequency in accordance with the low frequency signaling currents. The carrier frequency to be modulated may be supplied from any source having the de-

sired frequency, which in the case illustrated will be a frequency f_5 . The receiving channel RL_1 is also provided with suitable detecting and amplifying apparatus schematically indicated at D_1 , for the purpose of translating the received radio frequencies into low frequency signaling currents for transmission to the line L_1 . This detecting and amplifying arrangement may be of any well-known type and where the homodyne method of reception is employed, the detecting apparatus will be supplied with a homodyne frequency for beating the modulated radio oscillations, said homodyne frequency being the same as the carrier frequency assigned to the channel, which in this instance is f_6 . Similar modulating and detecting apparatus will, of course, be associated with the other channels which are not illustrated.

A monitoring set may also be provided for the use of an operator, in establishing a connection with the distant station, or for permitting the operator to talk with the subscriber upon the terminal line, or to permit of monitoring upon a connection established from the line L_1 over the radio system. This monitoring set, as indicated, consists of a transmitter T associated with the channel TL_1 through a transformer 20, and a receiver R bridged across the receiving channel RL_1 .

A receiving antenna having the construction above described will be directive and will produce the maximum effect upon the receiving channel, in response to radiations incoming in a direction along the line of the antenna structure. The sending antenna should therefore be located in a direction at right angles to the line of the receiving antenna structure, so that radiations from the antenna AT will produce equal and opposite effects upon the absorbing members 12 and 13, these effects tending to balance each member with respect to the receiving channels such as the channel RL_1 . If it is desired to receive signals from different directions, the receiving antenna AR may be arranged so that it may be rotated in a plane parallel with the surface of the earth and in this case the transmitting antenna AT should be located above the receiving antenna and in a line with the axis about which the receiving antenna may be rotated. Such an arrangement would be of considerable utility on board ships.

The operation is as follows: Low frequency signals incoming from the line L_1 will be transmitted through the transformer 11 to the transmitting channel TL_1 , to modulate a carrier frequency f_5 and after being amplified, the modulated carrier frequencies will be impressed through the tuned circuits 7 and 4 upon the transmitting antenna AT . At the same time other modu-

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lated carrier frequencies may be impressed upon the antenna through other transmitting channels (not shown). The several modulated carrier frequencies are now radiated by the antenna AT for reception at distant receiving stations. Part of the radiated energy, however, is impressed upon the sections 12 and 13 of the receiving antenna AR. The energy thus absorbed by the sections 12 and 13, however, impresses substantially equal and opposite potentials upon the transformer windings of the tuned circuits 14, 15 and 16, so that substantially no energy is impressed upon the receiving channels such as RL_1 . Since, however, the circuits 14, 15 and 16, as well as the associated tuned circuits in the receiving channels, are resonant at frequencies different from the frequencies radiated by the antenna AT, any energy impressed upon the receiving channel, due to unbalance, will be largely suppressed by means of the tuned circuits. Modulated radio frequencies transmitted from a distant sending station located along the line of maximum energy absorption of the receiving antenna AR will, upon striking the antenna, tend to cause oscillations to flow serially through the sections 12 and 13 of the antenna, thereby being transmitted through the tuned circuits 14, 15 and 16 to the tuned circuits 17, 18 and 19, which are tuned to the several radio frequencies transmitted from the distant station. The energy thus impressed upon the tuned circuit 19 will be detected and amplified in a well-known manner, by means of the apparatus D_1 and will then be transmitted to the line L_1 .

Instead of employing a directive antenna of the character illustrated in Figure 1, a loop antenna may be utilized, as illustrated in Figure 2. In this embodiment of the invention the loop antenna is used both for transmitting and receiving. In this figure A designates generally the antenna structure, which consists of a loop having two halves, 21 and 22, inductively related through a transformer 23 to a receiving circuit 24, the transformer 23 being so arranged that the antenna winding is divided in two parts, one part being included in each half of the antenna loop. A grounded transmitting circuit 25 is connected to the midpoint of the split winding of the antenna 24 and includes a plurality of tuned circuits, 26, 27 and 28, each inductively associated with tuned circuits 29, 30 and 31. The tuned circuits 29, 30 and 31 are included in the transmitting channels TL_1 , etc., of which only the channel TL_1 is illustrated. This channel includes modulating and amplifying apparatus M_1 , similar to that illustrated in Figure 1 and is associated through a transformer 11 with a low frequency signaling line L_1 . A corresponding receiving channel RL_1 , including detecting and amplifying appara-

tus D_1 , similar to that illustrated in Figure 1, is connected to the midpoints of the line windings of the transformer 11 and the circuits TL_1 and RL_1 are rendered substantially conjugate by balancing the line L_1 by means of a network N_1 . The receiving channel RL_1 terminates in a tuned circuit 32, the other receiving channels (not shown) similarly terminating in tuned circuits 33 and 34. These tuned circuits are coupled to similarly tuned circuits 35, 36 and 37 respectively, in the common receiving circuit 24 of Figure 2.

The operation is as follows: Signals incoming from the line L_1 are transmitted through the transformer 11 to the transmitting channel TL_1 and upon being amplified and translated into radio frequencies by the apparatus M_1 are impressed as radio frequencies upon the tuned circuit 29. Other radio frequencies may be at the same time impressed upon the tuned circuits 30 and 31, from the other transmitting channels. The several frequencies now react upon the tuned circuits 26, 27 and 28 and are thereby impressed through the conductor 25 upon the directive loop antenna A, for radiation to a distant receiving station. The energy impressed upon the loop flows in opposite directions through the two halves of the loop antenna winding of the transformer 23, so that a relatively small amount of transmitted energy is impressed upon the common receiving circuit 24, due to unbalance. This energy may be suppressed, however, by transmitting and receiving at different frequencies, as described in connection with Figure 1, so that the transmitted energy impressed upon the circuit 24 will be suppressed by means of the tuned circuits therein. Radio frequencies transmitted from a distant sending station are received by the loops 21 and 22 and transmitted through the transformer 23 to the common receiving circuit 24. The several frequencies are selected to the proper receiving channels by means of the pairs of tuned circuits 35—32, 36—33 and 37—34. The radio frequency thus impressed upon the channel RL_1 is detected and amplified in a well-known manner, by means of the apparatus D_1 and is then transmitted to the line L_1 .

Figure 3 illustrates still another embodiment, in which the transmitting antenna AT_3 comprises a grounded vertical member 38 and an aerial made up of three elements, 39, 40 and 41, all connected in parallel to the vertical member 38.

L_1 designates a low frequency transmission circuit which is coupled through a transformer 11 with a transmitting channel TL_1 , including a modulator M_1 of well-known construction, whereby the low frequency signaling current may modulate a carrier frequency f_1 assigned to the transmitting chan-

nel TL_1 . A band filter TF_1 is included in the output circuit of the modulator, for the purpose of providing frequency selectivity between the channel TL_1 and other transmitting channels, such as TL_2 and TL_3 , all of which are associated with the common transmitting circuit TL . This band filter is preferably of the general type disclosed in the U. S. Patents Nos. 1,227,113 and 1,227,114, issued to George A. Campbell, May 22, 1917, and are so designed as to transmit a band of frequencies in the neighborhood of the carrier frequency f_1 assigned to the channel, the band being of sufficient width to accommodate frequency variation due to modulation.

The several modulated frequencies impressed upon the common transmitting circuit TL through the several transmitting channels, may be stepped up in frequency by means of a power modulator M , which is supplied with a frequency f . This power modulator may be of any well-known type and functions to produce in its output circuits frequencies corresponding to the modulated frequencies of the transmitting channel, plus the frequency f and frequencies corresponding to the modulated frequencies of the transmitting channels minus the frequency f . In order to suppress the latter group of frequencies, a band filter BF is included between the power modulator M and the vertical member 38 of the antenna AT_3 . This band filter may likewise be of the general type disclosed in the patents to Campbell, above referred to, and is designed to transmit the higher group of frequencies, while suppressing the lower group.

A receiving channel RL_1 is associated with the line L_1 , by being connected to the midpoints of the line windings of the transformer 11, and this channel is rendered substantially conjugate with respect to the channel TL_1 , by means of a network N_1 , balancing the line L_1 . Similar receiving channels will be associated with other transmitting lines, said channels being indicated at RL_2 and RL_3 as being connected with the common receiving circuit RL .

The directive receiving antenna AR_3 comprises absorbing elements 42 and 43, oppositely directed and grounded through separate vertical members 44 and 45. The absorbing elements 42 and 43 may be quite low and in some instances may even be placed under ground or in a stream of water, if suitably insulated. The vertical members 44 and 45 are associated through transformers 46 and 47 with separate branches of the common receiving circuit RL , these branches including phase shifting elements 48 and 49. These phase shifting elements may be suitable networks including inductance and capacity elements whereby the phase relation of the oscillations received by the absorbing elements 42 and 43 may be regulated with

respect to the common receiving circuit RL . The absorbing elements 42 and 43, as indicated, are in the line of radiation from the transmitting antenna AT_3 and are preferably separated at their midpoints by about one-half wave length, as indicated. By suitably adjusting the phase shifting elements 48 and 49 it will be apparent that a wave striking the absorbing element 42 and a fraction of a wave length later striking the absorbing element 43, may be impressed upon the common receiving circuit RL in opposite phase relation, so as to be balanced out with respect to said receiving circuit. A wave received from a distant transmitting station located in a direction normal to the absorbing sections 42 and 43 will produce a cumulative action upon the receiving circuit RL , since such a wave will strike both absorbing elements at the same instant.

The receiving circuit RL may include a demodulator D , supplied with a local source of beating current f' , whereby the modulated radio frequencies may be stepped down in frequency by reason of the fact that components will appear in the output circuit of said demodulator, corresponding to the received radio frequencies minus the frequency f' . The receiving channel RL_1 includes a band filter RF_1 for selecting out the stepped down frequency corresponding to this channel, it being understood that similar band filters will be included in the other receiving channel. These band filters are preferably of the general type illustrated in the patents to Campbell, aforementioned. The receiving channel RL_1 also includes a detector D_1 of any well-known character, for detecting the low frequency signaling currents in accordance with which the radio frequencies were modulated at the distant station.

The operation is as follows: Low frequency signaling currents incoming from the line L_1 are impressed upon the transmitting circuit TL_1 through the transformer 11 and modulate the frequency f_1 , through the action of the modulator M_1 , in a well-known manner. The modulated carrier currents are then passed through the filter TF_1 and impressed upon the power modulator M , which adds and subtracts the frequency f , so that the modulated carrier frequencies are both stepped up and stepped down in frequency. The band filter BF eliminates the lower set of frequencies, but transmits the stepped up frequencies to the antenna AT_3 for radiation. Waves radiated from the antenna AT_3 and striking the absorbing members 42 and 43, balance out with respect to the receiving circuit RL , due to the action of the phase shifters 48 and 49, as already described.

Radio frequencies transmitted from a distant sending station in a direction substantially normal to the absorbing members 42

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and 43 will be simultaneously impressed upon the members 42 and 43 and simultaneously transmitted through the transformers 46 and 47 to the phase shifters 48 and 49.

Due to the action of these phase shifters the effects upon the receiving circuit RL are cumulative and radio oscillations are impressed upon the demodulator D and stepped down by means of the beating action of the frequency f' . If the frequency of the oscillations transmitted from the distant station are different from the frequencies used in sending from the antenna AT_3 , these frequencies when stepped down by subtracting the frequency f' therefrom, will correspond to the frequencies passed by the filters such as RF_1 in the several receiving channels such as RL_1 , while any energy radiated from the antenna AT_3 and appearing in the receiving circuit RL_1 , due to unbalance, will, when the frequency f' is subtracted therefrom, appear in the output circuit of the demodulator D as frequencies which do not correspond to the frequencies admitted by the filters RF_1 , etc., so that such energy will be suppressed. The stepped down frequencies radiated from the distant station, however, will pass through the filters such as RF_1 and will be detected by detectors such as D_1 in a well-known manner and transmitted over the receiving channels such as RL_1 to the signaling lines such as L_1 . Where the receiving antenna AR_3 is located at some distance from the transmitting antenna AT_3 , as will usually be the case, the receiving channels such as RL_1 will of course be transmission lines of sufficient length to interconnect the two antennae.

A slightly different modification is shown in Figure 4. In this form of the invention instead of translating the low frequency signaling currents into high frequency currents by two steps, as in Figure 3, the translation takes place in one step. The advantage of making the translation by two steps, as in the case of Figure 3, is that the selection between the transmitting channels TL_1 , TL_2 and TL_3 takes place at the intermediate frequency where it is much easier to obtain frequency selection between branching circuits, since the frequency differences between different channels will be relatively large as compared with the actual carrier frequencies involved. Were the several transmitting channels in Figure 3, directly associated with the transmitting antenna and the frequency translation made in a single step, so that frequency selection would take place at radio frequencies, the frequency difference would be so small as compared with the actual radio frequencies that considerable difficulty would be experienced in selecting between channels.

The above difficulty is overcome in the arrangement of Figure 4 and frequency selec-

tion at radio frequencies is rendered possible by a special arrangement of the antenna structure. In this case the transmitting antenna AT_4 is composed of three aerial sections, 39, 40 and 41, as before, but these sections are insulated from each other and constitute in effect separate aerials for three different antennae having vertical members 50, 51 and 52. Each of the vertical members is tuned to a different radio frequency corresponding to different transmitting channels and the several transmitting channels are coupled to the vertical members through transformers 53, 54 and 55, respectively. The transmitting channel TL_1 , associated with the vertical member 50, includes a power modulator M_1 of any well-known type, which is supplied with carrier oscillations of frequency f_1 . These oscillations may be supplied by a generator G_1 , which may be of any well-known type, but is preferably the well-known vacuum tube oscillator. The modulator M_1 operates to modulate the radio frequency f_1 in accordance with signals incoming from the line L_1 and the modulated oscillations are then impressed upon the aerial section 50.

The receiving antenna AR_4 and associated apparatus, are constructed as already described in connection with Figure 3, except that in this form of the invention the absorbing members 42 and 43 are arranged in a line normal to the direction of radiation from the transmitting antenna AT_4 . The phase shifters 48 and 49 are therefore so adjusted that a wave from the antenna AT_4 simultaneously impressed upon the sections 42 and 43 will be impressed upon the common receiving circuit RL in opposing phase relation, so that substantially no effect is produced on said circuit. Waves from a distant transmitting station, however, radiated in the direction of the lengthwise extension of the members 42 and 43, will strike the two absorbing members a fraction of a wave length apart, so that the effect upon the circuit RL is cumulative and said circuit will therefore respond to signals from the distant station.

Where it is desired that the directive receiving antenna shall be enabled to receive waves coming from distant stations located in different directions, the receiving antenna may be arranged so that the absorbing sections 42 and 43 may be rotated, so that its maximum reception will be in the direction of the desired station. In this case the transmitting antenna may be located above the receiving antenna, so that the rotation of the latter will not affect its opaqueness to radiations from the transmitting antenna. The same considerations apply also to the antenna arrangement of Figure 3. It will also be obvious that instead of rotating the antenna structure it-

self, the direction of maximum reception may be rotated by suitable adjustment of the phase controlling elements 48 and 49.

The operation of the arrangement of Figure 4 is as follows: Low frequency signaling currents incoming from the line L_1 are transmitted through the transformer 11 to the transmitting channel TL_1 and modulate the radio frequency f'_1 assigned to that channel, through the medium of the power modulator M_1 . The modulated oscillations are then applied through the transformer 53 of the vertical member 50 and radiated from the aerial member 39 of the antenna AT_1 . Other modulated radio frequencies may be simultaneously radiated from the aerial sections 40 and 41. The energy radiated by these antenna sections in the direction of the receiving antenna AR_1 will be balanced out by means of the directive effect of the members 42 and 43 in connection with the adjustment of the phase shifters 48 and 49, as previously described, so that substantially no energy reacts upon the receiving circuit RL . Such energy, however, as is transmitted to this circuit, due to unbalance, will be impressed upon the detector D , so that the several frequencies will be stepped down by an amount equal to the frequency f' . If the receiving apparatus is designed for reception at different frequencies from those used for transmission, the several frequencies resulting from the step down action of the detector D will not correspond to the frequency admitted by the filters RF_1 , RF_2 and RF_3 in the several receiving channels and will therefore be suppressed. Radio frequencies from a properly located distant transmitting station will strike the absorbing members 42 and 43 of the receiving antenna AR_1 in such a manner as to produce a cumulative effect upon the circuit RL and upon being stepped down in frequency by means of the detector D , the several frequencies will be selected by means of the filters RF_1 , RF_2 and RF_3 and passed into the corresponding receiving channels, such as RL_1 . The modulated oscillations passed to the channel RL_1 will be detected in a well-known manner by means of the detector D_1 and transmitted to the line L_1 .

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. A radio signaling station comprising a transmitting antenna, a directive receiving antenna comprising a plurality of absorbing members, each in non-conductive relation to said transmitting antenna, a receiving apparatus associated with said mem-

bers, said members being so organized and so related to said receiving apparatus that said receiving antenna structure may have its maximum productive effect shifted in order to receive maximum energy from any desired transmitting station, and when so shifted a maximum effect will be produced upon said receiving apparatus, and said sending antenna being so related to the members of said receiving antenna that however the maximum directive effect of the receiving antenna may be shifted, said transmitting antenna will impress upon the members of said receiving antenna energy components which will be balanced out with respect to said receiving apparatus.

2. A radio station comprising a sending antenna, a receiving antenna comprising a pair of symmetrical absorbing members each in non-conductive relation to said sending antenna, a receiving apparatus so arranged with respect to the said absorbing members that energy absorbed by said members from a given direction will produce maximum cumulative effects upon said receiving apparatus, while energy received from a different direction will produce equal and opposite effects with respect to said receiving apparatus, said receiving antenna being so arranged that the direction of maximum directive effect may be varied at will and said sending antenna being located in such a position with respect to the members of said receiving antenna that energy radiated therefrom and absorbed by the members of said receiving antenna will produce substantially no effect upon said receiving apparatus, regardless of variation in the maximum directive effect of the receiving antenna.

3. A radio station comprising a sending antenna, a receiving antenna comprising a pair of symmetrical absorbing members, a receiving apparatus so arranged with respect to the said absorbing members that energy absorbed by said members from a given direction will produce maximum cumulative effects upon said receiving apparatus, while energy received from a different direction will produce equal and opposite effects with respect to said receiving apparatus, said receiving antenna being so arranged that the direction of maximum direction effect may be varied at will, and said sending antenna being located so that energy radiated therefrom to the receiving antenna will be radiated along lines symmetrical with respect to the axis about which the maximum directive effect of the receiving antenna may be rotated.

4. A radio signaling station comprising a directive receiving antenna having a pair of low horizontal members, a receiving apparatus so associated with said members that maximum cumulative effects will be

produced on said receiving apparatus by energy absorbed by said members in a direction corresponding to the line of maximum directive effect, said members being capable of rotation in a horizontal plane, to permit of maximum reception from different directions, and the sending antenna located above said receiving antenna, so that energy radiated from said sending antenna will produce equal and opposite effects upon said members of the receiving antenna with respect to the receiving apparatus.

5. In a radio signaling station, a receiving antenna comprising a pair of absorbing members, a receiving channel so associated with said absorbing members that cumulative effects will be produced upon said channel by energy absorbed by said absorbing members in the line of maximum directive effect, a sending antenna so located with respect to said receiving antenna that energy radiated therefrom and absorbed by said absorbing members will produce opposite effects with regard to said receiving channel, a transmitting channel associated with said sending antenna, and a low frequency signaling circuit so associated with said transmitting and receiving channels that said channels will be conjugate with respect to each other as regards low frequency signals.

6. In a radio signaling station, a directive receiving antenna comprising a pair of absorbing members, a plurality of receiving channels so associated with said absorbing members that energy absorbed by said members in the line of maximum directive effect will produce maximum effect upon said receiving channels, a sending antenna so located with respect to said receiving antenna that energy radiated therefrom will pro-

duce opposite effects upon said absorbing members with respect to said receiving channel, a plurality of transmitting channels associated with said transmitting antenna, and a plurality of low frequency signaling circuits, each so related to a transmitting and receiving channel that said channels will be substantially conjugate with respect to low frequencies.

7. In a radio signaling station, a directive receiving antenna comprising a pair of absorbing members, a plurality of receiving channels so associated with said absorbing members that energy absorbed by said members in the line of maximum directive effect will produce maximum effect upon said receiving channels, a sending antenna so located with respect to said receiving antenna that energy radiated therefrom will produce opposite effects upon said absorbing members with respect to said receiving channel, a plurality of transmitting channels associated with said transmitting antenna, and a plurality of low frequency signaling circuits, each so related to a transmitting and receiving channel that said channels will be substantially conjugate with respect to low frequencies, means in said transmitting channels to translate low frequency currents into radio frequencies, means in said receiving channels to translate radio frequencies into low frequency signaling currents, and selective means whereby frequency separation may be maintained between each transmitting channel and its corresponding receiving channel.

In testimony whereof, I have signed my name to this specification this 29th day of September, 1919.

LLOYD ESPENSCHIED.