July 29, 1924. **1,502,813**

L. ESPENSCHIED

HIGH FREQUENCY MULTIPLEX SIGNALING SYSTEM

Original Filed Sept. 30, 1919

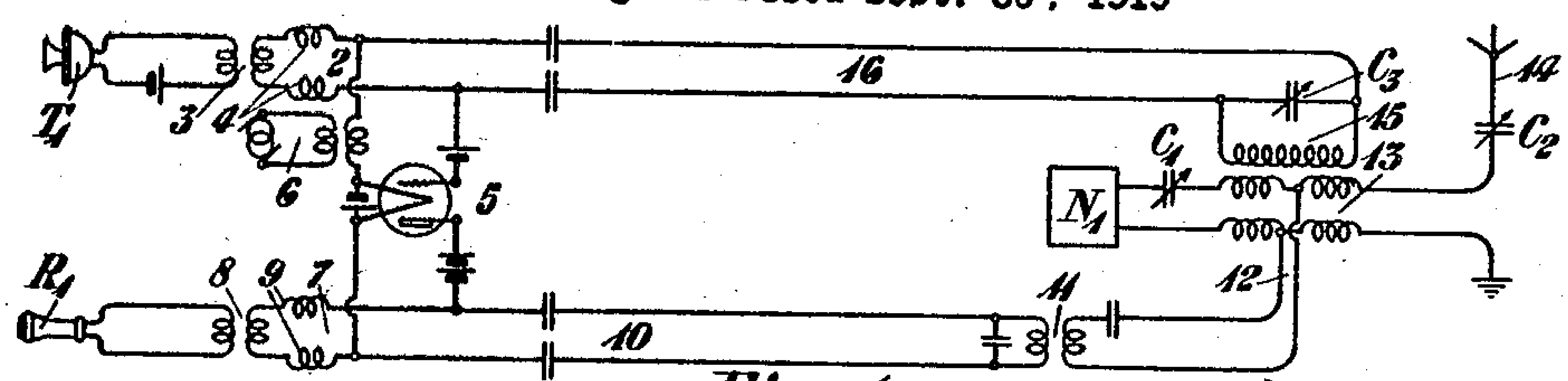

Fig. 1

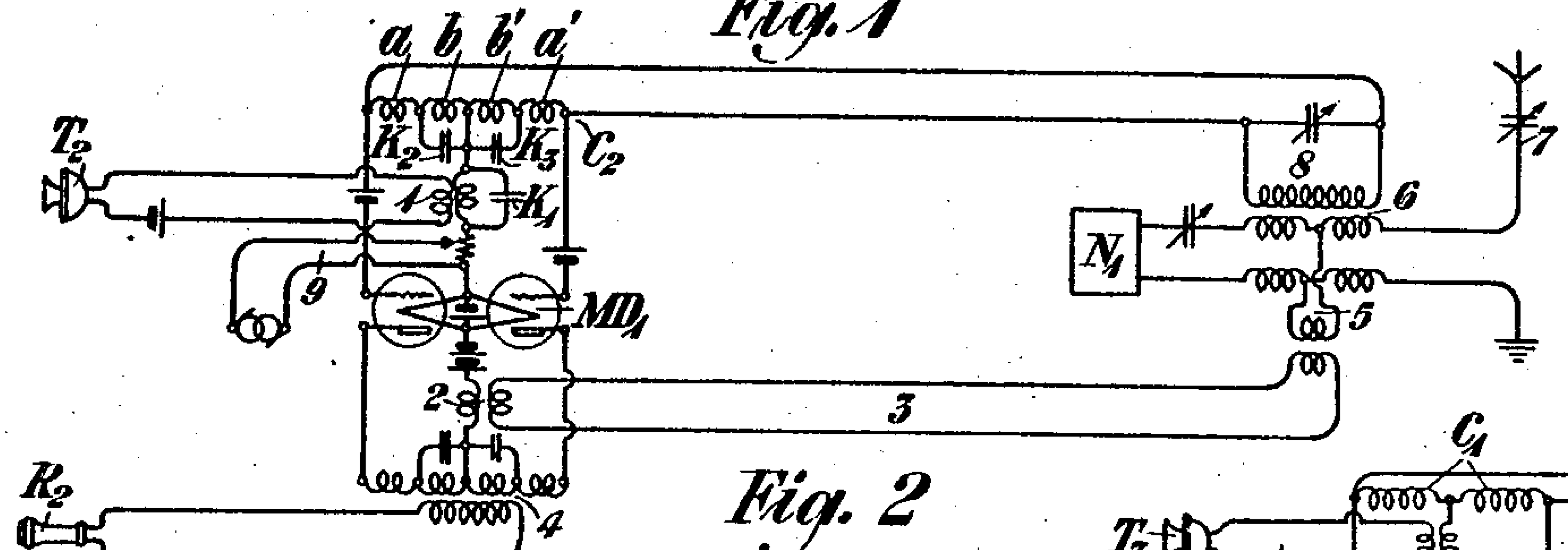

Fig. 2

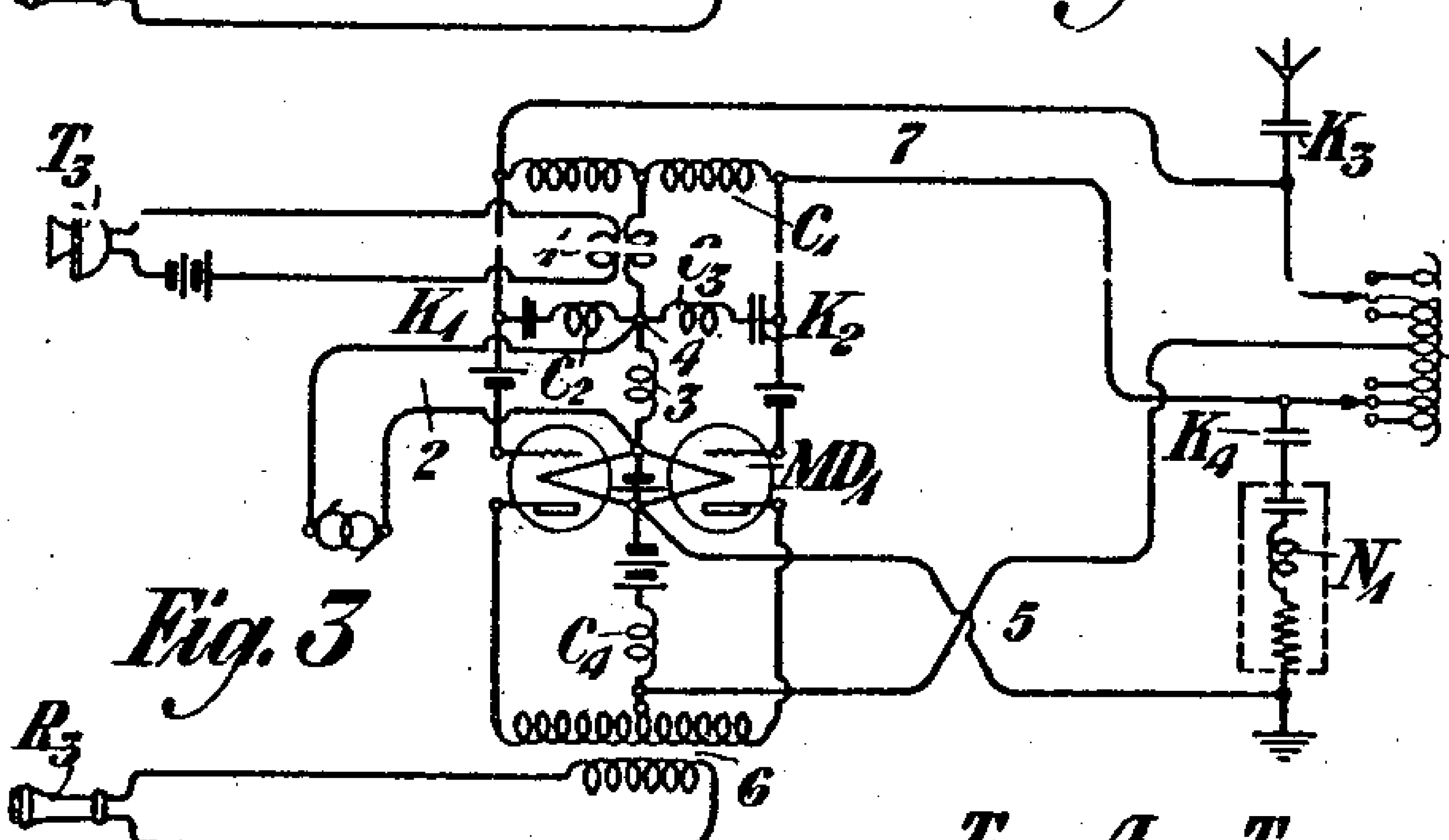

Fig. 3

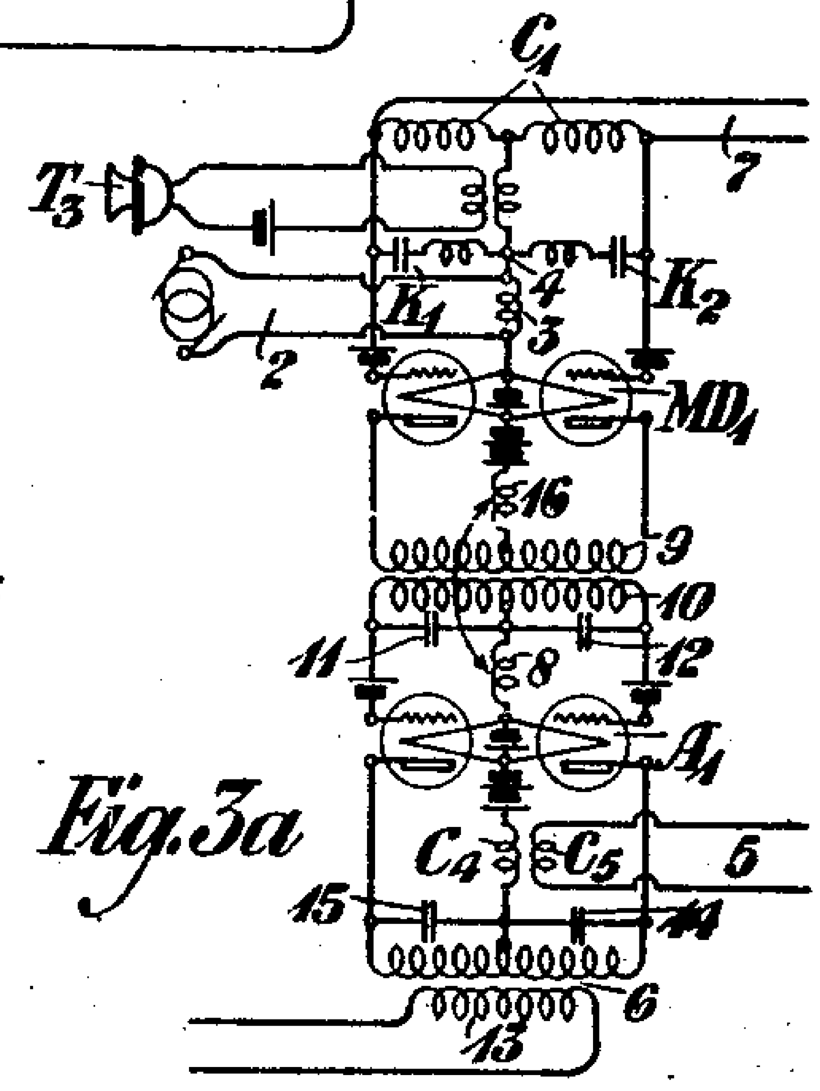

Fig. 3a

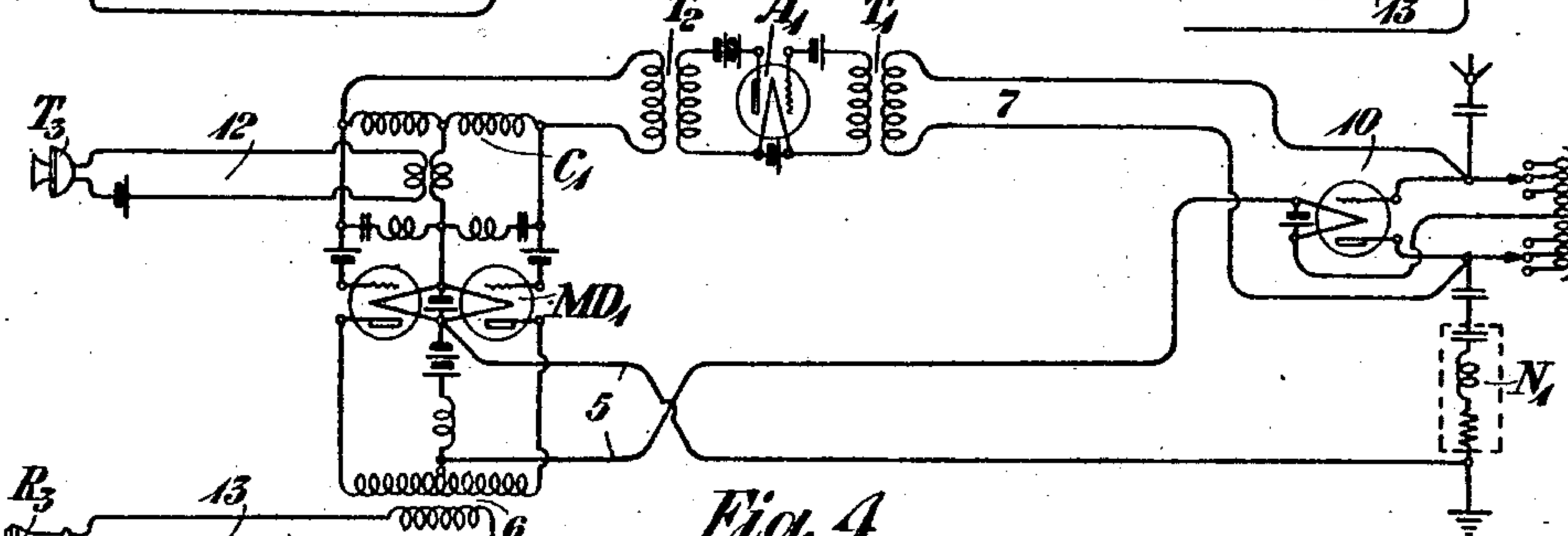

Fig. 4

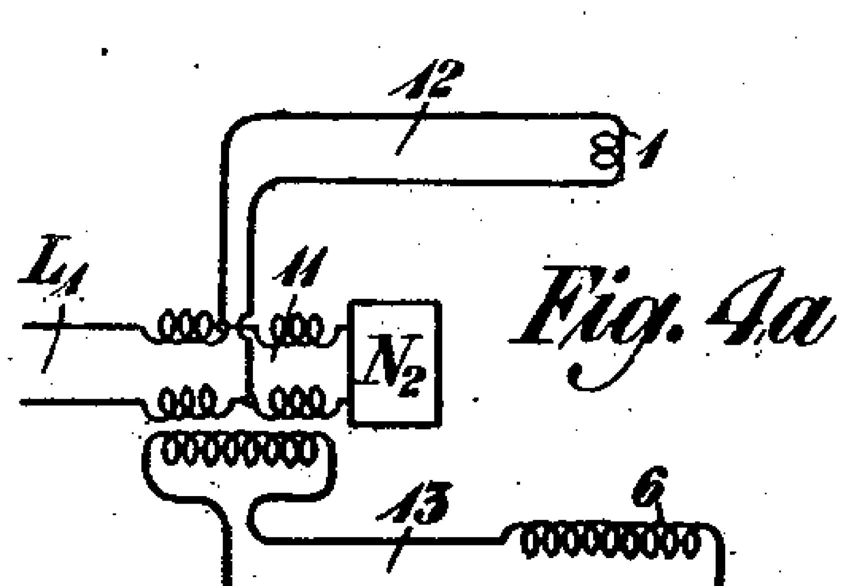

Fig. 4a

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By his Attorney
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UNITED STATES PATENT OFFICE.

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

HIGH-FREQUENCY MULTIPLEX SIGNALING SYSTEM.

Original application filed September 30, 1919, Serial No. 327,500. Divided and this application filed April 16, 1921. Serial No. 461,965.

To all whom it may concern:

Be it known that I, Lloyd Espenschied, residing at Queens, in the county of Queens and State of New York, have invented certain Improvements in High-Frequency Multiplex Signaling Systems, of which the following is a specification.

This invention relates to high frequency multiplex signaling systems and more particularly to a radio terminal circuit arrangement embodying the use of a common translating circuit adapted both to modulate the transmitted current and to demodulate the high frequency received current.

This application is a division of my copending application, Serial No. 327,500, filed September 30, 1919, entitled "High frequency multiplex signaling systems."

In the multiplex signaling systems heretofore used which employ a plurality of carrier currents of various frequencies, it has been customary to insert in the transmitting and the receiving branches of the terminal circuit a translating device individual to each of said branches. It is the object of the present invention to adapt the terminal circuit arrangement so that the processes of modulation, demodulation and amplification of the various currents in both the transmitting and receiving branches of the terminal circuit may be performed by a single translating device. Although the preferable form of translating device is a single thermionic vacuum tube or a plurality of such tubes in combination adapted to function as a single unit with respect to the two branches of the terminal circuit, yet any well known type of translating device such as the mechanical repeater may be used.

Another object of this invention is to provide a circuit arrangement whereby the modulating and demodulating device may be operated so as to produce amplification without causing the circuit to sing. A further object of this invention is to provide a means whereby additional amplification may be given to the currents traversing the terminal circuit either before or after the modulating or demodulating process has taken place.

Other and further objects of this invention will be apparent from the following description when read in connection with the attached drawing, of which Figure 1 shows a radio transmitting and receiving circuit having a common translating circuit comprising a single vacuum tube; Figure 2 shows a circuit characterized by the use of a balanced tube circuit. Figure 3 shows an arrangement which differs from Figure 2 principally in the mode of connecting the input and output circuits to the antenna circuit. Figure 3^A shows a type of translating circuit involving the use of an amplifier to amplify the currents after modulation and demodulation have taken place. Figure 4 shows a transmitting and receiving circuit characterized by the use of an oscillator connected with the antenna circuit and also by the use of an amplifier adapted to amplify currents before the process of modulation and demodulation has taken place, and Figure 4^A shows an arrangement whereby the transmitting and receiving circuit may be connected with a low frequency line circuit.

In Figure 1 the transmitter T_1 is connected inductively to an input circuit 2 by means of a transformer 3, circuit 2 being bridged across the input side of the translating device 5. Impedance coils 4 are connected with circuit 2 to prevent high frequency oscillations from passing to the transmitter T_1. Also associated with the input side of the said translating device is a source of high frequency oscillations 6 which may be any of the well known type of high frequency oscillation producer. A receiver R_1 is connected inductively by means of a transformer 8, with circuit 7 which has therein impedance coils 9 and which is bridged across the output side of the translating device 5. The output circuit 10 of the translating device is loosely coupled by means of the transformer 11 with the circuit 12, which is bridged across the midpoint of two of the windings of the triple-winding transformer 13. This triple-winding transformer is the well-known type in which the windings are conjugate, so that disturbances impressed upon the transformer by one of the circuits connected therewith will produce no effect upon the circuit which is conjugate to the circuit in which the disturbance arises. Associated with the triple-winding transformer is a network N_1 having associated therewith a variable condenser C_1 which jointly are adapted to balance the antenna 14 and its variable condenser C_2. The input coil of the triple-winding transformer and the variable condenser C_3 constitute a resonant circuit 15 for oscillations of reception frequency which will be impressed upon circuit 16 and thereby upon the input side of the translating device 5. This input coil or third winding of the transformer may be loosely coupled to the line windings of said transformer to facilitate tuning of circuit 15.

In the operation of this circuit the low frequency voice currents from the transmitter T_1 are impressed by means of the circuit 2 upon the input side of the translating device 5, and serves to modulate the high frequency carrier current from the high frequency source 6. The modulated high frequency oscillations pass from circuit 10 to circuit 12 by means of the loose coupling 11, and are impressed upon the antenna by means of the triple-winding transformer 13. The translating device 5 not only modulates the high frequency carrier current but may also serve to amplify the same. The degree of amplification which can be employed depends upon the degree of balance between the input and output circuits of the triple-winding transformer 13. If these circuits are not properly balanced and the amplification produces a gain that is greater than the loss in the terminal circuit itself, singing will take place around the circuit including the translating device and circuits 10, 12, 15 and 16. It will be noted furthermore that in this circuit the high frequency oscillations will be continuously radiated, due to the fact that the modulating device is not of the balanced type in which the high frequency oscillations are suppressed except during the period in which they are being modulated. The high freqnency oscillations received by antenna 14 will produce oscillations of like frequency in circuit 15 which are transferred by circuit 16 and impressed upon the translating device 5. Since the carrier supply 6 is of substantially the same frequency as received oscillations the said received oscillations will be demodulated by means of the translating device 5 and the low frequency current resulting from demodulation will pass into the circuit 7 and be impressed upon the receiver R_1. The impedance coils 4 and 9 associated with the transmitting and receiving circuits respectively prevent passage of high frequency received oscillations and high frequency transmitted oscillations to the transmitter and receiver respectively. From the foregoing it may be seen that this circuit arrangement provides means whereby a single translating device may produce modulation and demodulation of the transmitted and the received oscillations respectively, and also produce a certain degree of amplification of both sets of oscillations.

In Figure 2 transmitter T_2 is connected by means of the transformer 1 with the common conductor of a duplex translating device MD_1, one of the windings of the said transformer being associated with the transmitter circuit and the other winding being connected into the said common conductor. A condenser K_1 is bridged across the winding in the common conductor in order to afford a free passage for the high frequency oscillations from the source 9. Bridged across the input side of the duplex device is the reactance coil arrangement C_2. This is preferably made of two independent coils one designed for high frequency and comprising windings a a' and the other for low frequencies and comprising the windings b b'. The object of these coils is to permit currents to pass between the common conductor and the two outside conductors in parallel without short circuiting the outside conductors for incoming current from circuit 8. The low frequency retardation coil b b' may be shunted by condensers K_2K_3 to facilitate by-passing the high frequency currents from generator A. In the common conductor of the output side of the said translating device is a transformer 2 whereby the modulated carrier oscillations may be impressed upon the output circuit 3. The output circuit is also connected with the receiver R_2 by means of the transformer 4, the coil arrangement of which is similar to that of C_2. One set of low frequency windings is connected with the translating circuit and the other winding with the receiver circuit as indicated. The transmitting circuit 3 is connected by means of the circuit 5 across the midpoint of two of the windings of the triple-winding transformer 6. A network N_1 is connected with the transformer 6 in order to balance the antenna circuit 7. A resonant receiving circuit 8 tuned to reception frequency is connected with the input side of the transformer 6. The circuit 8 is connected across the coil C_2 in such a manner that the received oscillations will be impressed across the input side of the duplex translating device. The high frequency carrier oscillations are impressed by a source 9 upon the common conductor of the input side of the translating device. In the operation of this circuit the low frequency voice currents from the transmitter T_2 are impressed upon the common conductor in the input side of the translating device, upon which are also impressed the high frequency carrier oscillations. By means of the modulating device the carrier oscillations are modulated by the voice currents and the modulated carrier oscillations are impressed by the transformer 2 upon the output circuit 3, which in turn impresses them upon the circuit 5 and thence upon the antenna 7 from which they are radiated. Oscillations received by antenna 7 are impressed upon the resonant circuit 8, and in turn upon the input side of the translating device across coil C_2. The modulated high frequency oscillations pass into the translating device together with the unmodulated carrier oscillations from source 9 and the former oscillations are demodulated thereby. The low frequency current resulting therefrom is impressed by the transformer 4 upon the receiver R_2. It will be seen that the input connection to the translating device is made transversely across the duplex modulator circuit whereas the output connection is made longitudinally in the common conductor of the plate circuit. In accordance with this arrangement the input and output circuits are mutually balanced with respect to the amplifying action of the translating devices, thus preventing high frequency singing around the circuit 2, 3, 5, 8, C_2. It will be apparent therefore, that this arrangement is less susceptible to singing and therefore is more desirable than the arrangemeent shown in Figure 1 when greater amplification is desired.

In the circuit arrangement shown in Figure 3 the transmitter T_3 is connected with the common conductor of the duplex translating device by means of the transformer 1. A source of high frequency oscillations 2 is connected across the impedance 3 located also in the common conductor 4 of the duplex translating device. Bridged across the input side of the translating device is a coil C_1 across which the high frequency received oscillations are impressed upon the translating device. Condensers K_1 and K_2 in series with the two halves of coil C_2 C_3, respectively, constitute paths between the grid conductors and the common conductor 4 of the translating device for the carrier frequency. In the common conductor of the output side of the translating device is a coil C_4 in series with the plate battery. Across these two elements in series are bridged the conductors of the output circuit 5. Across the output side of the translating device is a transformer 6 by means of which the low frequency currents resulting from demodulation are impressed upon the receiver R_3. The transmitting circuit 5 is connected between the ground side of the antenna and the midpoint of a variable inductance connected in series in the said antenna. This antenna is of the balanced type having a network N_1 inserted therein which has characteristics simulating those of the said antenna. Condensers K_3 and K_4 are inserted in the antenna circuit for purposes of tuning. The receiving circuit 7 is bridged across two symmetrical points of the variable inductance and the received oscillations are thereby impressed upon the said circuit and in turn upon the coil C_1 at the input side of the translating device.

The low frequency voice currents from the transmitter T_3, which are impressed upon the common conductor 4, serve to modulate the high frequency oscillations which are impressed upon the same common conductor by the generating device 2. These modulated high frequency oscillations are impressed upon the output circuit by means of the coil C_4 in the common conductor of the output side of the translating device, and the said oscillations are in turn impressed upon the antenna between the midpoint of the variable inductance and the ground, and are radiated by the said antenna. The incoming high frequency oscillations to which the antenna is resonant are impressed upon the circuit 7, which in turn impresses them upon the input side of the translating circuit by means of the coil C_1. Since the frequency of the oscillations from the generating circuit 2 differs from that of the incoming oscillations from circuit 7 to the extent of the signaling frequency, the received oscillations will be demodulated, and the demodulated low frequency current will be impressed upon the receiver R_3 by means of the transformer 6. Singing of the circuit is prevented by the combination of the high frequency antenna balance and the balance between the input and output circuits of the translating devices.

Figure 3^A represents a translating circuit comprising a modulating and demodulating arrangement, as shown in Figure 3, together with an amplifier whereby the modulated outgoing signals and the demodulated incoming signals may be amplified before impressing them upon their respective circuits. In the arrangement shown in this figure, the winding 16 in the common conductor of the modulating and demodulating device is inductively connected with the winding 8 in the input circuit of the amplifier A_1. In like manner the winding 9 in the output circuit of the modulating and demodulating device MD_1 is inductively related to the winding 10 across the input side of the amplifier A_1. Bridged across the input circuit of the amplifier A_1 in parallel with the winding 10 are the condensers 11 and 12, and in like manner the condensers 14 and 15 are bridged across the output circuit in parallel with one of the windings of the transformer 6. The output circuit of the amplifier is connected by means of the coils C_4 and C_5 with the high frequency output circuit 5, and by means of the windings of the transformer 6 with the low frequency receiving circuit 13. When the low frequency voice signals, for example, are impressed by the transmitter T_3 upon the input circuit of the modulating and demodulating device MD_1, simultaneous with the impression thereon of unmodulated high frequency oscillations by the source 2, the latter oscillations will be modulated in accordance with the voice signals and the resultant modulated oscillations will be impressed by the winding 16 in the output circuit of the modulating and demodulating device upon the winding 8 in the input circuit of the amplifier. These latter oscillations will be amplified and will then be impressed by the winding C_4 upon the high frequency output circuit 5. Since this circuit is balanced the oscillations impressed upon the common conductor of the two tubes will not be impressed by the transformer 6 upon the low frequency circuit 13, but will appear only in the circuit 5. The modulated high frequency oscillations received by the antenna will be impressed upon the circuit 7 and consequently will establish a difference of potential across the winding C_1 in the input side of the modulating and demodulating device MD_1. These modulated oscillations will be demodulated by the oscillations from the local source 2, and the resultant low frequency oscillations will be impressed by the winding 9 upon the winding 10 across the amplifier circuit A_1. The amplified currents will be impressed by the transformer 6 upon the low frequency circuit 13. Since the currents resulting from demodulation are impressed across the winding 10, the resultant amplified currents will produce an effect in transformer 6 but will produce no effect in the windings C_4 and C_5 which are connected with the circuit 5.

Figure 4 differs from the arrangement shown in Figure 3 principally by the insertion of a vacuum tube oscillator in the antenna circuit, and also by the use of an amplifier in the receiving branch of the four-wire circuit. In the arrangement shown in Figure 4, one side of the output circuit 5, which in Figure 3 is connected directly with the midpoint of the inductance C_5, is connected with the filament of the oscillating vacuum tube and thence with the midpoint of the inductance. The aerial side of the antenna is connected with the grid of this tube and the side of the antenna which is grounded through the aerial network N_1 is connected with the plate of the said tube. The inductance C_5, together with the inductance and capacity of the antenna to ground produces a resonant feed-back circuit which will cause the vacuum tube circuit to act as a producer of high frequency oscillations of the same frequency as that to which the antenna is tuned, which is the frequency of the incoming waves. The incoming modulated high frequency oscillations and the unmodulated oscillations produced by the tube 10 will be impressed upon the input circuit 7 and amplified by means of the amplifier A_1, which is connected in the said circuit by means of the transformers T_1 and T_2. The amplified oscillations, both modulated and unmodulated, will be impressed upon the input side of the duplex translating device MD_1 by means of the coil C_1. The received oscillations will be demodulated by the said translating device, and the low frequency currents resulting therefrom will be impressed upon the receiver R_3 by means of the transformer 6. In like manner the low frequency oscillations from the transmitter T_3 will be impressed upon the common conductor of the input side of the translating device, and will in turn modulate the high freqency oscillations received from the device 10, producing in the output circuit 5 modulated high frequency waves, which will be impressed upon the antenna circuit between the midpoint of the inductance C_5 and ground. Since the output circuit is connected between the midpoint of the inductance and ground, and since the network N_1 simulates the characteristics of the antenna, the input and the output circuits 5 and 7 are mutually balanced with respect to the antenna. Consequently the circuit will not sing, except for the oscillation of the tube 10. A further advantage of this circuit arrangement arises from the location of the high frequency generator within the antenna circuit itself, so that its frequency is controlled by the tuning of the antenna. In this way substantial identity of the frequency of the transmitted and received oscillations mav be automatically maintained. The circuit arrangement of Figure 4 shows also means for giving the required degree of amplification to the impressed modulated and unmodulated oscillations, whereby the quality of the detected signal may be accordingly improved. Furthermore, since the output and input circuits are balanced the required degree of amplification may be obtained without singing around the high frequency circuit.

The circuit shown in Figure 4^A indicates the manner in which a four-wire terminal circuit such as shown in Figure 4 may be connected with a two-wire low frequency signaling circuit. The low frequency transmitting and receiving circuits of the four-wire terminal circuit may be connected with the triple winding transformer 11 in the manner shown, the low frequency two-wire circuit L_1 being balanced by the network N_2. In a similar manner each of the other circuits shown in Figures 1, 2 and 3 may be terminated as a two-wire circuit instead of the four-wire circuit as shown in the figures.

It will be seen from the foregoing description of the various forms of circuits shown in the figures that the incoming and outgoing radio signals may be modulated and demodulated or amplified by a single circuit arrangement common to the incoming and the outgoing paths of the terminal circuit. Although this invention has been disclosed in certain particular forms and embodiment of parts, it is to be understood that it is capable of embodiment in other and different forms without departing from the spirit and scope of the invention as described in the appended claims.

What is claimed is:

1. In a radio signaling system, the combination with an antenna of a transmission line and a four-wire circuit effectively connecting the said antenna and said line, means to impress upon the said four-wire circuit currents from the said antenna and from the said line, the said four-wire circuit having connected therewith a translating circuit common to the paths of travel of the currents from the said antenna and the said line and having means to modulate and demodulate the currents impressed on the said four-wire circuit.

2. In a radio signaling system, the combination with an antenna of a transmission line and a four-wire circuit effectively connecting the said antenna and said line, means to impress upon the said four-wire circuit currents from the said antenna and from the said line, the said four-wire circuit having connected therewith a translating circuit common to the paths of travel of the currents from the said antenna and the said line and having means to modulate and demodulate and means to amplify the currents impressed on the said four-wire circuit.

3. In a radio signaling system, the combination with an antenna of a network adjusted to balance the said antenna, a transmission line, a four-wire circuit effectively connecting the said antenna and the said line, means to impress upon the said four-wire circuit currents from the said antenna and from the said line, the said four-wire circuit having connected therewith a translating circuit common to the paths of travel of the currents from the said antenna and the said line and having means to modulate and demodulate the currents impressed on the said four-wire circuit.

4. In a radio signaling system, the combination with an antenna of a network adjusted to balance the said antenna, a transmission line, a four-wire circuit effectively connecting the said antenna and the said line, means to impress upon the said four-wire circuit currents from the said antenna and from the said line, the said four-wire circuit having connected therewith a translating circuit common to the paths of travel of the currents from the said antenna and the said line and having means to modulate and demodulate and means to amplify the currents impressed on the said four-wire circuit.

5. In a radio signaling system, the combination with an antenna of a network adapted to balance the said antenna and a four-wire circuit connected with said antenna and having connected therewith transmitting and receiving means and also having modulating and demodulating means common to the paths of travel of the currents from the transmitting means to the said antenna and from the said antenna to the said receiving means.

6. In a radio signaling system, the combination with a balanced antenna of a four-wire transmitting and receiving circuit providing two paths for the transmitted and received currents, the said four-wire circuit having a translating circuit common to the transmitting and receiving paths thereof containing means adapted to modulate and demodulate the transmitted and received currents, and means for impressing the transmitted and received currents on the said translating circuit.

7. In a radio signaling system, the combination with a balanced antenna of a conjugate transformer, an input circuit tuned to reception frequency, an output circuit, a translating circuit common to said input and said output circuits having means to demodulate and modulate the received and transmitted currents, and means for impressing the said currents upon the said translating circuit.

8. In a radio signaling system, the combination with a balanced antenna of a conjugate transformer, an input circuit tuned to reception frequency, an output circuit, and a translating circuit common to said input and said output circuits having connected therewith transmitting and receiving means, a source of carrier current and means whereby the transmitted and received currents may respectively be modulated and demodulated, and means for impressing the currents from the said input circuit upon the said translating circuit.

9. In a radio signaling system, the combination with a balanced antenna circuit of a transmitting and receiving circuits connected therewith, and a translating circuit common to the said transmitting and receiving circuits having a source of high frequency currents, and means to beat the said high frequency currents with the incoming and outgoing currents for the detection and modulation of the same, and means to impress upon the translating circuit the said transmitted and received currents.

10. In a radio signaling system, the combination with an antenna of a terminal circuit having transmitting and receiving paths, and a translating circuit common to both paths characterized by a source of unmodulated high frequency oscillations and means for the modulation and demodu-

lation of the transmitted and received currents, and means to impress upon the translating circuit the said transmitted and received currents.

11. In a radio signaling system, the combination with a balanced antenna circuit of a four-wire circuit having connected therewith transmitting and receiving means, and a plurality of means common to the transmitting and receiving paths of the said four-wire circuit for the modulation and detection and for the amplification of the currents flowing through the said paths.

12. In a radio signaling system, the combination with a balanced antenna circuit of a four-wire circuit comprising a modulating-demodulating circuit, and an amplifying circuit for the amplification of currents after modulation and demodulation.

13. In a radio signaling system, the combination with a four-wire terminal circuit comprising two two-wire branches of a balanced antenna coupled thereto, transmitting apparatus connected with one two-wire branch and receiving apparatus connected with the other branch, and a translating circuit common to both two-wire branches having an amplifier connected therewith.

14. In a radio signaling system adapted for the transmission of low frequency currents by high frequency carrier currents, the combination with a terminal circuit of a balanced antenna loosely coupled thereto, the said terminal circuit having separate transmitting and receiving paths and also having a translating circuit common to both of said paths having means to modulate and demodulate the currents of the transmitting and receiving paths respectively.

15. In a radio signaling system adapted for the transmission of low frequency currents by means of high frequency carrier currents, the combination of a four-wire terminal circuit having transmitting and receiving paths, each having suitable devices associated therewith, and coupled to an antenna by means of a triple-winding transformer, an artificial line adapted to balance said antenna, and a translating circuit common to the transmitting and receiving paths of the four-wire circuit.

16. In a radio signaling system adapted for the transmission of low frequency currents by high frequency carrier currents, the combination with a four-wire terminal circuit having transmitting and receiving devices associated therewith of an antenna circuit, means to loosely couple the antenna circuit and the four-wire circuit, the said coupling means having an artificial line associated therewith to balance the said antenna, and a translating circuit associated with the said terminal circuit having a source of unmodulated carrier current associated therewith, and means to modulate and demodulate the currents in the transmitting and receiving paths respectively.

17. In a radio signaling system adapted for the transmission of low frequency currents by means of high frequency carrier currents, the combination with an antenna circuit of a four-wire terminal circuit comprising two two-wire branches coupled with said antenna circuit and balanced with respect thereto, whereby oscillations in one of the two-wire branches of the four-wire circuit will not produce an appreciable effect in the other two-wire branch, and a duplex translating circuit connected with the said two-wire branches and having a source of unmodulated carrier current associated therewith, the output and input sides of the said translating circuit being conjugately related to prevent singing over the said four-wire circuit.

18. In a radio signaling system adapted for the transmission of low frequency currents by means of high frequency carrier currents, the combination with a four-wire terminal circuit having a duplex translating circuit associated therewith, of an antenna circuit having a variable inductance and a balancing network associated therewith, and a vacuum tube oscillator having the grid circuit connected with said antenna circuit and the plate circuit connected with the translating circuit, thereby supplying the carrier oscillations for the said translating circuit.

In testimony whereof, I have signed my name to this specification this 15th day of April, 1921.

LLOYD ESPENSCHIED.