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L. ESPENSCHIED

MEANS FOR RINGING OVER MULTIPLEX TRANSMISSION CHANNELS

Filed July 30, 1920 2 Sheets-Sheet 1

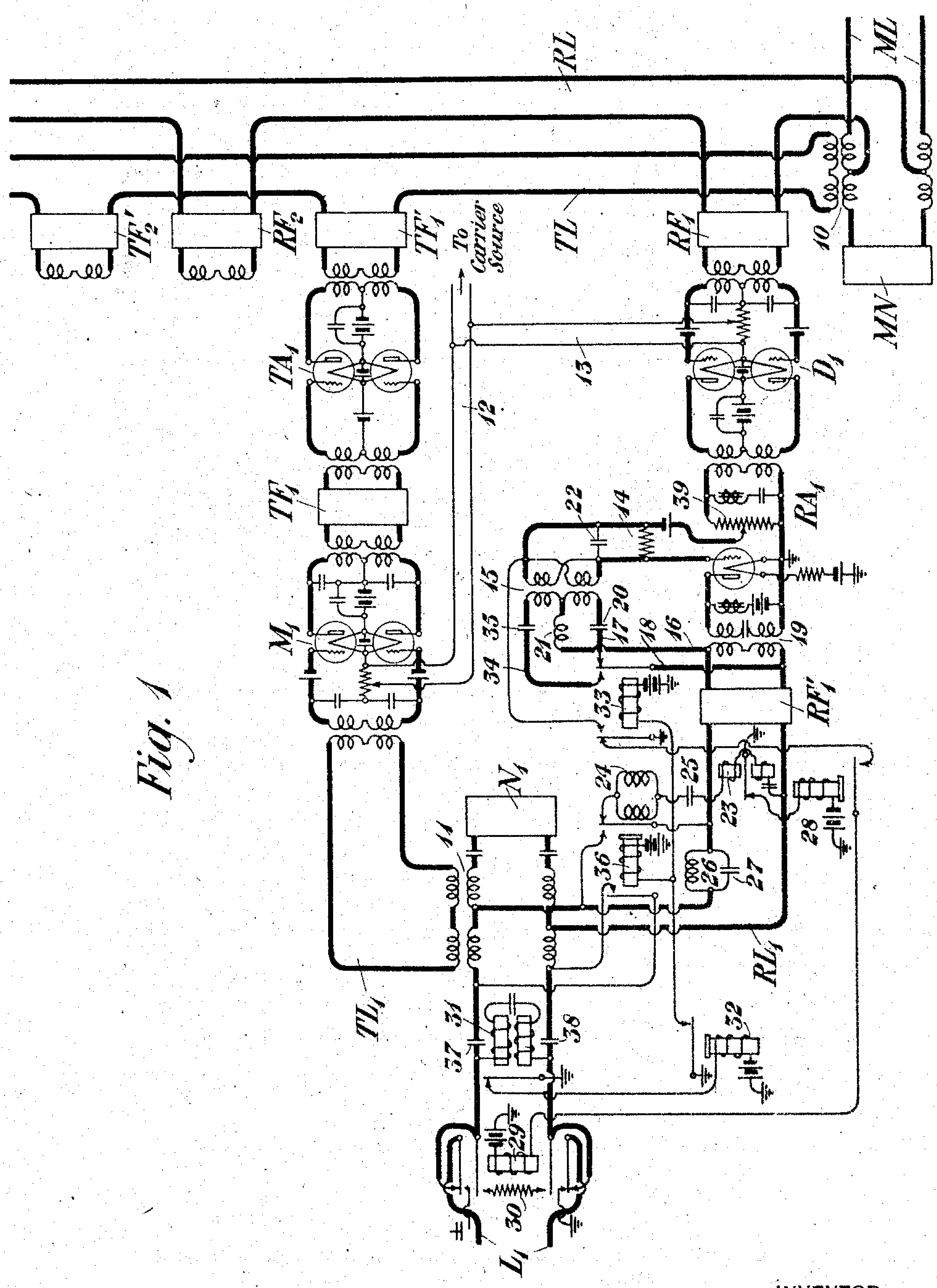

Fig. 1

INVENTOR

Lloyd Espenschied

BY

ATTORNEY

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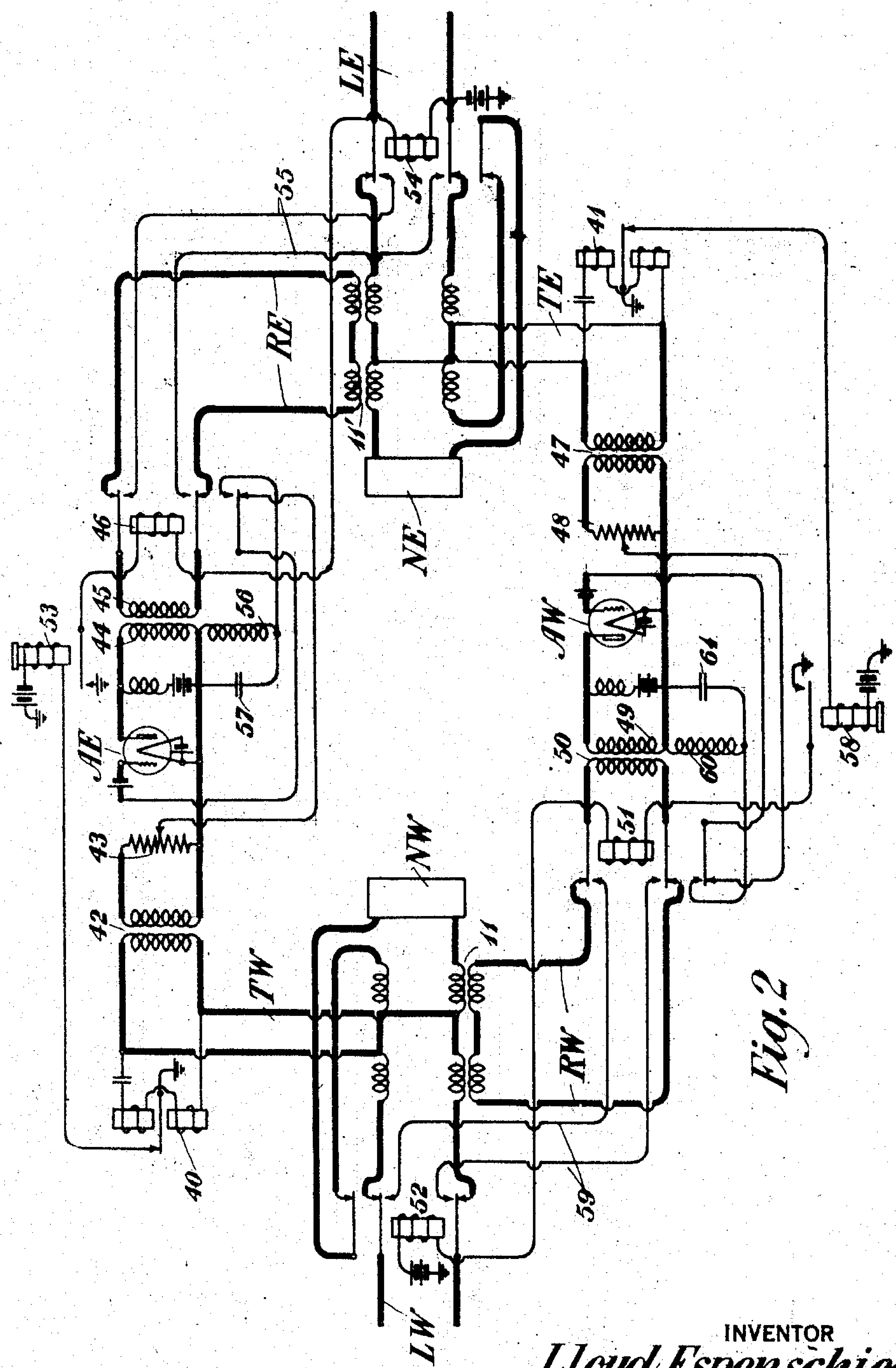

Fig. 2

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ATTORNEY

Patented May 8, 1923. **1,454,159**

UNITED STATES PATENT OFFICE.

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

MEANS FOR RINGING OVER MULTIPLEX TRANSMISSION CHANNELS.

Application filed July 30, 1920. Serial No. 400,045.

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 Means for Ringing Over Multiplex Transmission Channels, of which the following is a specification.

This invention relates to transmission systems and more particularly to multiplex transmission systems employing carrier currents. The present application is a continuation as to common subject matter of applicant's prior application, Serial No. 314,074, filed July 29, 1919.

Where multiplex transmission is attained by the use of carrier currents a plurality of carrier frequencies are transmitted over a common transmission line, the carrier frequencies being separated sufficiently to prevent interference, and each frequency being assigned for use as a separate channel of communication so that signals, such, for instance as telephonic variations, may be transmitted by impressing them upon the carrier frequencies. Several channels may thus be superposed upon a common transmission line and each channel performs the functions of an ordinary telephone transmission line.

In ordinary telephone transmission it is customary to transmit over the line, in addition to the telephone currents, ringing currents or other signaling currents, for the purpose of signaling between operators in establishing connections. In order to obtain practical telephone service over each carrier communication channel, it is desirable that the channel be utilized for the transmission of such ringing or other signaling currents as well as for the transmission of ordinary telephone currents.

This invention, therefore, concerns means whereby ringing and other signals may be transmitted for each carrier channel.

The invention likewise has reference to the provision of a transmission system having included therein a vacuum tube which normally acts to produce one desired result, but which under other conditions, operates as a generator of oscillations.

A further feature of the invention is the provision in a transmission circuit of an amplifier, which, while normally serving as an amplifier only, will under certain conditions operate to produce oscillations.

Still another part of the invention relates to an amplifier between two line sections for the amplification of current transmitted from one line section to the other, which in response to currents transmitted from said last mentioned line section, will act as a generator of oscillations to be transmitted to the first line section.

The above features, as well as others more fully hereinafter appearing, are exemplified by the arrangements set forth in the following description and illustrated in the accompanying drawing, Figure 1 of which is a diagram of such portions of the apparatus and circuits of a carrier system as are necessary for a full understanding of the invention, and Figure 2 of which illustrates the invention as applied to an ordinary 22 repeater system.

Referring to Fig. 1 of the drawing, ML designates a main line employed for the transmission of a plurality of carrier frequencies between two main stations at which terminal carrier equipment is provided for separating the frequencies into their respective channels and for associating them with low frequency transmission lines. A portion of the apparatus at one station only is illustrated, it being understood that similar apparatus will be provided at the other station. At the station illustrated in the drawing, the main line ML is balanced by an artificial line MN and is associated through a balanced transformer arrangement 10 with a common transmitting circuit TL and a common receiving circuit RL, the arrangement being such that these two circuits are conjugate with respect to each other, so that electrical variations arising in the one circuit will be without effect upon the other.

The common transmitting and receiving circuits TL and RL are associated with a terminal low frequency line L_1 through a two-way circuit comprising a transmitting channel TL_1 and a receiving channel RL_1, the former channel being inductively associated with the common circuit TL through a connection including a filter TF_1 and the latter channel being inductively associated with the common receiving circuit RL through a connection including a filter RF_2. The transmitting and receiving channels TL_1 and RL_1 are interconnected at their ends through a transformer arrangement 11 with the terminal line L_1, the latter line being balanced by an artificial line or network N_1 so that the transmitting and receiving channels TL^1 and RL^1 will be conjugate with respect to each other. The common transmitting and receiving circuits TL and RL may be similarly associated with one or more other low frequency terminal lines through transmitting and receiving channels similar to TL_1 and RL_1, the manner in which additional channels are associated with the common circuits TL and RL being indicated by the connections including the filters TF_2' and RF_2.

The transmitting channel TL_1 includes, in addition to the filter TF_1', a similar filter TF_1. These filters are preferably broad band filters of the general type illustrated in U. S. patents issued to George A. Campbell, Nos. 1,227,113 and 1,227,114, dated May 22, 1917. These filters should be so designed as to transmit a band of frequencies equal in width to the band of frequencies employed in ordinary telephonic transmission, said band extending from the carrier frequency assigned to the channel to a limiting frequency either above or below said carrier frequency an amount equal to the width of the band.

In order to translate the low frequency signaling currents transmitted over the line L_1 into high frequency currents for transmission over the main line ML, the transmitting channel TL_1 is provided with a modulator M_1. This modulator is preferably of the duplex vacuum tube type illustrated and described in the U. S. application of B. W. Kendall, Serial No. 125,349, filed October 13, 1916, or in the U. S. patent to John R. Carson, No. 1,343,307, issued June 15, 1920. The modulator M_1 is supplied with carrier oscillations of the frequency assigned to the channel over a circuit 12, but as these oscillations are impressed on the common conductor of the balanced circuit normally no oscillations are transmitted through the modulator.

The transmitting channel TL_1 is also provided with an amplifier TA_1 included in said circuit between the filters TF_1 and TF_1'. This amplifier may be of any well known type, but as illustrated, is a duplex vacuum tube amplifier of the so-called push and pull type.

The receiving channel RL_1, includes, in addition to the filter RF_1, a filter RF_1'. These filters are likewise of the general type illustrated and described in the patents to Campbell above referred to, the filter RF_1 being similar in structure and transmitting a band of frequencies similar to that transmitted by the filters TF_1 and TF_1'. The filter RF_1', however, is a low frequency filter designed to transmit a range of frequencies extending from zero up to the upper limiting frequency employed in ordinary telephonic transmission.

The receiving channel RL_1 also includes a demodulator or detector D_1. This detector may be of any well know type but is illustrated as being of the duplex vacuum tube type, illustrated and described in the U. S. patent to John R. Carson, No. 1,343,308, issued June 15, 1920. As set forth in the said patent to John R. Carson, this demodulator operates in accordance with the so-called homodyne method of receiving and is, therefore, supplied with oscillations of the same frequency as the corresponding modulator. These oscillations are supplied over the circuit 13 to the common branch of the balanced input circuit of the demodulator so that normally no high frequency oscillations are transmitted through the demodulator.

The receiving channel RL_1 is also provided with an amplifier RA_1 for the purpose of amplifying the detected low frequency currents. This amplifier may be of any well known type, but as illustrated is a vacuum tube having its input circuit coupled with its output circuit through a connection including a circuit 14 inductively coupled through a transformer 15 with a circuit including conductors 16, 17 and 18, conductors 16 and 18 being connected to one winding of a transformer 19 in the output circuit of the amplifier. Conductor 17 is normally connected in series with conductor 18 and includes a condenser 20, while the conductor 16 includes an inductance 21. A condenser 22 is bridged across the primary windings of the transformer 15, thereby forming a circuit resonant at a critical frequency.

In the amplification of telephonic currents which may be considered to extend over a range from about 300 cycles to about 2,000 cycles, the feed back connection above described is without substantial effect and the amplifier operates to amplify telephonic frequencies in the ordinary manner. It is desirable, however, that the detected ringing currents which will be impressed upon the amplifier as hereinafter described, shall be amplified to a greater degree than the talking currents. These ringing currents should be of some frequency outside the telephone range described, as, for instance, 133 cycles. By means of the condenser 22, the circuit 14 is therefore tuned to resonate at 133 cycles. The primary of the feed back coil 15 is divided into two parts similar but reversed in respect to their subsequent circuits. The phase relations established by one of these circuits, that associated with condenser 20, is such as to cause reamplification but no singing of the feed back circuit, while that of the other winding associated with condenser 35 is such as to cause singing. Each of the two primary circuits are tuned by means, respectively, of condensers 20 and 35 to the frequency of the ringing current. In the normal receiving condition the feed back circuit is established through the reamplifying but non-singing secondary circuit as illustrated.

In order to control the transmission of ringing current of suitable frequency to the terminal line L_1 in response to ringing signals received, detected and amplified by the apparatus in the receiving channel RL_1, a relay 23 is bridged across the receiving channel RL_1 beyond the filter RF_1 by means of a circuit tuned to 133 cycles through the agency of an inductance 24 and a condenser 25. This bridged circuit forms a path of low impedance to ringing currents of 133 cycles, but offers a high impedance to telephonic currents which may be in general above 300 cycles. In order to insure that the maximum amount of ringing current shall flow through the bridge including the relay 23, a circuit including an inductance 26 and condenser 27 is serially inserted in one side of the channel RL_1 beyond the bridge including the relay 23. The condenser 27 and the inductance 26 are so chosen as to form a circuit which is anti-resonant at 133 cycles, thereby preventing the flow of current of this frequency beyond the bridge including the relay 23. The relay 23, while being unresponsive to currents of voice frequency, is readily responsive to ringing currents of 133 cycles and operates through relay 28 a relay 29, whereby the terminal line L_1 is disconnected from the channels TL_1 and RL_1 and ringing current from a local source of some suitable frequency, such as 16 cycles or 133 cycles, is applied to said line. In order to prevent the unbalance of the two-way circuit including the channels TL_1 and RL_1 during this operation, the relay 29 also operates to connect an auxiliary network or resistance 30 across the terminals of the windings of the transformer 11 in order to balance the artificial line N_1.

In order that ringing signals incoming from the line L_1 may be transmitted over the line ML to a distant station through the transmitting channel TL_1, a relay 31 is bridged across the line L_1, said relay being responsive to ringing current of any desirable frequency, as, for instance, 16 cycles or 133 cycles. This ringing responsive relay 31, upon being actuated, operates through a slow acting relay 32 to apply ringing current from a local source upon the input circuit of the modulator M_1. While any local source of ringing current may be utilized for this purpose, it is convenient to utilize the amplifier RA_1 as a source of ringing current.

For this purpose the feed back circuit of the amplifier RA_1 is so arranged that by the operation of relay 33 under the control of relay 32, the conductor 18 is shifted from connection with the conductor 17 and is serially connected to a conductor 34 including a condenser 35. This condenser is of such capacity as to resonate to 133 cycles the circuit which includes one primary winding of coil 15 and coil 21. This one of the two primary windings is so connected that the feed back circuit causes the amplifier RA_1 to oscillate at 133 cycles and to thereby generate ringing current. It will be understood that other known methods of adjustment to change the circuit from the non-singing to the oscillating condition may be used, instead of that above described.

In order that the ringing current generated by the amplifier RA_1 may be transmitted to the modulator M_1, a relay 36 is provided under the control of relay 32, said relay being arranged to short circuit the line L_1 between the transformer 11 and the relay 31, thereby unbalancing the transformer connection between the transmitting channel TL_1 and the receiving channel RL_1 so that the channels are no longer conjugate. The oscillations supplied by the amplifier RA_1 may therefore be transmitted from the receiving channel RL_1 to the transmitting channel TL_1 and applied to the modulator M_1. In order to prevent the oscillations thus transmitted from operating the relay 23 and in order to provide a transmission path of low impedance for the 133 cycle currents, the relay 36 is arranged to disconnect the bridge including the relay 23 and to short circuit the anti-resonant combination 26—27.

Further details of the apparatus will be clear from a description of the operation which is as follows:

Telephone currents incoming from the line L_1 are transmitted over the outer back contacts of relay 29 and through the transformer 11 to the transmitting channel TL_1 without actuating the relay 31, the circuit of which is so designed as to offer a large impedance to currents of telephonic frequency. The telephone currents upon being transmitted to the channel TL_1 are impressed upon the input circuit of the modulator M_1. As already stated, the circuit of the modulator M_1 is normally balanced so that carrier oscillations from the source 12 are not transmitted. The telephonic currents impressed upon th modulator, however, unbalance its circuit so that carrier oscillations are transmitted by the modulator whose amplitude is directly proportional to the amplitude of the modulating voice wave.

These modulated oscillations are passed through the filters TF_1, amplified by the amplifier TA_1, and then passed through the filter TF_1' to the common transmitting circuit TL. Simultaneously modulated carrier currents of other frequencies from other channels are impressed upon the circuit TL. The several modulated frequencies are transmitted through the transformer 10 and over the main line ML to the distant station.

Carrier currents having frequencies corresponding to the several channels at the station of Fig. 1 and modulated at the distant station in accordance with telephone signals, after being transmitted over the line ML, pass into the common receiving circuit RL, from which the different carrier frequencies are selected into the proper receiving channels through the agency of filters such as RF_1, RF_2, etc. The modulated carrier oscillations passed through the filter RF_1 are impressed upon the input circuit of the demodulator D_1 where they react with unmodulated oscillations from the source 13 to produce in the output circuit of the demodulator low frequency telephonic currents corresponding to the telephone currents, in accordance with which the high frequency oscillations were modulated at the distant station. The low frequency telephone currents thus supplied are impressed upon the amplifier RA_1 and are transmitted through the amplifier without substantially affecting the feed back circuit, which, as already stated, is so arranged as to cause the amplifier to reamplify oscillations having a frequency of 133 cycles which is below the lower limit of telephone currents. The telephone currents are therefore amplified by the amplifier RA_1 in the normal manner and are transmitted through the transformer 19, passing through the low frequency filter RF_1' to the midpoints of the transformer 11. The bridges including the relay 23 and the anti-resonant combination 26—27 do not materially decrease the transmission of the channel RL_1, since they are designed to be affected with regard to currents in the neighborhood of 133 cycles only. The telephone currents upon arriving at the midpoints of the windings of the transformer 11 divide, part of the energy flowing to the artificial line N_1 and part of the energy flowing over the back contacts of the relay 29 to the line L_1.

Ringing current transmitted over the line L_1 from a distant terminal station passes over the back contacts of the relay 29 and through the windings of the ringing responsive relay 31. Condensers 37 and 38, having a high impedance to ringing currents, but readily permitting the passage of telephone currents, may be inserted between the relay 31 and the transformer 11 to insure that the greater proportion of the energy of the ringing current transmitted from the line L_1 shall be impressed upon the relay 31. Relay 31, in response to the ringing current, opens a circuit of the slow acting relay 32, which completes circuits energizing relays 33 and 36. Relay 33, upon being energized, at its left-hand contact disconnects ground from the normally opened circuit of the relay 29 to prevent any possibility of this relay being actuated to connect ringing current from a local source to the line L_1. At its front left-hand contact relay 33 connects ground directly to the grid of the amplifier RA_1 through the primary winding of the transformer 15, thereby short circuiting the potentiometer 39. At its right-hand front contact relay 36 disconnects conductor 18 from conductor 17 and connects it to conductor 34 which includes the condenser 35, so that the feed back circuit is so adjusted that the amplifier RA_1 oscillates at 133 cycles to generate ringing current. A distinct advantage arises from the short circuiting of the potentiometer 39 in the manner just described, due to the fact that the setting of the potentiometer is varied from time to time, under practical operating conditions, to vary the amplification of the amplifier RA_1 in accordance with the transmission conditions of the circuit, and by short circuiting the potentiometer, the amplifier when functioning as an oscillator will always be enabled to generate oscillations of the same amplitude.

The relay 36 upon being energized, at its right-hand front contact opens the bridge including the relay 23, thereby preventing said relay from being actuated by the 133 cycle oscillations supplied by the amplifier RA_1 and at the same time it short circuits the anti-resonant combination 26—27, which, if it remained in the circuit, would substantially prevent the transmission of the oscillations to the transformer 11. At its left-hand front contact relay 36 connects a short circuit across the left-hand terminals of the line windings of the transformer 11, thereby unbalancing the circuit so that transmission may take place from the receiving channel RL_1, through the transformer 11 to the transmitting channel TL_1. The 133 cycle oscillations are now transmitted from the amplifier RA_1, through the filter RF_1' and through the transformer 11 to the input circuit of the modulator M_1. The 133 cycle oscillations thus transmitted operate to modulate the carrier frequency through the agency of the modulator M_1 in the same manner as described in connection with telephone currents. High frequency oscillations modulated in accordance with the ringing currents supplied by the amplifier RA_1 are, therefore, transmitted from the modulator M_1, through the filter TF_1, amplifier TA_1, filter TF_1', common circuit TL, transformer

10 and over the main line ML to the distant station.

In case it is desired to ring over the line L_1 from the distant station, the carrier apparatus at that station will be operated in a manner similar to that just described, so that carrier oscillations modulated in accordance with 133 cycle ringing current will be transmitted over the main line ML and into the common receiving circuit RL. The carrier oscillations are then selectively transmitted through the filter RF_1 to the input circuit of the demodulator D_1. These modulated oscillations react in the demodulator D_1 with unmodulated oscillations from the circuit 13 to produce in the output circuit of the demodulator 133 cycle ringing currents, which are then impressed upon the amplifier RA_1. This amplifier having its feed back circuit in its normal condition acts as a reamplifier at a frequency of 133 cycles and consequently the ringing currents are amplified to a much greater degree than in the case of telephone currents. The highly amplified ringing currents are then passed through the filter RF_1' and flow through the bridge, including the relay 23 to operate said relay, the anti-resonant combination 26—27 at the same time functioning to prevent any substantial amount of the ringing energy from being transmitted beyond the relay 23. Relay 23 upon being energized opens the circuit of the slow acting relay 28, thereby completing the circuit of relay 29, which at its outer front contacts disconnects the line L_1 from the transformer 11 and applies a local source of ringing current to said line. At its inner front contacts, relay 29 at the same time substitutes an auxiliary line 30 for the line L_1 so that the balance of the transmitting and receiving channels TL_1 and RL_1 is maintained.

Fig. 2 illustrates the use of a device which normally functions as an amplifier as a source of ringing current for ringing through an ordinary 22 repeater circuit. In this figure, LE and LW designate two low frequency transmission lines balanced by artificial lines or networks NE and NW respectively. Amplifiers AE and AW are shown, these amplifiers being, as illustrated, of the well known vacuum tube type, although the invention is equally applicable to other well known types of amplifiers. A transmitting channel TW leads from the line LW to the amplifier AE and a receiving channel RW leads from the amplifier AW to the line LE, being inductively associated therewith through the transformer 11. The transmitting channel TE connects the line LE to the amplifier AW while the receiving channel RE leads from the amplifier AE to the line LE, being inductively associated therewith through the transformer 11′.

The amplifiers AE and AW normally function to amplify currents of telephonic frequency in a well known manner, but they are so arranged that the input and output circuits may be coupled together so that the tubes oscillate at some suitable ringing frequency, as, for example, 133 cycles per second. The coupling of the input and output circuits of the amplifier AE is controlled through suitable relay arrangements, the action of which is determined by a ringing responsive relay 40, bridged across the transmitting channel TW. The ringing responsive relay 40 also functions to provide a path whereby the ringing current generated by the amplifier AE may be transmitted to the line LE. In a similar manner, a ringing responsive relay 41, bridged across the transmitting channel TE, controls through a suitable chain of relays the coupling of the input and output circuits of the amplifier AW to transmit ringing current to the line LW.

Further details of the apparatus will be clear from a description of its operation, which is as follows:

Telephone currents to be transmitted from the line LW to the line LE, pass to the circuit TW and through the transformer 42 and potentiometer 43 to the amplifier AE. The amplified telephone currents appearing in the output circuits of the amplifier pass through the transformer comprising windings 44 and 45, and over the normal contacts of the relay 46 to the circuit RE, from which they are transmitted through the transformer 11′ to the line LE. Similarly, telephone currents from the line LE pass to the circuit TE and through the transformer 47 and potentiometer 48 to the amplifier AW. The amplified currents are then transmitted through the transformer comprising windings 49 and 50, over the normal contacts of the relay 51 to the circuit RW, from which circuit they are transmitted through the transformer 11 to the line LW.

Ringing current incoming over the line LW passes over the normal contacts of the relay 52, into the circuit TW and through the windings of the ringing responsive relay 40. The ringing responsive relay 40 causes the release of the slow acting relay 53, which closes the circuit through relays 46 and 54. Relay 46, upon being energized, shifts the connection from the winding 45 of the output transformer of the amplifier AE from the circuit RE to the circut 55. The lower armature of the relay 46 at the same time disconnects the grid of the amplifier AE from the potentiometer 43 and connects said grid to an oscillating circuit including a winding 56 and a condenser 57. The winding 56 is in inductive relation with the windings 44 and 45, and the output and input circuits of the amplifier AE are now coupled together so that the amplifier acts as a generator of oscillations, the frequency of which is determined by the oscillating circuit. The oscillating circuit is so tuned that the frequency generated will be a frequency suitable for ringing, such for example, as 133 cycles. The ringing current thus generated is transmitted to the circuit 55. The relay 54, which was energized at the same time as relay 46, disconnects the line LE from the transformer 11′ and directly connects said line to the circuit 55 so that the ringing current is transmitted over the line LE.

In a similar manner, ringing current incoming over the line LE passes over the normal contacts of the relay 54 to the circuit TE, actuating the ringing responsive relay 41. The relay 41 opens the circuit of the slow acting relay 58 which in turn closes the circuit of relays 51 and 52. Relay 51, upon being actuated, disconnects the winding 50 of the transformer in the output circuit of the amplifier AW from the circuit RW and connects said winding to the circuit 59. At the same time, the lower armature of the relay 57 disconnects the grid of the amplifier AW from the potentiometer 48 and connects said grid to an oscillating circuit including a winding 60 and a condenser 61. The winding 60 is inductively related to the windings 49 and 50 so that the input and output circuits of the amplifier are now coupled together and the amplifier oscillates at a frequency determined by its oscillation circuit. This frequency is set at the desired ringing frequency, which in the case under consideration, may be 133 cycles per second. This ringing frequency is transmitted over the front contacts of the relay 51 to the circuit 59. Relay 52, upon being energized, disconnects line LW from the transformer 11 and connects said line to the circuit 59 so that the ringing current generated by the amplifier AW is transmitted to the line LW.

It will be seen that by means of the arrangements above described a simple and yet efficient circuit has been provided whereby ringing signals may be transmitted over the same channel of a multiplex system as is used for telephonic transmission. It will also be seen that in accordance with this invention, a vacuum tube is provided, which, while normally functioning to produce one result, may be, under certain circumstances, caused to function as a generator of ringing current, and while in the system as herein disclosed, it has seemed most convenient to employ the vacuum tube which normally functions as an amplifier for this purpose, any other vacuum tube in the system might equally well be used for the same purpose. It will likewise be obvious that while the invention has been illustrated as embodied in certain apparatus which has been found to be desirable from a practical standpoint, 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. In a signaling system, a transmission path, an amplifier and circuits therefor associated with said path, and means whereby the circuits of said amplifier may be controlled over said path to convert the amplifier into a generator of oscillations.

2. In a signaling system, two transmission line sections, an amplifier interconnecting said sections for amplifying currents transmitted from one section to the other, and means responsive to currents incoming from the latter section to cause said amplifier to function as an independent source of oscillations for transmission to the former section.

3. In a signaling system, two transmission line sections, an amplifier interconnecting said sections for amplifying ringing currents transmitted from one section to the other, and means responsive to ringing currents incoming from the latter section to cause said amplifier to function as a generator of ringing current for transmission to the former sections.

4. In a signaling system, two transmission line sections, a two-way circuit interconnecting said sections, said two-way circuit comprising two paths for transmission in opposite directions, an amplifier in one of said paths, means to convert said amplifier into a generator of oscillations at will, and means to transmit the oscillations so generated to one of said line sections.

5. In a signaling system, two transmission line sections, a two-way circuit interconnecting said sections, said two-way circuit comprising two paths for transmission in opposite directions, an amplifier in one of said paths, and means responding to current transmitted from one of said line sections to convert said amplifier into a generator of oscillations.

6. In a signaling system, two transmission line sections, a two-way circuit interconnecting said sections, said two-way circuit comprising two paths for transmission in opposite directions, an amplifier in one of said paths, and means responding to ringing current transmitted from one of said line sections to convert said amplifier into a generator of ringing current.

7. In a signaling system, a transmission path, a vacuum tube and circuits therefor normally functioning with respect to said path to translate currents transmitted over said path, and means whereby the input and output circuits of said tube may be coupled together at will under the control of said

path so that said tube becomes a generator of oscillations.

8. In a signaling system, a transmission path, a vacuum tube and circuits therefor normally functioning with respect to said path to translate currents transmitted over said path, and means whereby the circuits of said vacuum tube may be controlled over said path, so that the tube will function as a generator of oscillations.

In testimony whereof, I have signed my name to this specification this 29th day of July 1920.

LLOYD ESPENSCHIED.