Jan. 13, 1925.

1,522,580

L. ESPENSCHIED

COMPOSITED MULTIPLEX TRANSMISSION SYSTEM

Filed July 29, 1919

2 Sheets-Sheet 1

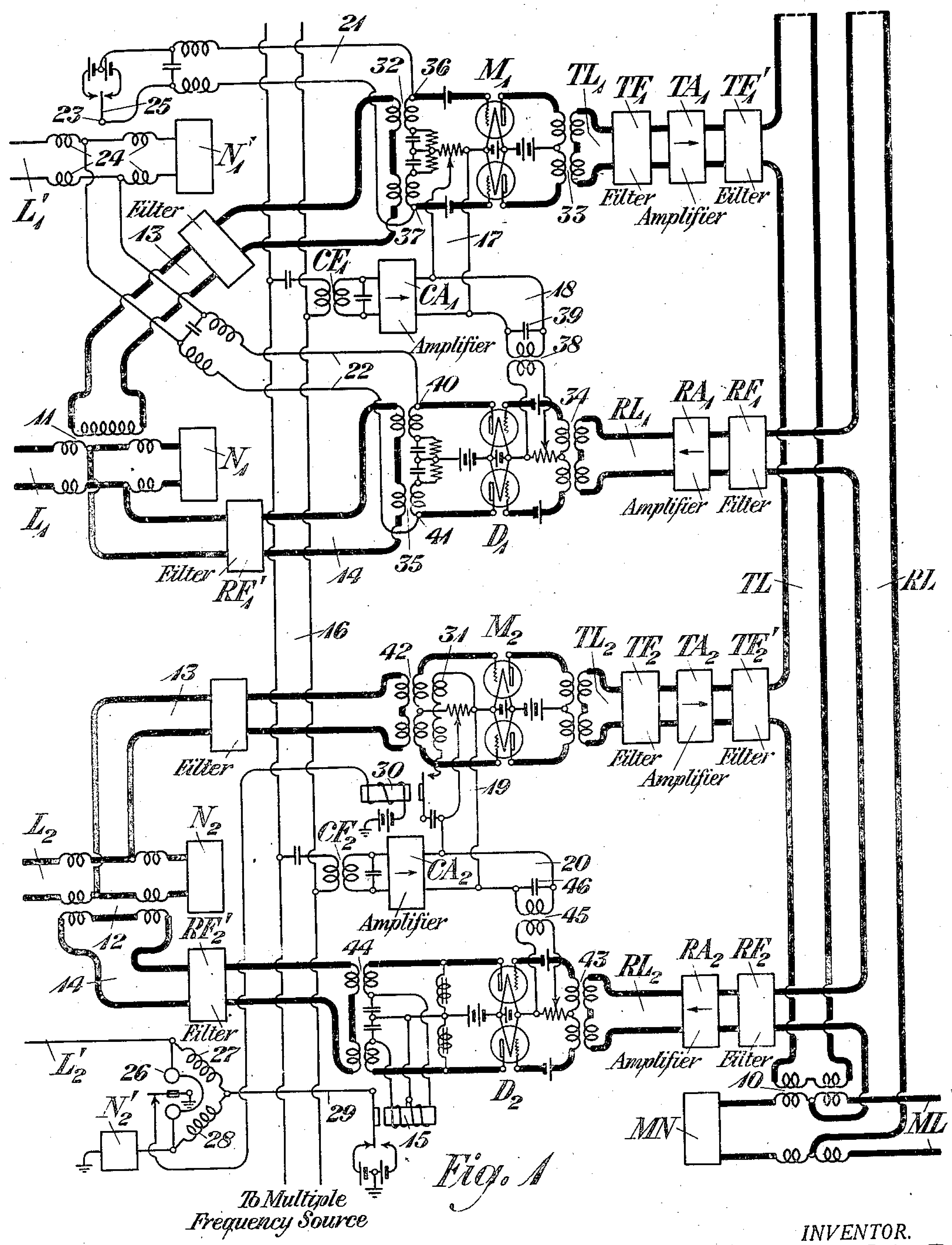

Fig. 1

INVENTOR.

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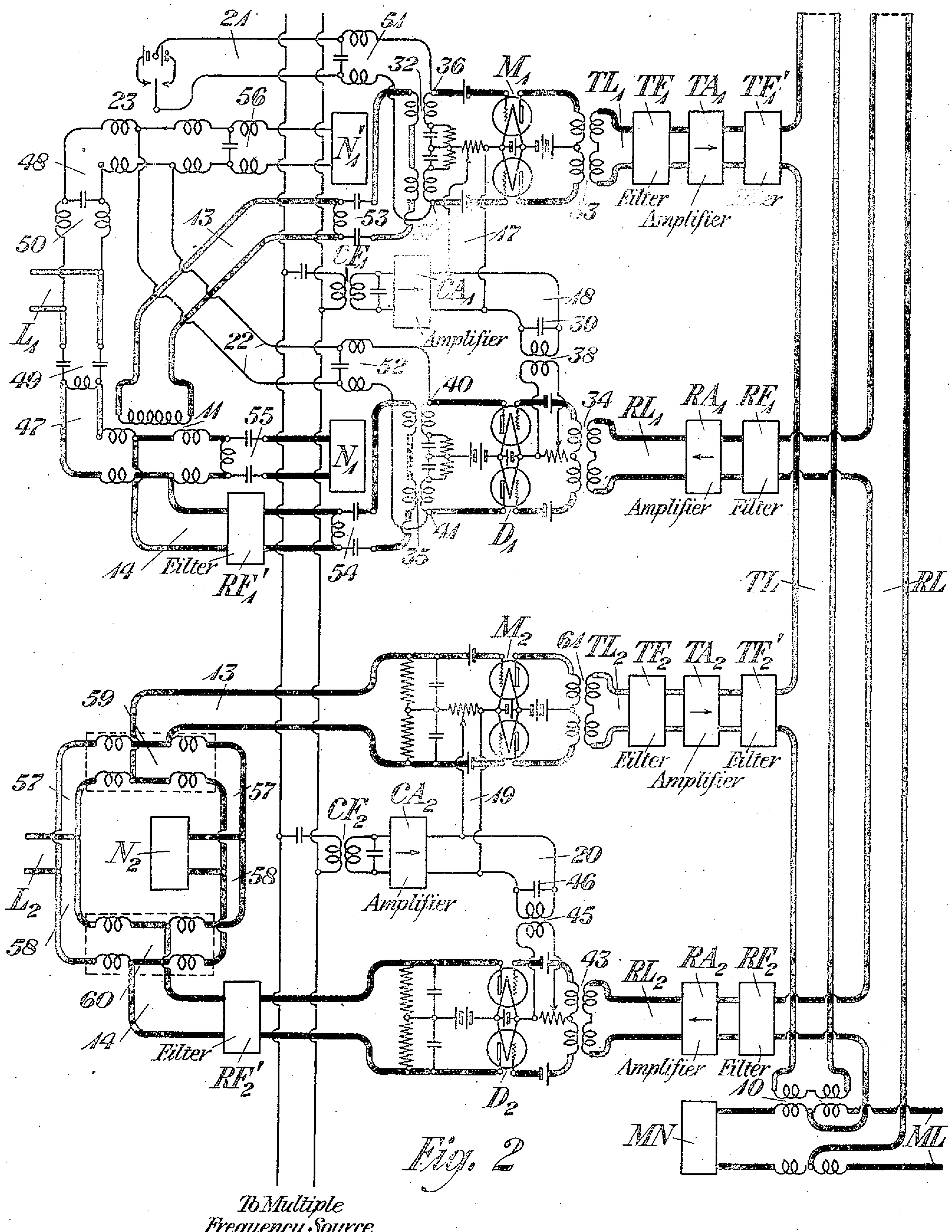

Fig. 2

INVENTOR.
Lloyd Espenschied
BY
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Patented Jan. 13, 1925. **1,522,580**

UNITED STATES PATENT OFFICE.

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

COMPOSITED MULTIPLEX TRANSMISSION SYSTEM.

Application filed July 29, 1919. Serial No. 314,073.

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 Composited Multiplex Transmission Systems, of which the following is a specification.

This invention relates to transmission systems and more particularly to multiplex transmission systems employing carrier currents.

Where multiplex transmission is secured 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 usual practice to transmit over the line, in addition to the usual telephone currents, signaling currents, such as, for instance, D. C. Morse currents. This is accomplished by the use of the so-called composite sets for separating the telephone currents from signaling currents of other characters. In order to obtain the maximum service from each carrier communication channel, it is desirable that the channel be utilized for the transmission of Morse or other signaling currents in addition to the telephone currents. It is therefore one of the objects of this invention to superimpose upon each channel of a multiplex carrier current system, both telephonic signals and signals of a different character, such as Morse signals. Another object of the invention is to provide means, whereby the transmission currents of carrier frequency may be simultaneously modulated in accordance with a plurality of signaling currents. Still another object of the invention is to provide means, whereby a plurality of signals, which have been simultaneously impressed upon the same carrier current, may be separated after transmission to a distant point. It is also an object of the invention to provide an arrangement whereby direct current impulses of opposite polarity may be translated into carrier frequency currents having the same amplitude and frequency for waves of opposite polarity, but the carrier currents corresponding to a direct current of one polarity being opposite in phase to those corresponding to direct current of the other polarity. The invention also contemplates translating a carrier current having the characteristics just described into direct current impulses of opposite signs. Other and further objects of the invention will be apparent as the description of the invention proceeds.

The frequencies transmitted over the channels of a carrier telephone system are those of the individual carrier frequencies, modified in frequency by the voice frequencies. Where, for instance, four channels having frequencies of 10,000, 15,000, 20,000 and 25,000 cycles, respectively, are employed, the 20,000 cycle channel is modified by the voice frequency so that it varies from instant to instant in accordance with the voice frenquencies from 20,000 cycles minus 2,000 cycles to 20,000 cycles plus 2,000 cycles (2,000 cycles being taken as the extreme of the telephone frequencies employed). Where a system is employed in which the carrier frequency and one side frequency is suppressed, only the frequencies above or below 20,000 cycles would be transmitted. For instance, if the frequencies from 20,000 cycles up are suppressed by means of a band filter, only frequencies ranging between 18,000 and 20,000 cycles would be transmitted.

The operation of translating an ordinary telephone circuit into a carrier channel may be regarded as being that of merely elevating the frequency band occupied by the telephone circuit to a higher position in the broad frequency scale where it occupies a band of frequencies of the same width as it did at the ordinary telephone frequencies; that is, the several telephone circuits fitting into a carrier system may be regarded as being merely shifted in frequency from their absolute values, the different circuits being displaced by different amounts in frequency so that they do not overlap in the carrier frequency scale. From this conception it may be readily appreciated that the low frequency band of each telephone circuit which is so shifted may extend down to zero frequency and include such channels as are ordinarily superimposed upon a telephone circuit between zero frequency and the lower edge of the ordinary telephone band, say 300 cycles. The principal among such channels is, of course, the "D. C." channel which requires a frequency band for ordinary manual Morse operation from zero frequency to 50 or 100 cycles. Other low frequency signaling channels, such, for instance, as a channel for the transmission of ringing current may be included between the Morse channel and the lower edge of the telephone band.

If we imagine the entire range of ordinary communication frequencies of from zero cycle up to about 2,000 cycles (including the Morse channel as well as the telephone channel) to be stepped up to a higher level, for instance, that corresponding to the 20,000 cycle channel, we then have this frequency band of zero to 2,000 cycles referred to the frequency of the carrier channel; for instance, for the 20,000 cycle channel the frequency range extends from the carrier frequency, both up and down the scale to the extent of 2,000 cycles.

As indicated above, the carrier frequency when modulated by a lower frequency is changed in frequency in both a plus and minus direction by the value of the lower frequency, the 2,000 cycle range of the ordinary telephone channel causing the 20,000 cycle channel, for instance, to vary between extremes of 18,000 and 22,000 cycles. By eliminating one of the two bands by means of a band filter the other band extending, for instance, from 20,000 cycles down to 18,000 only, may be transmitted. In this transmitted band the range occupied by the Morse channel composited on the telephone channel would be 20,000 cycles minus the telegraph band (zero to say, 100 cycles), or down to about 19,900 cycles. The lower frequency edge of the telephone band would commence at, say, 19,700 cycles and extend down to about 18,000 cycles.

This elevation of the composited frequency range from, say, zero to 2,000 cycles up to a band referred to a carrier frequency, such as 20,000 cycles, is accomplished by modulation in the usual manner. Similarly, the stepping down at the receiving end of this composite frequency band is done by demodulation. The several signaling currents imposed upon the same channel may be separated at low frequency by the usual methods employed in compositing ordinary telephone circuits.

In order to utilize signaling methods involving the transmission of telegraphic signals by direct currents of opposite polarity, the arrangements of the invention comprise, among other things, a modulator so arranged as to translate direct currents of opposite polarity into carrier currents of the same frequency and amplitude (where the direct current impulses of opposite polarity are of the same amplitude) with a difference in phase introduced in the carrier frequency each time the modulating telegraph signal changes polarity. Similarly, a demodulator is provided to translate a carrier current having constant amplitude and frequency, but reversed in phase at different intervals, into direct currents whose signs change with each phase reversal of the carrier frequency.

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

Referring to Fig. 1, ML designates a transmission line on which may be superimposed a number of carrier channels. The main transmission line ML is associated with the terminal carrier apparatus through a balanced transformer 10 of a well known type and a balancing net work or artificial line MN. The terminal apparatus includes a common transmitting circuit TL and a common receiving circuit RL connected to the main line ML through the transformer and artificial line arrangement in such a manner that the two circuits will be conjugate with respect to each other; that is, will be so related that an electrical disturbance arising in the one circuit will not affect the other. A plurality of transmitting channels, such as TL_1 and TL_2 are associated with the common transmitting circuit TL, and similarly a plurality of receiving channels, such as RL_1 and RL_2 are associated with the common circuit RL.

A telephone transmission line L_1 is associated with the transmitting and receiving channels TL_1 and RL_1, through circuits 13 and 14, respectively, the line L_1 being connected to the circuits 13 and 14 through a transformer arrangement 11, similar to the transformer 10 already described and said line being balanced by an artificial line or net work N_1

The transmitting channel TL_1 includes a modulator M_1, a filter TF_1, and amplifier TA_1 and a filter TF_1'. The filters TF_1 and TF_1' are of the general type illustrated and described in the U. S. patents to George A. Campbell Nos. 1,227,113 and 1,227,114 dated May 22, 1914. Each of these filters is designed to transmit a band of frequencies extending from the basic frequency assigned to that channel down to a frequency differing from the basic frequency by a frequency corresponding to the upper limit employed in ordinary telephonic transmission, which may be taken to be, for instance, 2,000 cycles. If, therefore, the basic carrier frequency of this channel be taken as 20,000 cycles, the filters TF_1 and TF_1' would transmit frequencies lying between 18,000 and 20,000 cycles.

The amplifier TA_1 may be of any well-known type, but is preferably of the well-known vacuum tube type. The modulator M_1 may be of any well-known type, but is preferably a duplex modulator of the general type illustrated in the application of B. W. Kendall, Serial No. 125,349 filed October 13, 1916, or in the patent to John R. Carson, No. 1,343,307 issued June 15, 1920.

The transmitting channel TL_2 includes a modulator M_2, band filters TF_2 and TF_2' and amplifier TA_2. The modulator M_2 is similar to the modulator M_1 already referred to and the amplifier TA_2 may be substantially the same as the amplifier TA_1. The filters TF_2 and TF_2' will be of the same character as the filters TF_1 and TF_1' already referred to, but will be so designed as to transmit an equal range of frequencies at a different position on the broad frequency scale. For instance, if the frequency assigned to the channel TL_2 is 15,000 cycles, these filters may be arranged to transmit frequencies lying between 13,000 and 15,000 cycles.

The receiving channel RL_1 includes a detector D_1, receiving amplifier RA_1 and high frequency band filter RF_1. The filter RF_1 and the amplifier RA_1 may be practically identical in construction with the filter TF_1' and the amplifier TA_1 of the transmitting channel TL_1. The detector or demodulator D_1 may be of any well-known type, but is preferably of the duplex vacuum tube type illustrated and described in the patent to John R. Carson, No. 1,343,308 issued June 15, 1920.

The circuit 14 which associates the telephone line L_1 with the receiving channel RL_1 may be provided with a low frequency filter RF_1'. This filter may likewise be of the general type disclosed in the patents to Campbell above referred to and should preferably be so designed as to transmit a band of frequencies extending over the range of frequencies employed in ordinary telephonic transmission, but excluding frequencies above and below said range.

The receiving channel RL_2 is provided with a filter RF_2 and an amplifier RA_2, similar in all respects to the corresponding elements in the receiving channel RL_1. A demodulator or detector D_2 is also provided which is similar to the demodulator D_1 already described in so far as it functions to detect telephonic currents. In order to detect Morse currents, however, the demodulator D_2 is provided with a differentially wound relay 15, having one winding in each half of the balanced output circuit. The operation of this relay in detecting Morse impulses will be more fully described hereinafter. The circuit 14 includes a low frequency filter RF_2' similar in all respects to the filter RF_1' already described.

The several demodulators or detectors used in the system herein disclosed, preferably operate in accordance with the so-called homodyne principle and therefore each demodulator is supplied with carrier oscillations of the same frequency as the modulator. The several carrier frequencies may be supplied in any well-known manner, but preferably the frequency control system disclosed in the application of B. W. Kendall, Serial No. 130,350 filed November 5, 1916 may be used for this purpose. This frequency control system, since it forms no part of the present invention, is not illustrated in its entirety, but includes suitable means for impressing the frequencies which correspond to the several carrier channels upon a common circuit 16. The individual frequencies are then selectively transmitted through selective circuits which may constitute filtering means of any well-known type, but are herein illustrated as simply tuned circuits, such as CF_1 and CF_2. Amplifiers such as CA_1 and CA_2 are provided for the several channels in order to amplify the carrier frequency selected from the common circuit 16. These amplifiers may be of any well-known type but are preferably of the same type as the amplifiers TA_1 and TA_2 already referred to. From the output circuit of the amplifier CA_1 a branch circuit 17 extends to the common conductor of the duplex input circuit of the modulator M_1. A parallel branch 18 in a similar manner extends to the common conductor of the duplex input circuit of the corresponding demodulator D_1. The modulator M_2 and demodulator D_2 are supplied with carrier oscillations from the output circuit of the amplifier CA_2 through similar circuits 19 and 20.

In order that the transmitting channel TL_1 and the receiving channel RL_1 may be utilized for the transmission of signaling currents of a character other than the telephone currents transmitted from the line L_1, a line L_1', which may be any low frequency line, such as a Morse line, is associated with the input circuit of the modulator M_1 and the output circuit of the demodulator D_1 through circuits 21 and 22, respectively. The Morse line L_1' is provided with a receiving relay 23, comprising balanced windings 24 and an armature 25 under the control of which positive and negative impulses corresponding to units of a telegraph code may be transmitted over the circuit 21 to the modulator M_1. The receiving circuit

22 leading from the output of the demodulator D_1 is bridged across the mid points of the windings 24 so that impulses transmitted over this circuit from the demodulator will not actuate the receiving relay 23, an artificial line M_1' being provided for the line L_1' in order to insure that the two halves of the relay 23 will be balanced. The circuit 21, being connected directly to the grids of the two tubes of the modulator M_1, will function to unbalance the modulator so that high frequency currents of one phase will be transmitted when a direct current of one polarity is impressed upon the circuit 21, while high frequency currents of opposite phase will be transmitted when a direct current of opposite polarity is impressed upon the circuit 21. Similarly, the outgoing circuit 22, connected to the two plates of the two tubes of the demodulator D_1, will have a direct current of one sign impressed thereon by the output circuits of the two tubes when the applied carrier frequency from the channel RL_1 has one phase relation with respect to the locally supplied carrier, while a direct current of opposite sign will be supplied to the circuit 22 when the carrier from the circuit RL_1 is opposite in phase.

A slightly different arrangement is shown in connection with the transmitting channel TL_2 and receiving channel RL_2. In this case a Morse line L_2' of a well-known type having a grounded return is illustrated. This Morse line terminates in the usual duplex set, including the balancing artificial line N_2', and receiving polar relay 26 bridged across neutral points of inductances 27 and 28. Impulses received by the differential relay 15 of the demodulator D_2 are transmitted over a conductor 29 to the mid point of the inductances 27 and 28 so that the receiving polar relay 26 is unaffected thereby. In order to transmit impulses received over the Morse line L_2' to the modulator M_2 a relay 30 is provided under the control of the receiving polar relay 26. The relay 30, by means of its armature, controls an auxiliary connection from the output of the amplifier CA_2, whereby carrier oscillations may be impressed upon the modulator M_2 through the winding 31 which is cumulatively associated with the two halves of the input circuit of said modulator.

It will be noted that certain details of the apparatus associated with the receiving and transmitting channels TL_2 and RL_2 differ from corresponding elements associated with the channels TL_1 and RL_1. The two sets of apparatus are thus differently illustrated in order that two modifications of the invention may be disclosed without unnecessary duplication of the circuit diagram, and it will therefore be understood that in practice the channels may include apparatus of different types, as illustrated, or all the channels may include identical apparatus of either type.

Further details of the apparatus may now be best understood from a description of the operation which is as follows:

Telephone currents incoming from the line L_1 are transmitted through the transformer 11 to the circuit 13. From this circuit the low frequency variations are impressed upon the grids of the two vacuum tubes of the modulator M_1 through a transformer 32. At the same time oscillations of the carrier frequency assigned to this channel are impressed upon the input circuit of the modulator through the circuit 17. These oscillations are impressed upon the common conductor of the duplex input circuit, however, and affect both sides of the modulator alike so that normally no carrier oscillations are transmitted through the transformer 33 to the transmitting channel TL_1. Low frequency telephone variations impressed through the transformer 32, however, unbalance the modulator so that the high frequency oscillations vary in accordance with the low frequency telephone variations and are permitted to pass through the transformer 33 to the transmitting channel TL_1. These modulated oscillations are passed through the filter TF_1, amplified by the amplifier TA_1 and are then transmitted through the filter TF_1' to the common transmitting circuit TL. Similar modulated carrier currents may be transmitted from other transmitting channels upon the common circuit TL, from which the several modulated frequencies are passed through the transformer 10 to the main transmission line ML.

Modulated carrier oscillations transmitted over the line ML from a distant station are received into the common receiving circuit RL. From this circuit modulated oscillations corresponding to the several channels are selected into the proper receiving channels through the filters, such as RF_1, RF_2, etc. The modulated carrier oscillations passing through the filter RF_1 are amplified by the amplifier RA_2 and are then impressed through the transformer 34 upon the input circuit of the demodulator D_1. Normally, the input circuit of this demodulator is supplied with oscillations from the output circuit of the amplifier CA_1 through the circuit 18, the frequency of these oscillations being the same as that of the carrier oscillations, which after modulation at the distant station, were transmitted over the line ML and passed through the filter RF_1. Normally, the local oscillations produce no effect upon the demodulator since the circuit is balanced. As soon as modulated oscillations are impressed through the transformer 34, however, the demodulator is unbalanced thereby, so that low frequency telephonic variations corresponding to the telephone currents, in accordance with which the carrier oscillations were modulated at the distant station, are transmitted through the transformer 35 to the circuit 14. The resultant telephonic currents are passed through the low frequency filter RF_1' and are then transmitted over the telephone line L_1.

Simultaneously, with the operations above described, Morse currents incoming from the Morse line L_1' may actuate the receiving relay 23 to apply positive and negative potential differences between the points 36 and 37 of the modulator M_1. Normally, the two tubes being balanced, a carrier frequency determined by the circuit 17 will flow in the output circuit of each tube, the two currents being, however, of equal amplitude and opposite phase relation so that no current is transmitted through the transformer 33. When, however, the two tubes are unbalanced by a direct current flowing in the circuit 21 in one direction, the amplitude of the carrier frequency in the output circuit of one of the tubes will be greater than that of the other, so that a resultant carrier, whose amplitude is determined by the amount of the unbalance, and whose phase is determined by the tube through which the greatest current flows, will be transmitted through the transformer 33. If the tubes, however, be unbalanced by current flowing in the circuit 21 in the opposite direction then the carrier current flowing in the other tube will have the greatest amplitude and the resultant current transmitted through the transformer 33 will be of opposite phase, its amplitude, of course, depending upon the amount of the unbalance, if the direct currents of the two signs flowing in the circuit 21 be of equal amplitude the carrier frequency transmitted through the transformer 33 will be of constant amplitude and frequency, but a change in phase will occur each time the direct current in the circuit 21 changes sign. Actually, the oscillations passing through the transformer 33 will have superimposed thereon the telephonic variations due to the telephone currents transmitted over the circuit 13 so that the oscillations transmitted through the filter TF_1' will be modulated in accordance with a complex wave, which is the result of telephonic variations and the Morse variations.

Considering now that carrier currents of frequency corresponding to the receiving channel RL_1, having a constant amplitude determined by a Morse impulse at a distant station, are being transmitted from the distant station over the line ML. Such oscillations after passing over the common circuit RL and through the filter RF_1, are amplified by the amplifier RA_1 and are impressed through the transformer 34 upon the demodulator D_1. Since these oscillations are of constant amplitude and of the same frequency as the oscillations impressed upon the demodulator through the circuit 18, if a proper phase difference exists between the two sets of oscillations, the two plates of the tubes of the demodulator which are normally at the same potential will have a constant potential difference impressed upon them so that a direct current flows over the circuit 22 to the Morse line L_1' in one direction. The direction of this current flow will depend upon the phase difference between the oscillations impressed upon the modulator from the receiving channel RL_1 and from the circuit 18 and the direct current will therefore flow continually in one direction as long as there is no phase change in the incoming oscillations. When, however, oscillations of the same frequency but opposite in phase are impressed upon the demodulator, the potential difference between the plates of the two demodulating tubes will be opposite in sign to that just described, and a direct current will therefore flow in the circuit 22 to the Morse line in the opposite direction.

The maintenance of a proper phase relation between the two sets of oscillations is desirable in order to secure an effective working of the apparatus. If, for instance, the carrier oscillations entering the demodulator from the line and representing the direct current Morse signal of one sign happen to be a 90° out of phase, with respect to the oscillations from the circuit 18, no D. C. unbalance current flow would result in the output circuit of the demodulator and the Morse D. C. would not be received. The efficiency of demodulation for D. C. output current is a maximum when the carrier supply bears either a zero or a 180° phase relation to the unmodulated component of the received carrier current but in the one case the resultant direct current will be of one sign and in the other case the resultant direct current will be of opposite sign. In short, some direct current will flow in the circuit 22 for any phase relation other than 90 degrees between the locally supplied carrier and the incoming carrier frequency. The direction of this direct current will change if, for a given phase relation between the locally supplied carrier and the incoming frequency, the phase angle of the incoming frequency be changed 180 degrees. For a given amplitude of the incoming carrier frequency the amplitude of the direct current in the one direction or the other will increase, reaching the maximum when a zero phase difference exists between the incoming carrier and the locally supplied carrier for direct current in one direction, and when a phase difference of 180 degrees exists between the incoming and locally supplied carriers for direct current in the opposite direction. In order to maintain proper phase relations between the incoming and locally supplied carriers a transformer 38 having its primary winding shunted by a condenser 39 is included in the circuit 18, so that by varying the capacity of the condenser 39 the phase angle between the current and the electromotive force in the carrier supply circuit to the demodulator may be controlled.

When the carrier oscillations received from the main line ML contain, in addition to the direct current component due to the Morse signals, a variable component due to the telephone currents, the action of the demodulator is similar, except that in this case variable potential differences are created between the points 40 and 41 of the demodulator, these potential differences corresponding to a variable current which is a resultant of superimposing a low frequency telephone current upon a D. C. Morse current. The telephone variations pass through the transformer 35 to the circuit 14 and are transmitted through the filter RF_1' to the line L_1. The filter RF_1' does not permit the Morse current components to be passed to the line L_1 and, consequently, the D. C. Morse components are transmitted over the circuit 22 to the Morse line L_1'.

The operation of the apparatus associated with the transmitting channel TL_2 and receiving channel RL_2, so far as telephone transmission is concerned, is substantially the same as described with reference to the channels TL_1 and RL_1, the only difference being that the carrier oscillations for these channels are of a frequency sufficiently different from that of the other channels so that proper selectivity between the several channels may be secured by the filters. Morse currents received over the line L_2', however, actuate the receiving relay 26, which in turn controls the relay 30. In response to a Morse impulse the relay 30 closes a connection over its back contact from the output of the amplifier CA_2 to the winding 31 of the transformer 42. Carrier oscillations of constant amplitude are therefore passed through the modulator M_2 to the transmitting channel TL_2 so long as the Morse impulse persists. These oscillations will have superimposed thereon carrier oscillations modulated in accordance with telephone currents transmitted over the circuit 13 and will be passed through the filter TF_2, amplifier TA_2 and filter TF_2' to the transmitting circuit TL from which point the oscillations will be transmitted over the main line ML.

Similar oscillations received from the main line ML will pass into the common receiving circuit RL and through the filter RF_2 to the amplifier RA_2. After being amplified the variable oscillations will be impressed upon the input of the detector D_2 through the transformer 43. Normally, the demodulator D_2 is balanced so that the current in the plate circuits of the two tubes flows equally through the two windings of the differential relay 15 in the output circuit of the demodulator, and, consequently, this relay is deenergized. As soon as oscillations representing the Morse component from the receiving channel RL_1 are impressed upon the demodulator, the two tubes are unbalanced and the currents flowing in the two wndings have different values so that the relay 15 acts as a pole changer to transmit Morse impulses over the circuit 29 to the Morse line L_2'. The windings of the differential relay 15 have sufficient impedance to substantially prevent telephone variations which are detected by the demodulator D_2 from flowing through the relay and affecting its operation. To further assist in separating the Morse currents from the telephone currents condensers are provided in each plate circuit in shunt with the windings of the relay 15, these condensers offering a low impedance path for telephone currents. The telephone variations pass through the transformer 44 and after transmission through the filter RF_2' are impressed upon the telephone line L_2.

In order to maintain a proper phase relation between the unmodulated components of the received carrier currents which correspond to the Morse signals, and the carrier oscillations impressed upon the detector D_2 from the circuit 20, a transformer 45 and a condenser 46 are included in the latter circuit, these elements functioning in the same manner as the elements 38 and 39 of the carrier channel first described.

Fig. 2 illustrates certain modifications of the apparatus shown in Fig. 1, corresponding elements in the two figures being designated by the same reference characters. The arrangement shown in Fig. 2 differs from that of Fig. 1, principally, in the fact that the low frequency telephone line is composited so that the Morse signals are transmitted over the same line as the telephone signals. The line L_1, for instance, is used in transmitting both telephone and telegraph signals and at the carrier terminal is divided into two branches, one branch 47 transmitting the telephone currents and the other branch 48 transmitting telegraph currents. In order to prevent the telegraph currents from flowing into the branch 47, a filtering arrangement 49 of a well-known construction is provided. Similarly, a filtering arrangement 50 is provided in the branch 48 to prevent telephone currents from flowing over this branch.

The telephone branch 47 is associated

through a transformer 11 with circuits 13 and 14 leading to the modulator M_1 and the demodulator D_1 as in Fig. 1. In order to associate the telegraph branch 48 with the modulator and demodulator the receiving relay 23 and the circuits 21 and 22 are provided as in Fig. 1. Circuits 21 and 22 are provided with filtering arrangements 51 and 52 similar to the filtering arrangement 50 in order to prevent telephone currents from the circuits 13 and 14 from reacting in said circuits 21 and 22. In a similar manner the telephone branches 13 and 14 are provided with filtering arrangements 53 and 54 similar to the filtering arrangement 49 to keep out the telegraph currents. A balancing artificial line or net work N_1 is provided for balancing the apparatus associated with the branch 47 beyond the filtering arrangement 49, the latter element being balanced by an equivalent filtering arrangement 55. Similarly, a filtering arrangement 50 is balanced with respect to the telegraph receiving relay 23 by means of an equivalent filtering arrangement 56, while the net work N_1' is provided for balancing the apparatus associated with the circuit 48 beyond the filter 50.

Telephone and telegraph currents transmitted over the line L_1 are separated through the branches 47 and 48, respectively, due to the action of the filtering arrangements 49 and 50. The telephone currents are transmitted through the transformer 11, over the circuit 13, through the filtering arrangement 53 and through the transformer 32 to the modulator M_1. Telegraph currents actuate the receiving relay 23 so that D. C. telegraph impulses of opposite signs are transmitted over the circuit 21 to the modulator M_1. The telephone and telegraph currents are combined in the modulator M_1 in the same manner as described in connection with Fig. 1, and after being translated into high frequency currents are filtered, amplified and then transmitted over the main line ML to a distant station.

Corresponding high frequency currents transmitted from a distant station over the line ML flow over the common receiving circuit RL and are selected through the filter RF_1 into the receiving channel RL_1 where they are amplified by the amplifier RA_1. These high frequency currents react upon the demodulator D_1 with oscillations of the proper carrier frequency from the circuit 18 so that low frequency potential differences appear between the points 40 and 41 of the detector D_1, which potential differences correspond to the combined telephone and Morse currents in their low frequency state. The telephone currents are transmitted through the filtering arrangement 54 into the circuit 14, and after passing through the low frequency filter RF_1' are transmitted over the branch 47 to the line L_1. The Morse components on the other hand pass through the filtering arrangement 52 to the circuit 22 from which point they are transmitted over the branch 48 to the line L_1.

The arrangement described in connection with the transmitting and receiving channels TL_1 and RL_1 of Fig. 2 provides for the separation of the Morse and telephone currents before modulation and after detection. A slightly modified arrangement is shown in connection with the transmitting and receiving channels TA_2 and RA_2 in which the telephone and Morse components remain combined at all times, both in their low frequency and high frequency states. In this case the line L_1 is divided into two branches 57 and 58 including balanced transformer arrangements 59 and 60 respectively. Beyond the transformer arrangements the circuits 57 and 58 again merge and at their junction point an artificial line or net work N_2 is provided for balancing the line L_2. The transmitting circuit 13, which in this case is used for impressing both Morse and telephone currents upon the modulator M_2 is connected across the branch 57 at the mid points of the balanced transformer arrangement 59. Similarly, the receiving branch 14 which associates the demodulator D_2 with the line L_2 is connected across the branch 58 at the mid points of the transformer arrangement 60. The circuit 14 also transmits both telephone and Morse currents. By means of the arrangement above described the circuits 13 and 14 are rendered conjugate with respect to each other so that electrical variations arising in the one circuit do not affect the other.

Telephone and Morse currents flowing over the line L_2 are transmitted through the balanced transformer arrangement into the circuit 13 and from this circuit are impressed upon the modulator M_2, thereby modulating the high frequency oscillations supplied to the modulator from the circuit 19. High frequency oscillations modulated in accordance with the combined Morse and telephone currents are then transmitted through the transformer 61 and through the filter TF_2 to the amplifier TA_2. After being amplified the oscillations are transmitted through the filter TF_2' to the common transmitting circuit TL and thence through the transformer 10 to the main line ML. Similar currents transmitted from a distant station over the main line ML flow into the common receiving circuit RL and are filtered through the filter RF_2 into the receiving channel RL_2. Upon being amplified by the amplifier RA_2 the modulated oscillations are impressed through the transformer 43 upon the demodulator D_2. Low frequency variations corresponding to the superposed Morse and telephone currents appear in the output circuit of the demodulator and are transmitted through the filter RF_2' in the circuit 14 from which point they pass through the balanced transformer arrangement to the line L_2. The filter RF_2' in the circuit 13 should be so arranged as to transmit frequencies lying between zero and the upper limit of frequencies employed in ordinary telephonic transmission since the low frequency Morse currents must pass through this filter as well as the telephone currents.

As in the case of Fig. 1, two different forms of apparatus are disclosed in Fig. 2 in order to present different modifications without unnecessary duplication of the circuits. It will be understood, however, that in actual practice the apparatus of the different channels may be of the same character. Both of the arrangements shown in Fig. 2 function like the first arrangement described in connection with Fig. 1 in so far as the translation of direct currents of opposite signs into carrier currents of opposite phases and vice versa are concerned.

By means of the arrangements heretofore described it is possible to superpose upon each channel of a multiplex carrier system one or more signaling circuits in addition to the low frequency telephone circuit. These signaling circuits, while illustrated as Morse telegraph circuits, may be signaling circuits of any desired character. Furthermore, while the invention has been illustrated as embodied in certain forms, which are considered desirable from a practical standpoint, 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. In a signaling system, a transmission line adapted to transmit high frequency currents, a translating station at one end of said line, a modulating apparatus associated with said line at said station, means to transmit to said translating station telephone currents and low frequency unmodulated signaling currents of a different character, and means whereby said modulating apparatus is controlled by said telephone and other signaling currents to supply carrier currents to said transmission line modulated in accordance with said telephone and other signaling currents.

2. In a signaling system, a transmission line adapted to transmit high frequency currents, a translating station at each end thereof, a modulating apparatus associated with said line at one station, a demodulating apparatus associated with said line at another station, means to transmit to said first mentioned station telephone currents and unmodulated low frequency currents of a different character, means whereby said modulating apparatus is controlled by said telephone and other signaling currents to supply carrier currents to said transmission line modulated in accordance with said telephone and other signaling currents, and means at said second mentioned station whereby in response to said carrier currents said demodulating apparatus supplies telephone and other low frequency signaling currents simulating the currents transmitted to said first mentioned station.

3. In a signaling system, a transmission line adapted to transmit high frequency currents, a plurality of transmission channels associated with one end of the line, modulating apparatus for each channel adapted to supply to said line a plurality of different carrier frequencies characteristic of the individual channels, means to transmit to each of said channels telephone currents and unmodulated low frequency signaling currents of a different character, and means whereby the modulating apparatus of each channel is controlled by said telephone and other signaling currents to supply carrier currents to said transmission line modulated in accordance with said telephone and other signaling currents.

4. In a signaling system, a transmission line adapted to transmit high frequency currents, a plurality of transmission channels associated with each end thereof, modulating apparatus for each channel at one end of said transmission line, said modulating apparatus being adapted to supply to said line carrier frequencies characteristic of each channel, demodulating apparatus for each channel at the other end of the line, means to transmit to each of said first mentioned channels telephone currents and unmodulated low frequency signaling currents of a different character, means whereby the modulating apparatus of each channel is controlled by said telephone and other signaling currents to supply carrier currents to said transmission line modulated in accordance with said telephone and other signaling currents, means whereby said carrier currents are selectively transmitted to the several channels at the other end of the line, and means whereby the demodulating apparatus of each channel in response to said carrier currents supplies telephone and other low frequency signaling currents simulating the currents transmitted to the corresponding channel at the originating end of the transmission line.

5. In a signaling system, a main transmission line adapted for the transmission of high frequency currents, a second transmission line adapted to transmit telephone currents and other low frequency signaling currents of a different character, means interconnecting said lines adapted to translate said telephone and signaling currents into high frequency currents, said means

including a modulating apparatus and a source of carrier current, and means to impress said carrier currents, telephone and other signaling currents upon said modulating apparatus, whereby carrier currents are supplied to said main transmission line modulated in accordance with said telephone and other signaling currents.

6. In a signaling system, a main transmission line adapted to transmit high frequency currents, a plurality of terminal transmission lines each adapted to transmit telephone currents and other low frequency signaling currents of a different character, channels interconnecting each terminal line with said main line and each including means adapted to translate said telephone and signaling currents into high frequency currents, said means comprising a modulating apparatus and a source of carrier current having a frequency characteristic of the channel to which it is assigned, and means to impress upon the modulating apparatus of each channel the carrier frequency characteristic of each channel together with the telephone and other signaling currents transmitted to the channel, whereby carrier currents from each channel are modulated in accordance with the telephone and other signaling currents of each channel and then supplied to said main transmission line.

7. In a signaling system, a main transmission line adapted for the transmission of high frequency currents, terminal transmission lines at each end of said main line, said terminal lines being adapted to transmit both telephone currents and other low frequency signaling currents of a different character, means interconnecting one of said terminal lines with said main line adapted to translate said telephone and signaling currents into high frequency currents for transmission over said main line, said means including a modulating apparatus and a source of carrier currents, means to impress said carrier current, telephone and other signaling current upon said modulating apparatus, whereby carrier currents are supplied to said main transmission line modulated in accordance with said telephone and other signaling currents, means interconnecting said main line with the other terminal line adapted to translate said modulated carrier currents into low frequency currents, said means including a demodulating apparatus so arranged that when modulated carrier currents are supplied thereto from said main transmission line telephone and other low frequency signaling currents will be transmitted to said other terminal line.

8. In a signaling system, a main transmission line adapted for the transmission of high frequency currents, a plurality of terminal transmission lines at each end of said main line, said terminal lines being adapted to transmit both telephone currents and other low frequency signaling currents of a different character, channels interconnecting the terminal lines at one end of the main line with said main line, modulating devices for each channel adapted to translate the low frequency telephone and signaling currents into high frequency currents for transmission over said main line, a source of carrier current for each modulator having a frequency characteristic of the channel to which it is assigned, means to impress upon the modulating device of each channel the carrier frequency assigned to each channel together with the talking and other signaling currents transmitted to each channel, whereby carrier currents from each channel are modulated in accordance with the telephone and other signaling currents of each channel and then supplied to said main line, channels interconnecting the terminal lines at the other end of the main line with said main line, demodulating devices for each channel adapted to translate said modulated carrier currents into low frequency currents, said demodulating devices being so arranged that when modulated carrier currents are supplied thereto from the said main transmission line telephone and other low frequency signaling currents will be transmitted to said terminal lines.

9. In a signaling system, a main transmission line adapted for high frequency transmission, a translating station associated with one end of said line, a terminal line leading to said translating station, means whereby telephone currents and other low frequency signaling currents may be transmitted over said terminal line, a modulator at said translating station, a source of carrier current therefor, means at said station to separate said telephone and other signaling currents and impress them upon the same modulator, whereby carrier currents modulated in accordance with said telephone and other signaling currents are supplied by said modulator, and means to transmit the currents thus supplied to said main transmission line.

10. In a signaling system, a main transmission line adapted for high frequency transmission, a translating station associated with one end of said line, a plurality of terminal lines leading to said translating station, means whereby telephone and other signaling currents may be transmitted over said terminal lines, a modulator for each terminal line at the translating station, a source of carrier current for each modulator having a frequency characteristic thereof, means at said translating station to separate the telephone and other signaling currents transmitted over the terminal lines

and to impress said currents upon the modulator corresponding to each line, whereby carrier currents modulated in accordance with said telephone and other signaling currents are supplied by said modulators, and means to transmit the currents thus supplied to said main transmission line.

11. In a signaling system, a main transmission line adapted for high frequency transmission, a translating station associated with one end of said line, a terminal line leading to said translating station, means whereby telephone currents and other low frequency signaling currents may be transmitted over said terminal line, a modulator at said translating station, a source of carrier current therefor, means at said station to separate said telephone and other signaling currents and impress them upon the same modulator whereby carrier currents modulated in accordance with said telephone and other signaling currents are supplied by said modulator, means to transmit the currents thus supplied to said main transmission line, a second translating station associated with the other end of said main transmission line, a second terminal line leading to said second station, a demodulator at said second station, means to impress the modulated carrier currents upon said demodulator whereby said demodulator supplies the telephone and other signaling currents in accordance with which the carrier currents were modulated, means to separate the telephone and other signaling currents thus supplied, and means to impress the separated currents upon said second terminal line.

12. In a signaling system, a main transmission line adapted for high frequency transmission, a translating station associated with one end of said line, a plurality of terminal lines leading to said translating station, means whereby telephone and other signaling currents may be transmitted over said terminal lines, a modulator for each terminal line at the translating station, a source of carrier currents for each modulator having a frequency characteristic thereof, means at said translating station to separate the telephone and other signaling currents transmitted over the terminal lines and to impress said currents upon the modulator corresponding to each line, whereby carrier currents modulated in accordance with said telephone and other signaling currents are supplied by said modulators, means to transmit the currents thus supplied to said main transmission line, a second translating station associated with the other end of said main line, a plurality of terminal lines leading to said second station, a demodulator corresponding to each terminal line at said second station, means to impress the modulated carrier currents upon said demodulators whereby said demodulators supply the telephone and other signaling currents in accordance with which the carrier currents were modulated, means to separate the telephone and other signaling currents supplied by each demodulator, and means to impress the separated currents upon the terminal lines leading to said second station.

13. In a signaling system, a main transmission line adapted for high frequency transmission, a translating station associated with one end of said line, a terminal line leading from said translating station, a demodulator at said station, means whereby carrier currents modulated in accordance with telephone and other low frequency signaling currents of a different character may be transmitted over said main line to said demodulator, said demodulator in response thereto supplying telephone and other signaling currents in accordance with which said carrier currents were modulated, means to separate said telephone currents from the other signaling currents, and means whereby both said telephone and other signaling currents may be transmitted over said terminal line.

14. In a signaling system, a main transmission line adapted for high frequency transmission, a translating station associated with one end of said line, a plurality of terminal lines leading from said translating station, a demodulator corresponding to each terminal line at said station, means whereby carrier currents modulated in accordance with telephone and other low frequency signaling currents of a different character may be transmitted over said main line to said demodulators, said demodulators in response thereto supplying the telephone and other signaling currents in accordance with which said carrier currents were modulated, means to separate the telephone currents from the other signaling currents, and means whereby both said telephone and other signaling currents may be transmitted over said terminal lines.

15. In a signaling system, a main transmission line adapted for the transmission of high frequency currents, a terminal transmission line adapted to transmit low frequency currents, means interconnecting said lines adapted to translate high frequency carrier currents into low frequency signaling currents, said means including a demodulator, and means to impress upon said demodulator carrier currents modulated in accordance with telephone and other low frequency signaling currents of a different character, whereby the telephone and other signaling currents in accordance with which the carrier currents were modulated are supplied by the demodulator and impressed upon said terminal line.

16. In a signaling system, a main transmission line adapted for the transmission of high frequency currents, a plurality of terminal transmission lines adapted to transmit low frequency currents, means interconnecting each of said terminal lines with said main line, said means being adapted to translate high frequency carrier currents into low frequent signaling currents and each of said means including a demodulator and means to impress upon each demodulator a carrier current modulated in accordance with talking currents and low frequency signaling currents of a different character, whereby each demodulator supplies to a corresponding terminal line the telephone and other signaling currents with which the carrier currents were modulated.

17. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously transmitting a telephone current and a low frequency signaling current of a different character over a transmission path to a modulating station, impressing both currents upon the same modulating apparatus together with a current of carrier frequency at said station, producing thereby a carrier current modulated in accordance with both the telephone current and the other signaling current, and transmitting the modulated current over a second transmission path.

18. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously transmitting both a telephone current and a low frequency signaling current of different character over each of a plurality of transmission paths to a modulating station, impressing both currents from each path upon the same modulating apparatus at said station together with a carrier current whose frequency is assigned to the corresponding path, producing thereby a plurality of carrier currents each modulated in accordance with telephone currents and other signaling currents and transmitting the modulated currents simultaneously over a common transmission path.

19. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously transmitting a telephone current and a low frequency signaling current of a different character over a transmission path to a modulating station, impressing both currents upon the same modulating apparatus together with a current of carrier frequency at said station, producing thereby a carrier current modulated in accordance with both the telephone current and the other signaling current, transmitting the modulated current over a second transmission path, and then detecting the telephone and other signaling currents in accordance with which the carrier current was modulated.

20. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously transmitting a telephone current and a low frequency signaling current of a different character over a transmission path to a modulating station, impressing both currents upon the same modulating apparatus together with a current of carrier frequency at said station, producing thereby a carrier current modulated in accordance with both the telephone current and the other signaling current, transmitting the modulated current over a second transmission path, then detecting the telephone and other signaling currents in accordance with which the carrier current was modulated and transmitting both detected currents to the same transmission line.

21. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously transmitting both a telephone current and a low frequency signaling current of different character over each of a plurality of transmission paths to a modulating station, impressing both currents from each path upon the same modulating apparatus at said station together with a carrier current whose frequency is assigned to the corresponding path, producing thereby a plurality of carrier currents each modulated in accordance with telephone currents and other signaling currents, transmitting the modulated currents simultaneously over a common transmission path, and then detecting from the several carrier currents the telephone and other signaling currents in accordance with which they were modulated.

22. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously transmitting both a telephone current and a low frequency signaling current of different character over each of a plurality of transmission paths to a modulating station, impressing both currents from each path upon the same modulating apparatus at said station together with a carrier current whose frequency is assigned to the corresponding path, producing thereby a plurality of carrier currents each modulated in accordance with telephone currents and other signaling currents, transmitting the modulated currents simultaneously over a common transmission path, then detecting from the several carrier currents the telephone and other signaling currents in accordance with which they were modulated, and transmitting each detected telephone current together with the corresponding

signaling current to a separate transmission path.

23. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously modulating a carrier frequency in accordance with telephone currents and auxiliary signaling currents, transmitting the modulated carrier currents to a distant point, detecting both the telephone and auxiliary signal currents and transmitting both detected currents over the same path to a distant point.

24. The method of superposing auxiliary signaling channels upon carrier current telephone channels which consists in simultaneously modulating each of a plurality of carrier frequencies in accordance with both telephone currents and auxiliary signal currents, transmitting the modulated frequencies to a distant point, detecting both the telephone and auxiliary signal currents from each carrier frequency, and transmitting to each of a plurality of transmission paths a detected telephone current and a corresponding detected auxiliary signaling current.

25. In a signaling system, a pair of intercommunicating stations, a signaling channel at one station, a corresponding signaling channel at the other station, a modulator in said first mentioned channel, a demodulator in said second mentioned channel, means to apply telephone currents to said modulator, whereby high frequency oscillations modulated in accordance with telephone currents may be supplied by said modulator for transmission to the distant station, a third station at a distant point, means to apply signaling currents of a character different from said telephone currents and received from said distant point to said modulator whereby high frequency oscillations modulated in accordance with said signaling currents may be supplied by said modulator for transmission to the distant station, and means to impress the oscillations modulated in accordance with said telephone and signaling currents upon the demodulator in the corresponding channel at the distant station, whereby said demodulator translates the modulated oscillations into the telephone and signaling currents in accordance with which said oscillations were modulated.

26. In a signaling system, a pair of intercommunicating stations, a plurality of signaling channels at one station, a plurality of corresponding signaling channels at the other station, a modulator in each of said first mentioned channels, a demodulator in each of said second mentioned channels, means to apply telephone currents to each of said modulators whereby high frequency oscillations modulated in accordance with said telephone currents may be supplied by said modulator for transmission to the distant station, means to apply signaling currents of a character different from said telephone currents and received from distant points to each of said modulators whereby high frequency oscillations modulated in accordance with said signaling currents may be supplied by said modulators for transmission to the distant station, and means to impress the several oscillations modulated in accordance with said telephone and signaling currents upon the several demodulators in the corresponding channels at the distant station, whereby said demodulators translate the modulated oscillations into the telephone and signaling currents in accordance with which the oscillations were modulated.

27. In a signal system, a pair of intercommunicating stations, a signaling channel at one station, a corresponding signaling channel at the other station, a modulator in said first mentioned channel, means to apply telephone currents to said modulator whereby high frequency oscillations modulated in accordance with said telephone currents may be supplied by said modulator for transmission to the corresponding channel at the distant station, a third station at a distant point, and means to apply signaling currents of a character different from said telephone currents and received from said distant point to said modulator, whereby high frequency oscillations modulated in accordance with said signaling currents may be supplied by said modulator for transmission to the corresponding channel at the distant station.

28. In a signaling system, a pair of intercommunicating stations, a plurality of signaling channels at one station, a plurality of corresponding signaling channels at the other station, a modulator in each of said first mentioned channels, means to apply telephone currents to each of said modulators whereby high frequency oscillations modulated in accordance with telephone currents may be supplied by said modulators for transmission to the corresponding channels at the distant station, and means to supply signaling currents of a character different from telephone currents and received from distant points to each of said modulators, whereby high frequency oscillations modulated in accordance with said signaling currents may be supplied by said modulators for transmission to the corresponding channels at said distant station.

29. In a signaling system, a pair of intercommunicating stations, a signaling channel at one station, a corresponding signaling channel at the other station, a demodulator in said second mentioned channel, and means whereby high frequency oscillations modu-

lated in accordance with telephone currents and other signaling currents differing in character from telephone currents may be transmitted from said first mentioned channel to the distant station and applied to said demodulator, said demodulator functioning to translate said high frequency oscillations into the telephone currents and other signaling currents in accordance with which said oscillations were modulated, a third station at a distant point, and means to transmit said demodulated signal currents to said distant point.

30. In a signaling system, a pair of intercommunicating stations, a plurality of signaling channels at one station, a plurality of corresponding signaling channels at the other station, a demodulator in each of said second mentioned channels, and means whereby high frequency oscillations modulated in accordance with telephone currents and other signaling currents of a character different from telephone currents may be transmitted from each of said first mentioned channels to the distant station and applied to each of said demodulators, said demodulators functioning to translate said high frequency oscillations into the telephone currents and other signaling currents in accordance with which said oscillations were modulated, and means to transmit said demodulated signal currents to distant points.

31. A translating circuit for a carrier telegraph channel comprising a detecting device for detecting signal currents from modulated carrier currents, and a polarized relay having its windings conductively connected in series to the terminals of said device, said relay being responsive to detected signal currents of opposite signs.

32. In a carrier telegraph system, a translating device, an output circuit directly connected thereto, and means arranged to produce telegraphic code impulses of current of opposite polarities in said circuit in response to carrier currents impressed on said translating device.

33. In a carrier telegraph system, a carrier wave transmission path, a telegraph impulse circuit co-operating with said path in the transmission of messages, and means conductively connected to said impulse circuit and responsive to received carrier waves for producing plus and minus telegraphic code current impulses in said impulse circuit.

34. In a carrier telegraph system, means to produce code impulses of current of opposite polarities, means to translate said impulses into alternating current, and means to retranslate said alternating current into code impulses of current of opposite polarities for receiving purposes.

35. In carrier wave telegraphy, means to produce a carrier wave of constant frequency and unvarying maximum amplitude, means to produce phase reversals in said wave to transmit signals, and a translating device arranged to produce, under the control of the transmitted wave, direct current impulses reversed in polarity in correspondence with the phase reversals of said wave.

36. In a carrier telegraph system, means to transmit a continuous carrier wave, the phase of which is reversed at intervals denoting signals, a direct current telegraph receiving circuit, and a device arranged to translate said signals into direct current impulses of opposite polarities in said receiving circuit.

37. In a carrier telegraph system, means to transmit a continuous carrier wave, the phase of which is reversed at intervals denoting signals, a direct current telegraph receiving circuit, and a device arranged to translate said signals into direct current impulses of opposite polarities in said receiving circuit, said device being conductively connected to said receiving circuit.

38. In a carrier telegraph system, means to generate a carrier wave of substantially constant frequency and amplitude, a direct current circuit carrying impulses of positive and negative current, means under control of a positive impulse to transmit from said source a wave of a certain phase, and means under control of a negative impulse to transmit from said source a wave of opposite phase.

39. In a carrier telegraph system, means to transmit a substantially unbroken carrier wave of constant maximum amplitude, and means to derive from said wave for receiving purposes telegraphic code impulses of opposite polarities and current.

In testimony whereof I have signed my name to this specification this 28th day of July, 1919.

LLOYD ESPENSCHIED.