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CARRIER COMMUNICATION SYSTEM

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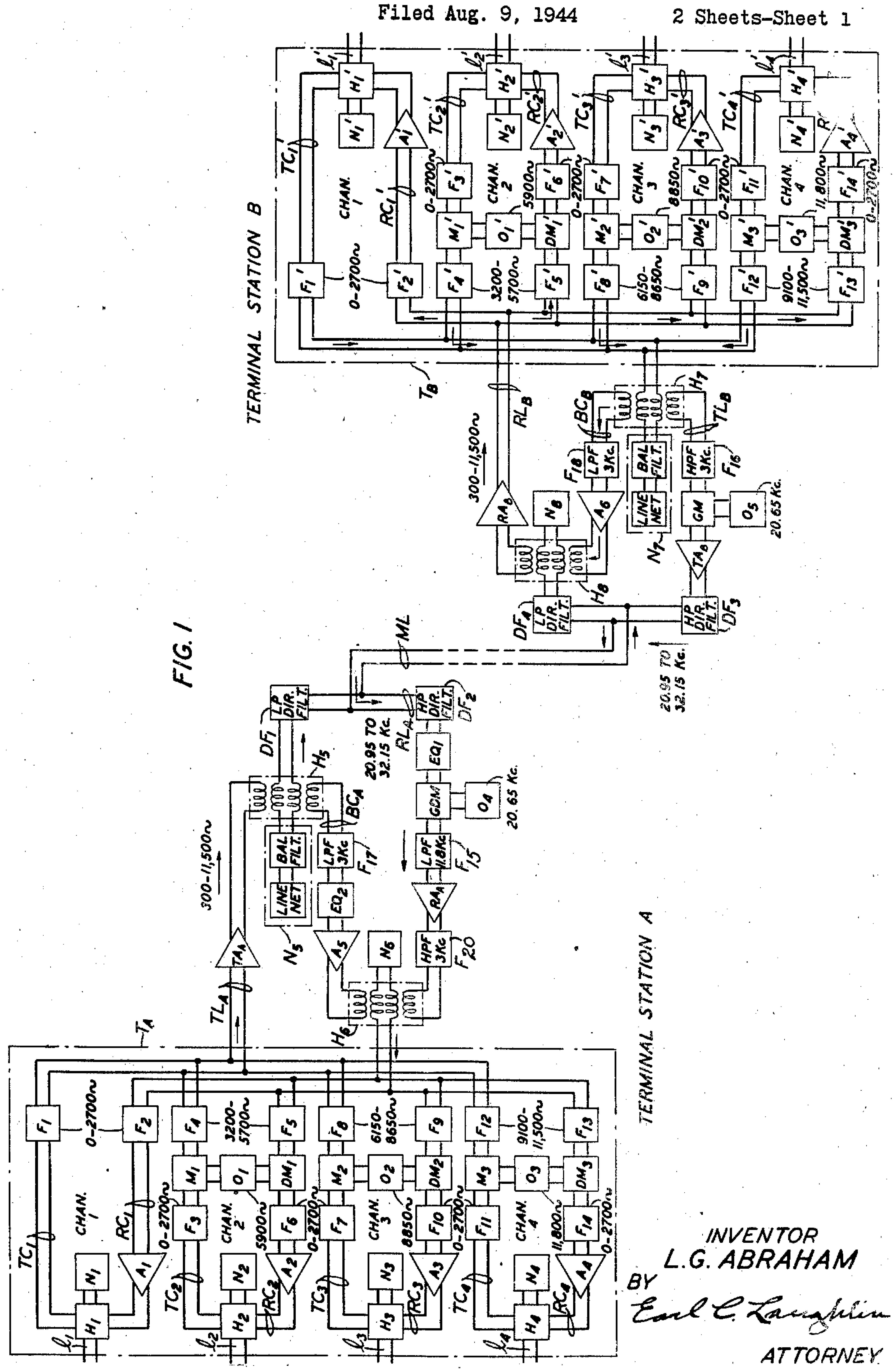

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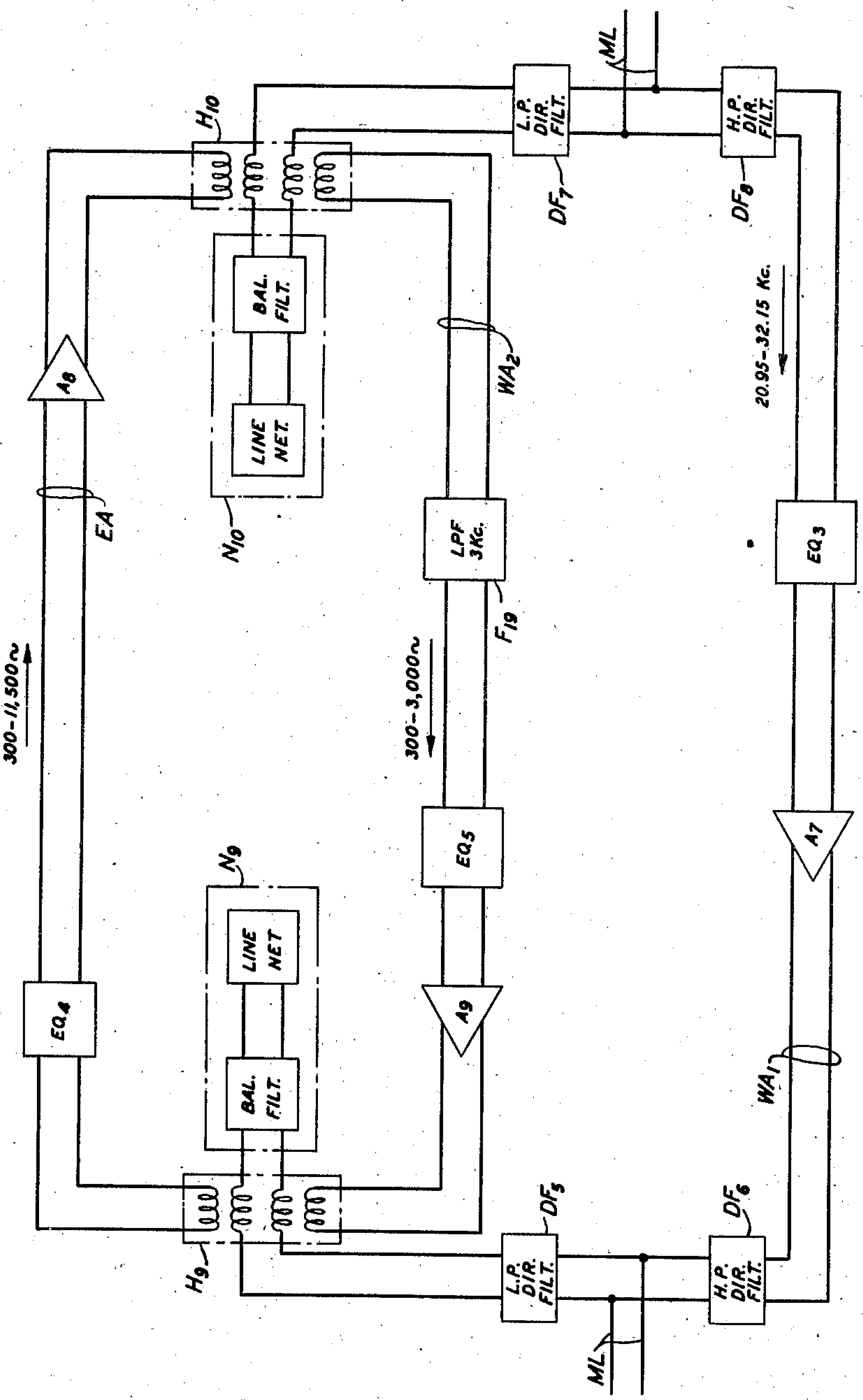

FIG. 2

REPEATER STATION C

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CARRIER COMMUNICATION SYSTEM

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The invention relates to communication systems and particularly to multiplex carrier communication systems.

The invention is specifically applicable to a two-way multiplex communication system in which one group of carrier communication channels occupying a given frequency range above the voice frequency range is transmitted in one direction and a second group of carrier communication channels occupying a higher frequency range is transmitted in the opposite direction, all of the channels being transmitted between the stations of the system over a common two-way, two-wire line.

An object of the invention is to adapt such a system for also transmitting a voice frequency channel in each direction over the system, which is on a voice frequency basis over the intermediate two-way line.

This object is attained efficiently and economically in accordance with the invention by simple arrangements employing a comparatively small amount of additional transmission apparatus for so coupling the low frequency portions of the transmitting and receiving circuits at the terminal stations or intermediate repeater points as to enable the outgoing voice channel at each terminal or repeater point to be transmitted to the two-wire line and the incoming voice channel at each terminal to be transmitted from the two-wire line to the signal reproducing circuit for that channel, over two-wire paths and without intermediate frequency changing operations.

The exact nature of the invention will be understood from the following detailed description when read in conjunction with the accompanying drawings Fig. 1 of which shows a block schematic of a multichannel, two-way carrier telephone system embodying the invention; and Fig. 2 of which shows a block schematic of an intermediate two-way repeater embodying the invention which may be used in the system of Fig. 1.

Referring to Fig. 1 of the drawings, the carrier system shown comprises a west terminal station, to be referred to hereinafter as terminal station A, and an east terminal station, to be referred to hereinafter as terminal station B, connected by an intermediate main two-wire line ML, which may be an open-wire line, operating in combination to provide four two-way telephone circuits, which may be designated as channels 1, 2, 3 and 4, between the stations. Each terminal station A and B includes an identical four-channel terminal shown within the dot-dash boxes labeled T_A and T_B, respectively, which are respectively associated with four two-wire telephone subscribers' lines at the respective stations.

As indicated, channel 1 of terminal T_A at terminal station A, which occupies the voice frequency band, includes a transmitting circuit

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branch TC_1 and a receiving circuit branch RC_1 which are coupled at the left by the hybrid coil H_1 and associated balancing network N_1 in conjugate relation with each other and in transmission relation with the two-wire line l_1 leading to one telephone subscriber's transmitting and receiving telephone equipment (not shown). The transmitting branch TC_1 includes the low-pass filter F_1 having a cut-off frequency of 2700 cycles, and the receiving branch RC_1 includes the low-pass filter F_2 having a cut-off frequency of 2700 cycles, and the receiving channel amplifier A.

Channels **2**, **3** and **4** of the four-channel terminal at station A are produced by shifting by modulation a voice frequency band to respectively higher frequency positions in the carrier frequency range below a given limiting frequency. Channel **2** comprises a transmitting circuit branch TC_2 and a receiving branch RC_2 coupled at the left by the hybrid coil H_2 and associated balancing network N_2 in conjugate relation with each other and in transmission relation with the two-wire line l_2 leading to the transmitting and receiving telephone equipment of a second telephone subscriber. The transmitting branch TC_2 includes a low-pass filter F_3 having a cut-off frequency of 2700 cycles, in its input, followed by a modulator M_1 and a 3200 to 5700 cycle band-pass filter F_4; and the receiving branch RC_2 includes the 3200 to 5700 cycle band-pass filter F_5 in its input followed by the demodulator DM_1, the low-pass filter F_6 having a cut-off frequency of 2700 cycles, and the receiving channel amplifier A_2. The modulator M_1 in the transmitting branch TC_1 and the demodulator DM_1 in the receiving branch TC_2 of channel No. **2** are supplied with a carrier frequency of 5900 cycles from the common oscillator O_1.

The carrier channel No. **3** comprises a transmitting circuit branch TC_3 and a receiving circuit branch RC_3 coupled by the hybrid coil H_3 and the associated balancing network N_3 in conjugate relation with each other and in transmission relation with the two-wire line l_3 leading to the telephone transmitting and receiving equipment of a third telephone subscriber. The transmitting branch TC_3 includes the low-pass filter F_7 having a cut-off frequency of 2700 cycles, in its input followed by the modulator M_2 and the 6150 to 8650 cycle band-pass filter F_8; and the receiving branch RC_3 includes the 6150 to 8650 cycle band-pass filter F_9 in its input followed by the demodulator DM_2, the low-pass filter F_{10} having a cut-off frequency of 2700 cycles, and the receiving channel amplifier A_3. The modulator M_2 in the transmitting branch TC_3 and the demodulator DM_2 in the receiving branch RC_3 of channel No. **3** are supplied with a carrier frequency of 8850 cycles from the common oscillator O_2.

Similarly, the transmitting circuit branch TC_4

and the receiving branch RC_4 of channel No. 4 are coupled at the left by the hybrid coil H_4 and associated balancing network N_4 in conjugate relation with each other and in transmission relation with the two-wire line l_4 leading to the telephone transmitting and receiving equipment of a fourth telephone subscriber at terminal station A. The transmitting branch TC_4 includes the low-pass filter F_{11} having a cut-off frequency of 2700 cycles, in its input followed by a modulator M_3 and the 9100 to 11,500 cycle band-pass filter F_{12}. The receiving branch RC_4 includes in its input the 9100 to 11,500 cycle band-pass filter F_{13} followed by the demodulator DM_3, the low-pass filter F_{14} having a cut-off frequency of 2700 cycles, and the receiving channel amplifier A_4. The modulator M_3 in the transmitting branch TC_4 and the demodulator DM_3 in the receiving branch RC_4 of channel No. 4 are supplied with a carrier frequency of 11,800 cycles from the common oscillator O_3.

The four-channel terminal T_B at terminal station B includes component circuit elements identical with those described above for the four-channel terminal T_A at terminal station A as indicated by use of the same identification characters for its corresponding circuit elements except that each is followed by a prime (′) mark, connected at the right to the four two-wire subscriber lines l' to l'_4 as shown.

As the frequencies on the open wire line ML of the carrier channels to be transmitted from terminal station A to terminal station B are different from those on the open wire line ML to be transmitted from terminal station B to terminal station A, the circuits provided for connecting terminal T_A to the west end of the two-wire line ML differ from those provided for connecting terminal T_B to the east end of the two-wire line ML, as follows.

The four transmitting branches TC_1 to TC_4 of the four-channel terminal T_A at terminal station A are connected at the right in parallel to the input of the common transmitting line TL_A for the four channels. The common transmitting line TL_A, which includes the group transmitting amplifier TA_A, has its output connected to the west end of line ML through a low-pass directional filter DF_1 having a pass frequency range which includes the frequencies of the voice channels, and of the three low frequency carrier channels to be transmitted in the west-to-east direction, and excludes the frequencies of the three higher frequency carrier channels to be transmitted in the east-to-west direction. The four receiving branches RC_1 to RC_4 of the four-channel terminal T_A are connected at the right in parallel to the output of the common receiving line RL_A the input of which is connected to the west end of the main line ML through the high-pass directional filter DF_2 the pass frequency range of which includes the frequencies of the three higher frequency carrier channels to be transmitted in the east-to-west direction, and excludes the frequencies of the three low frequency carrier channels to be transmitted in the west-to-east direction, and those of the voice frequency channels. The common receiving line RL_A includes between the high-pass directional filter DF_2 and the four-channel terminal T_A, reading from right to left, an equalizer EQ_1, the group demodulator GDM supplied with the group carrier frequency of 20.65 kilocycles from the associated oscillator O_4, the low-pass filter F_{15} having a cut-off at a frequency of 11.8 kilocycles and the receiving group amplifier RA_A.

The four transmitting branches $TC_{1'}$ to $TC_{4'}$ of terminal T_B at terminal station B are connected at the left in parallel to the input of the common transmitting line TL_B including the group modulator GM supplied with a carrier frequency of 20.65 kilocycles from the associated carrier oscillator O_5, followed by the group transmitting amplifier TA_B the output of which is connected through a high-pass directional filter DF_3 having the same frequency pass range as the high-pass directional filter DF_2 at the west terminal station A, to the east end of the main line ML. The four receiving branches $RC_{1'}$ to $RC_{4'}$ of terminal T_B are connected in parallel at the left to the output of the common receiving line RL_B which includes the group receiving amplifier RA_B, and the input of the common receiving line RL_B is connected to the east end of the main line ML through the low-pass directional filter DF_4 having the same frequency pass range as the low-pass directional filter DF_1 at terminal station A.

In addition to the circuits which have been referred to above, in accordance with the invention, terminal station A includes a voice frequency by-pass circuit BC_A having its input coupled to the output of the common transmitting line TL_A by the hybrid coil H_5 and associated line and balancing filter network N_5, in conjugate relation with the output of the group transmitting amplifier TA_A and in transmission relation with the west end of line ML through the low-pass directional filter DF_1; and its output coupled by hybrid coil H_6 and associated line balancing network N_6, in conjugate relation with the output of the group receiving amplifier RA_A and in transmission relation with the four parallel-connected receiving branches RC_1 to RC_4 of the four-channel terminal T_A. The by-pass circuit BC_A includes in its input the low-pass filter F_{17} cutting off at a frequency of 3 kilocycles, followed by an equalizer EQ_2 and a one-way amplifier A_5. Also, a high-pass filter F_{20} cutting off at a frequency of 3 kilocycles, is inserted in the common receiving line RL_A between the output of receiving amplifier RA_A and hybrid coil H_6.

Also, in accordance with the invention, terminal station B includes in addition to the circuits referred to above, the voice frequency by-pass circuit BC_B having its input coupled by hybrid coil H_7 and associated line and balancing filter network N_7, to the input of the common transmitting line TL_B in conjugate relation with the input to group modulator GM in that line, and in transmission relation with the four parallel-connected transmitting branches TC'_1 to TC'_4 of the four-channel terminal T_B; and its output coupled by hybrid coil H_8 and associated line balancing network N_8 to the input of the common receiving line RL_B in conjugate relation with the input of the group receiving amplifier RA_B and in transmission relation with the main line ML through the low-pass directional filter DF_3. The by-pass BC_B circuit includes the low-pass filter F_{18} cutting off at the frequency 3 kilocycles, in its input, followed by the one-way amplifier A_6. Also, a high-pass filter F_{16} cutting off at a frequency of 3 kilocycles is inserted in the common transmitting line TL_B between hybrid coil H_7 and the input of group modulator GM.

The channel and group modulators and demodulators used in the circuits described above are preferably of the balanced carrier suppression type, and the oscillators, filters and the other transmission apparatus used may be of any suitable type.

The system of Fig. 1 operates as follows for transmission from the terminal A to terminal B. The voice frequency signals received over the subscriber's line l_1 at the terminal station A pass through the hybrid coil H_1 to the low-pass filter F_1 in the transmitting branch TC_1 of channel No. 1 which restricts the frequency band to about 2700 cycles and prevents the higher speech frequencies from causing interference in the other three channels. The restricted frequency band in the output of the low-pass filter F_1 passes into the input of the common transmitting line TL_A for all four channels. The voice frequency signals from the telephone subscribers associated with the two-wire lines l_2, l_3 and l_4, similarly pass through the hybrid coils H_2, H_3 and H_4, respectively, to the low-pass filters F_3, F_7 and F_{11} in the transmitting circuits TC_2 to TC_4 of the respective channels 2 to 4, which restrict them to frequencies below 2700 cycles. The restricted voice band in the output of filter F_3 in the transmitting branch TC_2 of channel 2 is combined in the modulator M_1 with the carrier frequency of 5900 cycles supplied from oscillator O_1, and the lower sideband 3200 to 5700 cycles of the resulting modulation products is selected by the band-pass filter F_4 in the modulator output. The restricted voice frequency band in the output of the low-pass filter F_7 in the transmitting branch TC_3 of channel 3 is combined in the modulator M_2 with a carrier frequency of 8850 cycles from oscillator O_2, and the lower sideband, 6150 to 8650 cycles, is selected by the band-pass filter F_8 from the resulting modulation products and is passed to the common transmitting line TL_A of the terminal. The restricted voice frequency band in the output of the low-pass filter F_{11} in the transmitting branch TC_4 is combined in the modulator M_3 with the carrier frequency of 11,800 cycles supplied from oscillator O_3, and the lower sideband, 9100 to 11,500 cycles, is selected by the band-pass filter F_{12} from the resulting modulation products and is passed to the common transmitting line TL_A of the terminal. The low-pass filter in conjunction with the band-pass filter in each transmitting channel prevents the frequencies of one channel from overlapping those of another channel.

The voice frequency band and the three carrier frequency bands occupying a frequency range between 300 and 11,500 cycles thus superposed in the common transmitting line TL_A are amplified by the group transmitting amplifier TA_A, and the amplified waves are passed out through the hybrid coil H_5 and the low-pass directional filter DF_1 to the main line ML in normal manner, and pass out over that line ML to the terminal station B.

At station B, the frequency band 300–11,500 cycles including the eastwardly directed voice channel and three low frequency carrier channels incoming over the line ML, is selected by the low-pass directional filter DF_4, and passes to the common receiving line RL_B of the station in which it will be amplified by the receiving amplifier RA_B and pass to the parallel-connected receiving branches of the four-channel terminal T_B.

The low-pass filter $F_{2'}$ in the receiving branch $RC_{1'}$ of channel 1 will select the frequencies 300 to 2700 cycles of channel 1, and reject the frequencies of the other three channels, and the amplifier $A_{1'}$ will amplify the selected voice frequencies to the proper level before they are impressed by hybrid coil $H_{1'}$ on the two-wire line $l_{1'}$ over which they will be transmitted to the telephone receiving equipment of the east subscriber associated with channel 1. The band-pass filter $5_{5'}$ in the receiving branch $RC_{2'}$ of channel 2 will select the frequencies 3200 to 5700 cycles of channel 2 and will reject the frequencies of the other three channels. The selected frequency band, 3200 to 5700 cycles, will be combined in the demodulator $DM_{1'}$ with the carrier frequency of 5900 cycles supplied from oscillator $O_{1'}$. The low-pass filter $F_{6'}$ in the output of the demodulator $DM_{1'}$ will select the lower sideband, which is the original voice frequency band 300 to 2700 cycles supplied to the transmitting branch of channel 2 at station A, from the resulting demodulation products, and will suppress the unwanted sideband demodulation products. The voice frequency signal band selected by filter $F_{6'}$ will be amplified by the channel receiver amplifier $A_{2'}$, and the amplified band will be impressed by hybrid $H_{2'}$ on the two-wire line $l_{2'}$ over which it will be transmitted to the telephone receiving equipment of the east subscriber associated with channel 2.

Similarly, the band-pass filter F_9' in the input of the receiving branch RC_3' will select from the impressed waves the frequency band, 6150 to 8650 cycles, of channel 3 and will suppress the frequencies of the other channels. The selected band will be combined in the demodulator DM_2' with the carrier frequency of 8850 cycles supplied by the oscillator O_2'. The low-pass filter F_{10}' in the output of the demodulator DM_2 will select the lower sideband from the demodulation products, which will be the original voice frequency band supplied to the transmitting branch of channel 3 at terminal station A. The selected voice frequency band will be amplified by the channel receiving amplifier A_3', and the amplified frequency band impressed by hybrid coil H_3' on the two-wire line l_3' leading to the telephone receiving equipment of the east subscriber associated with channel 3. The band filter F_{13}' in the receiving branch RC_4' of the four-channel terminal CT_B will select the frequency band, 9100 to 11500 cycles, of channel 4 from the impressed waves, and will reject the frequencies of the other three channels. The selected band, 9100 to 11500 cycles, will be combined in the modulator DM_3' with the carrier frequency of 11800 cycles from the oscillator O_3'. The low-pass filter F_{14}' in the output of that demodulator will select from the demodulation products the lower sideband, which will be the original voice frequency band supplied to the transmitting branch of channel 4 at terminal station A. The selected voice frequency band will be amplified in the amplifier A_4' and will be impressed by the hybrid coil H_4' on the two-wire line l_4' over which it will be transmitted to the telephone receiving equipment of the east subscriber associated with channel 4.

The operation of the system of Fig. 1 for signal transmission in the opposite direction from terminal B to terminal A is as follows:

The voice frequency signals received over the two-wire lines l_1', l_2', l_3' and l_4' from the telephone transmitting equipment of the four associated telephone subscribers are impressed by the hybrid coils H_1' to H_4', respectively, on the transmitting branches TC_1 to TC_4, respectively, of channels 1 to 4.

The speech frequencies impressed on transmitting channel TC_1' will pass to the low-pass filter

F_1' which will restrict the frequency band to frequencies below about 2700 cycles, and prevent the higher speech frequencies from causing interference in the other channels. The restricted frequency band in the output of the low-pass filter F_1' will pass into the common transmitting line TL_B.

The voice frequency signal band impressed on the transmitting channel TC_2' of the terminal T_B will be restricted by the low-pass filter F_3' to the frequency range below 2700 cycles, and the restricted frequency band will be combined in the modulator M_1' with the carrier frequency of 5900 cycles supplied by oscillator O_1' to produce modulation products of which the lower sideband, 3200 to 5700 cycles, will be selected by the band-pass filter F_4'. The selected band will be transmitted to the common transmitting line TL_B of terminal station B. Similarly, the voice frequency signals received by the transmitting circuits TC_3' and TC_4' of the four-channel terminal T_B from the east subscribers associated with the two-wire lines l_3' and l_4', respectively, will be restricted to frequencies below 2700 cycles by the low-pass filters F_7' and F_{11}' in the respective branches TC_3' and TC_4' and will be combined with the carrier frequencies of 8850 cycles and 11,800 cycles, respectively, in the modulators M_3' and M_4' of channels 3 and 4, respectively, to produce modulation products. The lower sidebands 6150 to 8650 cycles and 9100 to 11,500 cycles of the modulation products in the outputs of modulators M_3' and M_4', respectively, will be selected by the band-pass filters F_8' and F_{12}', respectively, and will be transmitted to the common transmitting line TL_B for all four channels.

One energy portion of the input band of frequencies ranging from 300 to 11,500 cycles passing through hybrid coil H_7 will be diverted to the outgoing portion of the common transmitting TL_B, in which it will be restricted to frequencies above 3 kilocycles by high-pass filter F_{16}. The restricted frequency band comprising the three low frequency carrier channels from terminal T_B, will be combined in the group modulator GM with the carrier frequency of 20.65 kilocycles from the associated carrier oscillator O_5 to translate them to the higher carrier frequency range for the east-to-west direction of transmission. The products of modulation will be amplified by the transmitting amplifier TA_B and supplied to the high-pass directional filter DF_3 which will pass the upper side-band comprising frequencies in the range 20.95 to 32.15 kilocycles to the line ML, and suppress the lower frequencies.

The other energy portion of the input frequency band of 300 to 11,500 kilocycles passing through hybrid coil H_7 will be diverted into the by-pass circuit BC_B. The 3-kilocycle low-pass filter F_{18} in that circuit will select the voice channel and suppress the three low frequency carrier channels. The selected voice frequency channel will be amplified by the amplifier A_6 in by-pass circuit BC_B, and the amplified voice frequencies will pass through the hybrid coil H_8 in the common receiving line RL_B of the terminal to the low-pass directional filter DF_4 which will transmit it to the line ML over which it will be transmitted, along with the carrier frequency band 20.95 to 32.15 kilocycles received through the high-pass directional filter DF_3, to the west terminal station A.

At terminal station A, the three carrier frequency channels in the frequecy range 20.95 to 32.15 kilocycles incoming over the line ML will

be selected by the high pass directional filter DF_2 and will pass through the high frequency equalizer EQ_1 to the group demodulator GDM in the common receiving line RL_A, in which they will be combined as a group with the carrier frequency of 20.65 kilocycles from the associated oscillator O_4 to produce modulation products of which the lower side-band within the frequency range 0 to 11.8 kilocycles is selected by the low-pass filter F_{15}. The selected frequency band comprising the three incoming carrier channels reduced to the frequency range which they had at the output of the four-channel terminal T_B at terminal station B, will be amplified by the receiving amplifier RA_A and passed to the high-pass filter F_{20} cutting off at 3 kilocycles, which will operate to suppress the voice frequencies and transmit the carrier frequencies to the receiving circuits of the four-channel terminal T_A at terminal A.

The voice frequency channel received at terminal station A over the line ML along with the three high frequency carrier channels, will be selected by the low-pass directional filter DF_1 at that station and will pass through the hybrid coil H_5 into the by-pass circuit BC_A in which it will be selected by the low-pass filter F_{17} cutting off at 3 kilocycles. The selected voice channel will pass through equalizer EQ_2 (which is a voice frequency equalizer to take care of the frequency characteristics of the preceding line, and then through the amplifier A_5 which for this purpose should be a low power output amplifier of moderate gain. The amplified voice frequency signals in the output of amplifier A_5 will pass through hybrid coil H_6 to the output portion of the common receiving line RL_A and will be passed over that circuit along with the frequencies of the three incoming carrier channels reduced to the same frequencies as the outgoing carrier channels received through that hybrid coil from the high-pass filter F_{20}, to the parallel-connected channel receiving branches of the four-channel terminal T_A.

The high-pass filter F_{20} cutting off at 3 kilocycles in the common receiving line RL_A in front of hybrid coil H_6, is provided so that if the same speech currents were impressed from the distant end upon the 20.65 to 32.45-kilocycle line frequencies, there would be no interference between the two transmission paths carrying the same speech. In some cases this blocking high-pass filter F_{20} might be omitted at a terminal and improved transmission for the over-all circuit obtained. For example, with 6 decibels loss over-all for the circuit by carrier means, allowing one direction of two-wire voice frequency transmission from an intermediate point to a terminal to be down 10 decibels by reducing the gain of the amplifier A_5 in the by-pass circuit BC_A by 10 decibels, would make transmission from one terminal to the other via the voice path substantially negligible for most purposes. The same expedient at an intermediate repeater point would make the loss greater from an intermediate point to a terminal or to another intermediate point into the terminal beyond the repeater, but would allow normal low loss from terminal to terminal without interference.

The incoming voice frequency channel impressed on the four-channel terminal T_A will be selected by the low pass filter F_2 in the receiving branch RC_1 of channel 1 and, after amplification by the amplifier A_1 therein, will be impressed by the hybrid coil H_1 on the two-wire line l_1 over which it will be transmitted to the telephone receiving equipment of the west subscriber associated with channel 1. The three carrier channels of frequencies 3200 to 5700 cycles, 6150 to 8650 cycles and 9100 to 11500 cycles, respectively, impressed from the output of the common receiving line RL_A on the receiving circuits RC_2 to RC_4 of channels 2, 3 and 4 of the four-channel terminal CT_A in a manner similar to that previously described for the similar four-terminal T_B at terminal station B for transmission in the opposite direction will be separated from each other and demodulated to voice frequencies for transmission over the associated two-wire lines l_2, l_3 and l_4 to the telephone receiving equipment of the respective subscribers associated with each channel.

Fig. 2 shows the circuit of a two-way repeater which may be inserted in the two-way line ML at a station C intermediate the terminal stations A and B of the system of Fig. 1, to provide a desired amount of amplification of the three carrier communication channels and one voice and communication channel transmitted in each direction over the system.

The two-way repeater at station C includes a low-pass directional filter DF_5 and a high-pass directional filter DF_6 connected in parallel to the west section of line ML leading to station A, and another low-pass directional filter DF_7 and another high-pass directional filter DF_8 connected in parallel to the east section of line ML leading to station B. The low-pass filters DF_5 and DF_7 have the same frequency pass range, 300 to 11,500 cycles, as the low-pass directional filters, DF_1 and DF_4 at terminal stations A and B, respectively, which includes the frequencies of the voice channels transmitted in both directions and of the three lower frequency carrier channels transmitted in the west-to-east direction and excludes the frequencies of the three higher frequency carrier communication channels transmitted in the east-to-west direction over the system. The high-pass filters DF_6 and DF_8 have the same frequency pass range, 20.95 to 32.15 kilocycles, as the high-pass directional filters DF_2 and DF_3 at terminal stations A and B, respectively, which includes the frequencies of the three higher frequency carrier channels transmitted in the east-to-west direction over the system and excludes the frequencies of the voice channels transmitted in both directions and of the three lower frequency carrier channels transmitted in the west-to-east direction over the system.

The high-pass filters DF_8 and DF_6 are connected to each other through the one-way repeating path WA_1 including the high frequency equalizer EQ_3 and the one-way amplifier A_7 pointed in the east-to-west direction. The path WA_1, therefore, serves to repeat in amplified form the three east-to-west carrier communication channels in the frequency range 20.95 to 32.15 kilocycles from the east to the west section of the two-way line ML.

The west section of the two-way line ML is connected through low-pass directional filter DF_5 and hybrid coil H_9 to the input of the one-way repeating path EA including the low frequency equalizer EQ_4 and the one-way amplifier A_8 pointed in the west-to-east direction, and to the output of the one-way repeating path WA_2 including the low-pass filter F_{19} cutting off at a frequency of 3 kilocycles in its input and the following low frequency equalizer EQ_5 and one-way amplifier A_9 pointed in the east-to-west direction. The output of the repeating path EA and the input of the repeating path WA_2 are connected through the hybrid coil H_{10} and the low-pass directional filter DF_7 to the east section of the two-way line ML. The hybrid coil H_9 and its associated line and balancing filter network N_9 serve to couple the input of the repeating path EA and the output of the repeating path WA_2 in conjugate relation with each other and in transmission relation with the west section of line ML through filter DF_5. Similarly the hybrid coil H_{10} and its associated line and balancing filter network N_{10} serve to couple the output of repeating path EA and the input of the repeating path WA_2 in conjugate relation with each other and in transmission relation with the east section of line ML through filter DF_7.

Thus, the voice channel and the three lower frequency carrier channels in the west-to-east direction occupying the frequency range 300 to 11,500 cycles received at the repeater station C over the west section of line ML will pass through the low-pass directional filter DF_5 and hybrid coil H_9 to repeating path EA in which they will be equalized by the common equalizer EQ_4 and amplified to the desired level in common amplifier A_8. The amplifier voice channel and lower frequency carrier channels in the output of amplier A_8 will pass through the hybrid coil H_{10} and low-pass directional filter DF_7 to the east section of the two-way line ML over which they will be transmitted to terminal station B.

The voice channel in the east-to-west direction received at the repeater station C over the east section of line ML from terminal station B, will pass through the low-pass directional filter DF_7 and hybrid coil H_{10} to the repeating path WA_2 in which it will be selected by the 3-kilocycle low-pass filter F_{19}, equalized by low frequency equalizer EQ_5 and amplified to the desired level by amplifier A_9. The amplified voice channel in the output of amplifier A_9 will pass through hybrid coil H_9 and low-pass directional filter DF_5 to the west section of line ML over which it will be transmitted to the west terminal station A along with the amplified carrier channels in the frequency range 20.95 to 32.15 kilocycles received through high-pass directional filter DF_6.

Thus, it will be seen that the effect of the added by-pass circuits and filters at terminal stations A and B and repeater station C in the multi-channel carrier system of Figs. 1 and 2 is to adapt the system for transmitting voice channels in both directions on a two-wire basis between the subscribers' lines at the terminal stations and from there to any intermediate point on the two-wire line. When filters F_{17} and F_{18} are omitted, over-all transmission is on a carrier basis but transmission to intermediate points is on a voice frequency basis in both directions.

Various modifications of the circuits illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. In a multiplex communication system, two terminal stations, a two-way, two-wire line connecting said stations, means at one station for providing a plurality of low frequency carrier communication channels for transmission to the other station, means at said other station for providing a plurality of higher frequency carrier communication channels for transmission to said one station, a low-pass directional filtering means

and a high-pass directional filter means at said one station for respectively supplying the outgoing low frequency carrier channels to said line and receiving the incoming higher frequency carrier channels from said line, another low-pass directional filtering means and another high-pass directional filtering means at said other station for respectively selecting the incoming low frequency carrier channels from said line and supplying the outgoing higher frequency carrier channels to said line, means at each station for separately supplying an outgoing voice frequency communication channel through the low-pass filtering means thereat to said line for transmission thereover, and means at each station connected to the drop side of the low-pass directional filtering means at that station, for selectively receiving the voice frequency channel incoming over said line.

2. In a multiplex communication station, terminal stations, a two-way, two-wire line connecting said stations, means at one station for providing a voice frequency communication channel and a plurality of low frequency carrier communication channels for transmission to the other station, means at said other station for providing another voice communication frequency channel and a plurality of higher frequency carrier communication channels for transmission to said one station, a low-pass directional filtering means and a high-pass directional filtering means respectively having a pass frequency range including the frequencies of the voice channels and said low frequency carrier channels, and of the higher frequency carrier channels, connected to the two-wire line at each terminal station, a common transmitting circuit including the low-pass directional filtering means at said one station for transmitting the first voice channel and said low frequency carrier channels to said line, a common transmitting circuit including the high-pass directional filtering means at said other station for transmitting said higher frequency carrier channels to said line, a common receiving circuit including the high-pass directional filtering means at said one station for selectively receiving the incoming higher frequency carrier channels from said line, a common receiving circuit including the low-pass directional filtering means at said other station for selectively receiving the voice frequency channel and plurality of low frequency carrier channels incoming over said line, means at said other station for impressing the outgoing voice channel on said line through the low-pass directional filtering means in the common receiving circuit of that station, and means at said one station for selectively receiving the voice channel incoming over said line through the low-pass directional filtering means in the common transmitting circuit of that station.

3. In a multiplex communication system, terminal stations, a two-way, two-wire line connecting said stations, means at one station for providing a voice frequency communication channel and a plurality of low frequency carrier channels for transmission to the other station, means at said other station for providing another voice frequency communication channel and a plurality of higher frequency communication channels for transmission to said one station, means at said other station for impressing the outgoing voice channel and said plurality of higher frequency carrier channels on said two-wire line for transmission thereover, and for separately receiving the incoming voice channel and low frequency carrier channels from said line, a low-pass directional filtering means and a high-pass directional filtering means having pass frequency ranges respectively including those of said voice channels and low frequency carrier channels, and those of said higher frequency carrier channels, connected to said two-wire line at said one station, means for impressing the outgoing voice frequency channel and low frequency carrier channels through said low-pass filtering means on said two-wire line at said one station, and means for selectively receiving the voice channel and higher frequency carrier channels incoming over said line at said one station from the drop sides of the low-pass filtering means and the high-pass filtering means, respectively, at that station.

4. In a multiplex communication system, terminal stations, a two-way, two-wire line connecting said stations, means at one station for impressing a voice frequency communication channel and a plurality of high frequency carrier communication channels on said two-wire line for transmission thereover to the other station, a common transmitting circuit at said other station, including a low-pass directional filtering means of suitable pass frequency range in its output for impressing another voice channel and a plurality of low frequency carrier channels on said two-wire line for transmission thereover to said one station, a common receiving circuit at said other station, including a high-pass directional filtering means of suitable pass frequency range in its input for selectively receiving the higher frequency carrier channels incoming over said line and means for demodulating the selected higher frequency carrier channels to desired lower frequencies, means connected to the drop side of said low-pass directional filtering means at said other station for selectively receiving the voice channel incoming over said two-wire line from said one station, and separate receiving means at said other station for the selected incoming voice channel and demodulated higher frequency carrier channels.

5. In a multiplex communication system employing a group of low frequency channels including a voice frequency channel and a plurality of low frequency carrier channels for signal transmission in one direction and a second group of channels including a voice frequency channel and a plurality of higher frequency carrier channels for signal transmission in the opposite direction, a two-wire line for transmitting all of the channels between terminals of said system, means at one terminal for generating the voice frequency channel and the low frequency carrier channels for said one direction, a transmitting circuit at said one terminal including a low-pass directional filter for transmitting the generated group of low frequency channels to said line, a receiving circuit at said one terminal, including a high-pass directional filter in its input for selecting the group of higher frequency carrier channels incoming over said line and means for demodulating the selected channels as a group to desired lower frequencies, a circuit at said one terminal for selectively receiving the voice channel incoming over said line, having its input connected to the drop side of said low-pass directional filter in said transmitting circuit, and its output connected to said receiving circuit in the output of said demodulating means, and means connected to the output of said receiving circuit for separating and detecting the communication signals from

the incoming voice channel and demodulated carrier channels therein.

6. The system of claim 5, in which the input of said circuit at said one terminal for selectively receiving the voice channel incoming over said line is coupled to said transmitting circuit in conjugate relation with the input thereof and in transmission relation with said line through said low-pass directional filter, and the output of the incoming voice channel selecting circuit is connected to said receiving circuit in conjugate relation with the output of said demodulating means and in transmission relation with said channel separating and signal detecting means.

7. The system of claim 5 in which a hybrid coil and associated line balancing network connects the incoming voice channel selecting circuit at said one terminal in conjugate relation with the input of said transmitting circuit and in transmission relation with said line through said low-pass directional filter, another hybrid coil and associated line balancing network connects the output of said incoming voice channel selecting circuit to said receiving circuit in conjugate relation with the output of said demodulating means therein and in transmission relation with said channel separating and signal detecting means, and filtering means adapted to suppress voice frequencies and to transmit higher frequencies is inserted in said receiving circuit between said demodulating means and the latter hybrid coil.

8. In a multiplex communication system, terminal stations, a two-way, two-wire line connecting said stations, a source of low frequency carrier communication channels and a voice frequency communication channel at each station, low-pass filtering and high-pass filtering means connected to said line at each station, a common channel transmitting circuit and a common channel receiving circuit at each station, the common transmitting circuit at one station being supplied with the low frequency carrier channels and the voice channel generated by said source thereat and including the low-pass filtering means at the station, the common transmitting circuit at the other station being supplied with the low frequency carrier channels and voice channel generated by said source thereat, and including modulating means for stepping up the supplied low frequency carrier channels to desired higher frequencies for transmission over said line to said one station, and the high-pass filtering means at the station, said low-pass and high-pass filtering means at the stations being respectively adapted for selectively transmitting the frequencies of the voice and low frequency carrier channels, and the frequencies of the stepped-up higher frequency carrier channels, the common channel receiving circuit at said other station including the low-pass filtering means thereat for selectively receiving the voice channel and low frequency carrier channels received over said line, the common channel receiving circuit of said one station including the high-pass filtering means thereat for selectively receiving the higher frequency carrier channels incoming over said line and demodulating means for translating the frequencies of the selected higher frequency carrier channels to their original low frequencies, a circuit at said other station selective to the frequencies of the outgoing voice frequency channel, having its input coupled to the common transmitting circuit at that station in front of the modulating means therein so as to be supplied with that channel from said source at the station, and having its output coupled to the input of the common receiving circuit at the station on the drop side of the low-pass filtering means therein, another circuit selective to the frequencies of the incoming voice channel having its input coupled to the output of the common transmitting circuit at said one station on the drop side of the low-pass filtering means therein, and its output connected to the common receiving circuit of that station beyond the demodulating means therein, and means connected to the output of the common receiving circuit at each station to separate the received voice and carrier channels therein and to detect the communication signals therefrom.

9. The system of claim 8 in which the circuit selective to the frequencies of the voice frequency channel at each station is connected to the common channel transmitting and receiving circuits at each terminal by hybrid coils and associated line balancing networks.

10. In a multiplex communication system, terminal stations, a two-way, two-wire line connecting said stations, means to supply to said line at one terminal station one voice frequency communication channel and a plurality of low frequency carrier communication channels above the voice frequency range, for transmission in one direction to the other terminal station, means to supply to said line at the other terminal station another voice frequency communication channel and a plurality of higher frequency carrier communication channels, for transmission in the opposite direction to said one station, and a two-way repeater connecting sections of said two-way line at a point intermediate said terminal stations, said repeater including low-pass filtering means and high-pass filtering means for respectively selectively transmitting the frequencies of the voice channels and said low frequency carrier channels and of said higher frequency carrier channels, connected to each of said two-way line sections, a one-way amplifying path including the high-pass filtering means connected to both of said line sections, for selectively repeating said higher frequency carrier channels in said opposite direction between said line sections, a second one-way amplifying path including the low-pass filtering means connected to both said line sections for selectively repeating one voice channel and said plurality of low frequency carrier channels in said one direction between said line sections and a third one-way amplifying path selective to voice frequencies, connected between the dropsides of the low-pass filtering means connected to the two-line sections, and in conjugate relation with said second amplifying path, for selectively repeating the voice channel in said opposite direction between said line sections.

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