Oct. 1, 1946. R. O. WISE 2,408,462

TELEPHONE SYSTEM

Filed June 8, 1943 3 Sheets-Sheet 1

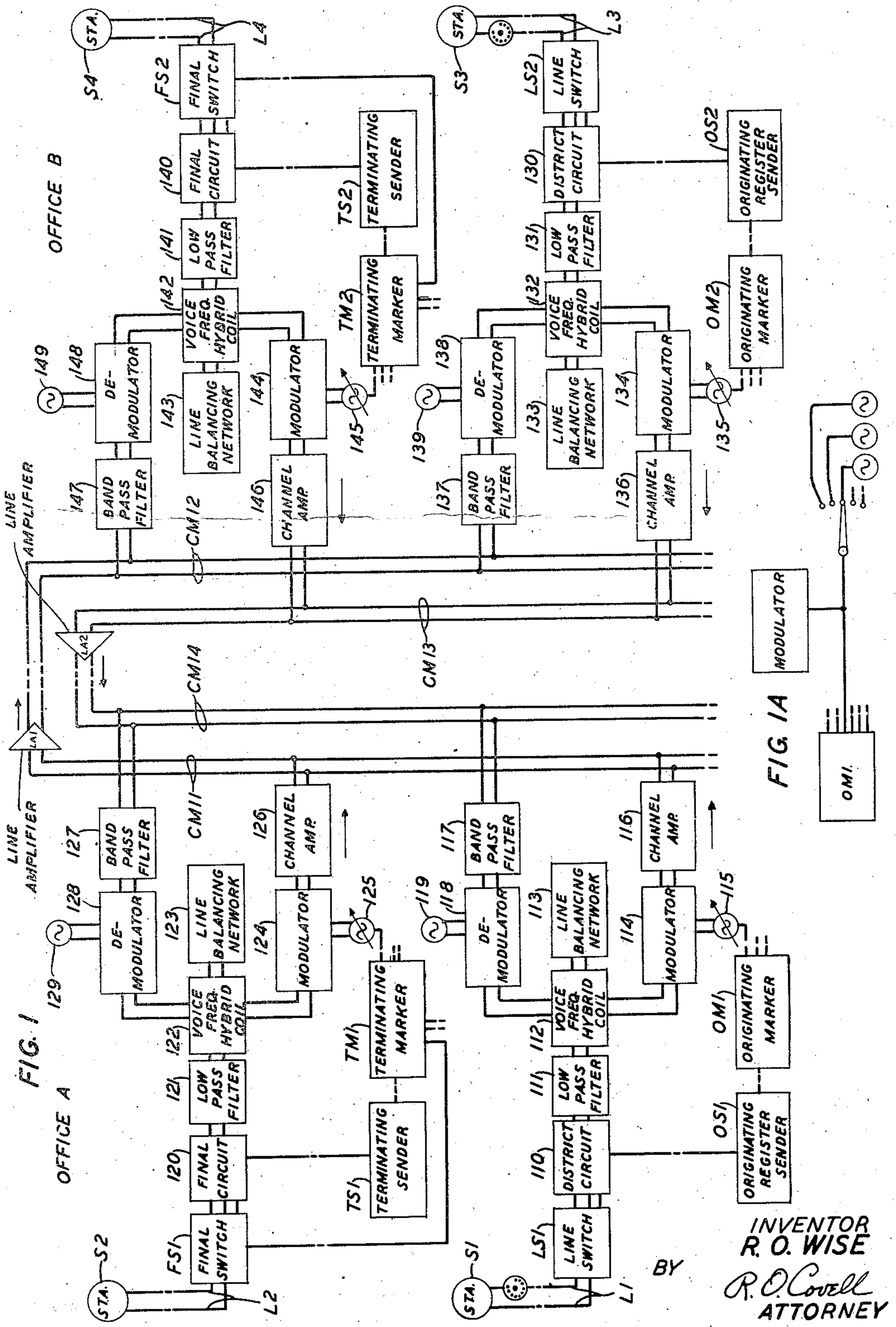


FIG. 1

FIG. 1A

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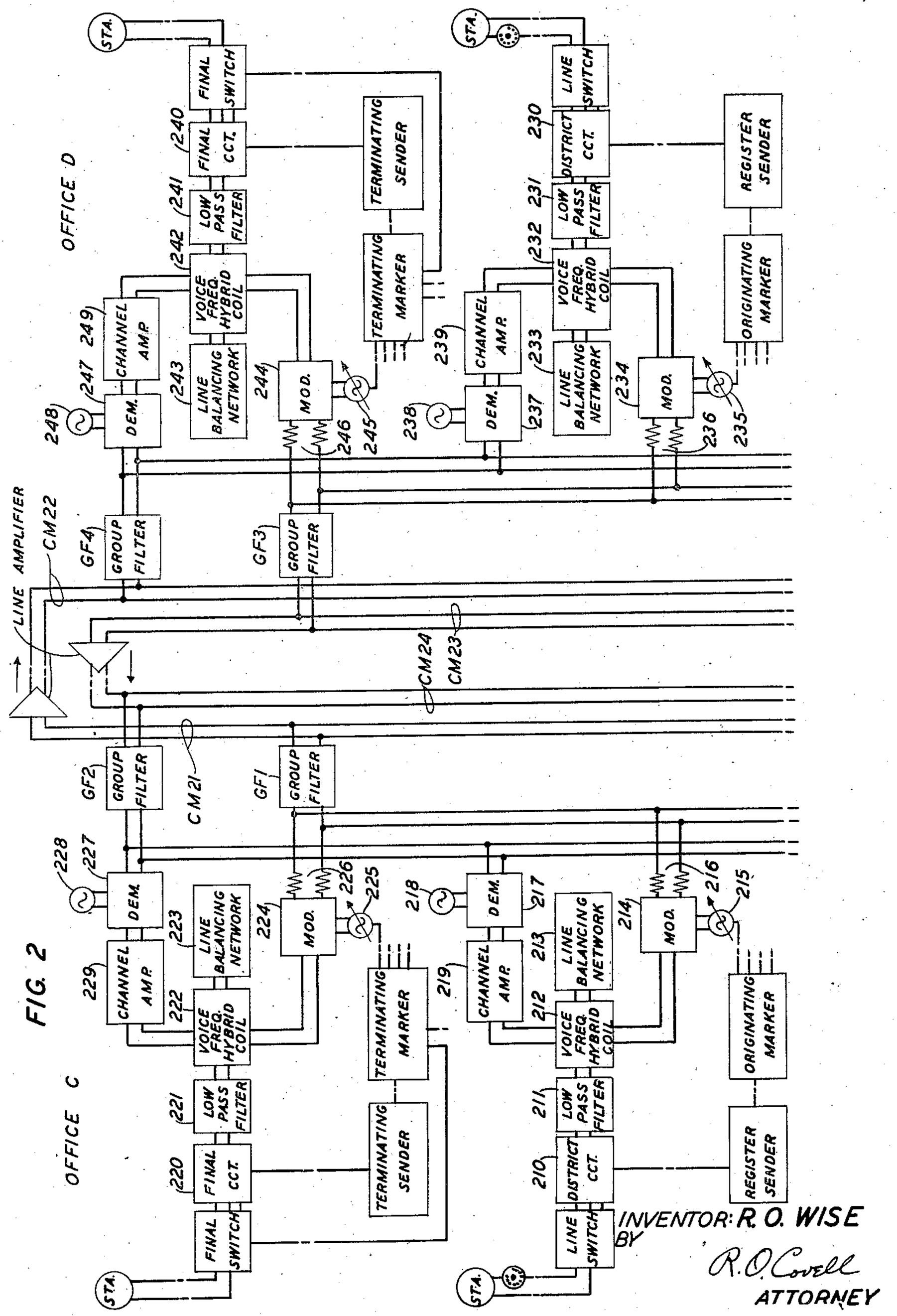


FIG. 2

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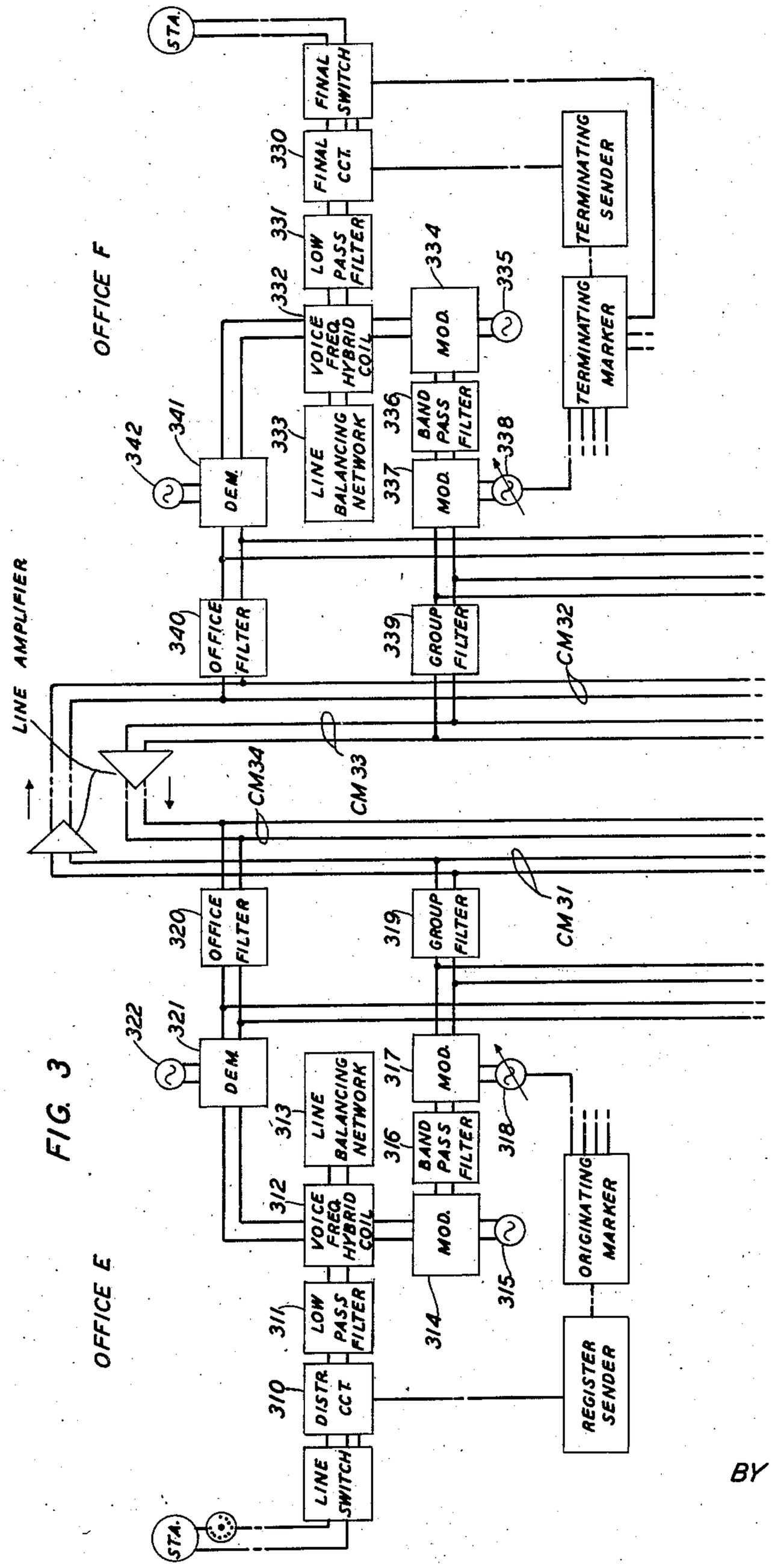


FIG. 3

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# UNITED STATES PATENT OFFICE

2,408,462

## TELEPHONE SYSTEM

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Application June 8, 1943, Serial No. 490,033

10 Claims. (Cl. 179—15)

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This invention relates to telephone systems and particularly to systems in which connections between calling and called lines are established by subscriber controlled automatic selection of idle channels through multichannel communication media.

Among the objects of the invention are the provision of a more efficient and reliable common medium multichannel exchange and the provision therein of the large number of channels necessary in an automatic telephone system without the use of expensive variable frequency filters.

This invention is an automatic telephone system in which connections between calling and called lines are automatically completed under the control of the calling subscriber over channels of multichannel transmission media, one channel being used for each direction of conversation to constitute a conversational connection, a feature of the invention being a trunking arrangement wherein a fixed band-pass filter is provided for the demodulator of each channel, carrier sources of required frequency are selectively associated with the modulators of the channels and a pentode amplifier is provided for each modulator to prevent interference between channels.

Another feature of the invention is a trunking arrangement including channels of a common medium wherein carrier sources of required frequency are selectively connected to the modulators, isolating resistances being provided for each modulator to prevent cross-talk between channels, the number of modulators connected in parallel to a group or line amplifier being large enough to prevent interference between channels.

A further feature is a trunking arrangement including the channels of a common medium wherein carrier sources of required frequency are selectively connected to the modulators, isolating resistances are provided for each modulator to prevent cross-talk between channels, group filters are provided for groups of channels, a carrier source of a different frequency is individually associated with each demodulator, and a channel amplifier is provided for each demodulator to obtain satisfactory volume.

A further feature is a carrier switching system for establishing connections between calling and called telephone lines under the control of the calling subscriber in which a double stage of modulation is employed to obtain single sideband operation, carrier sources of different frequencies are individually connected to first

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modulators of the channels, fixed band-pass filters interconnect the first and second modulators of the channels, carrier sources of required frequencies are selectively connected to the second modulators of the channels, and carrier sources of different frequencies are individually connected to the demodulators.

These and other features of the invention are embodied in the systems shown schematically in the drawings which form a part of this specification.

Referring to the drawings:

Figs. 1 and 1A show a telephone system comprising telephone offices A and B interconnected by multichannel transmission media CM11, CM12, CM13 and CM14;

Fig. 2 shows a telephone system comprising offices C and D interconnected by multichannel transmission media CM21, CM22, CM23 and CM24; and

Fig. 3 shows a telephone system comprising telephone offices E and F interconnected by multichannel transmission media CM31, CM32, CM33 and CM34.

Consider first the system represented in Fig. 1. The subscribers' stations S1, S2, S3 and S4 are of the usual type connected to lines terminating in common battery automatic telephone offices and each of the stations includes a dial or other impulse sending device for controlling the establishment of desired connections. The line switches LS1, LS2 and final switches FS1 and FS2 may be of the crossbar type, the line switches being operated in response to the initiation of calls at subscribers' stations to connect calling lines to district circuits and the final switches being directively controlled by sender-marker means to select called lines. Reference may be had to the patent to W. W. Carpenter 2,093,117, granted September 14, 1937, for a detailed description of the operations involved in connecting calling lines to district circuits and the operations of final switches in connecting with called lines in a crossbar system. The line switches LS1 and LS2 may be similar to the line switch shown in Figs. 14 and 15 of the aforementioned Carpenter patent, the final switches FS1 and FS2 may be similar to the final switch shown in Fig. 61 of said Carpenter patent, the originating senders OS1 and OS2 may be similar to the subscriber's register sender shown in Figs. 22 to 26 of said Carpenter patent, and the terminating senders TS1 and TS2 may be similar to the terminating senders shown in Figs. 46 and 47 of said Carpenter patent. The district and

final circuits 110, 120, 130 and 140 are similar to the district circuit D—1 shown in Fig. 5 of the patent to Hubbard-Matthies-Myers, No. 2,345,048 dated March 28, 1944 except that each of applicant's modulators 114, 124, 134 and 144 has a variable frequency carrier source associated therewith tunable under the control of an originating marker and each of applicant's demodulators 118, 128, 138 and 148 has a fixed frequency carrier source associated therewith; whereas in the Hubbard-Matthies-Myers patent the transmitter (modulator) T—5 of the district circuit D—1 has a fixed frequency carrier source associated therewith and the receiver (demodulator) R—5 of the district D—1 is tunable under the control of an originating marker to a desired channel frequency. Each of the originating markers OM1, OM2 and terminating markers TM1, TM2 is similar to the corresponding decoder markers of the aforementioned Carpenter patent except that it is arranged to control the tuning of the variable frequency carrier source of the modulator of a connected district or final circuit in similar manner to that in which the originating marker OM1 of the aforementioned patent to Hubbard-Matthies-Myers controls the tuning of the receiver R—5 of the district D—1 shown in Fig. 5. In the aforementioned Carpenter patent, the originating decoder marker is shown in Figs. 29 to 40 and the terminating decoder is shown in Figs. 50 to 56. In the Hubbard-Matthies-Myers patent the originating marker OM is shown in Figs. 12 to 20.

Each district circuit and each final circuit is connected, through a low-pass filter, to a voice frequency hybrid coil; and each hybrid coil is further connected to a line balancing network, to a modulator for one direction of communication, and to a demodulator for the other direction of communication. The low-pass filter passes frequencies below 3,000 cycles per second and the modulators are preferably of the double-balanced copper-oxide type to obtain maximum linearity and thus avoid extra band products which would increase cross-talk. Each demodulator has a particular carrier source associated therewith and is connected to a multichannel medium through a band-pass filter tuned to pass a band, the cut-off frequencies of which are equal to the carrier frequency of the associated demodulator plus and minus the voice frequency band. For instance, if the carrier frequency of a demodulator is 100,000 cycles per second, the band-pass filter associated with the demodulator in question passes a channel band of 97,000 to 103,000 cycles per second. Thus there are as many channels through the multichannel media CM11, CM12, CM13 and CM14 as there are demodulators connected thereto; and the carrier frequencies have at least an 8 kilocycle spacing. Each modulator is supplied with any desired one of a plurality of carrier sources, the connection of a desired carrier being under the control of the originating or terminating marker which is controlling the establishment of a desired conversational connection through the associated district or final circuit. As shown in Fig. 1 the marker tunes a variable frequency carrier source to the desired frequency; but this arrangement may be modified according to Fig. 1A in which a desired one of a plurality of carrier sources is selected under the control of the marker. Each modulator is connected through a pentode amplifier to one of the multichannel media, the inherent inefficiency of pentodes as plate modulator amplifiers being effective to prevent cross-modulation between channels.



Assuming now that a call is initiated at the subscriber's station S1, the line L1 is extended through a line switch LS1 to a district circuit 110 and an originating register sender OS1 is connected to the district, in the manner set forth in detail in the aforementioned Carpenter patent beginning on page 14, line 68, second column and ending on page 26, line 37, first column. The number of the subscriber's station, with which a conversational connection is desired, is dialed by the calling subscriber and is registered in the sender OS1, as described in the Carpenter patent beginning on page 32, line 5, first column and ending on page 36, line 41, first column. An originating marker OM1 is associated with the sender and the number registered in the sender is decoded, in the manner set forth in the aforementioned Carpenter patent beginning on page 36, line 44, first column and ending on page 40, line 38, first column.

The marker OM1, thereupon, makes a trunk test, in the manner set forth in detail in the aforementioned patent to Hubbard-Matthies-Myers beginning on page 3, line 71, second column and ending on page 5, line 46, second column, to select a trunk or channel through media CM11 and CM12 which is not in use and the demodulator of which in office B is associated with a final switch having access to the line of the called station. The variable frequency carrier source 115 of the modulator 114, which is associated with the district 110, is tuned to the required frequency under the control of the marker OM1 in similar manner to that in which the receiver R—5 of the district D—1 in the Hubbard-Matthies-Myers patent is tuned to the required frequency as described in the Hubbard-Matthies-Myers patent on page 6, beginning in line 54, first column. A seizure signal is transmitted from the district circuit 110 through the low-pass filter 111, hybrid coil 112, modulator 114 and channel amplifier 116, through common medium CM11, line amplifier LA1, common medium CM12, through the particular band-pass filter 147 which is tuned to pass the carrier wave and signal band transmitted by modulator 114, to the demodulator 148 whose carrier source 149 is of the same frequency as that of the source 115 connected to modulator 114. The demodulated seizure signal is thus further transmitted through hybrid coil 142 and low-pass filter 141 to the final circuit 140. In response to the seizure signal reecived by final circuit 140, a terminating sender TS2 is connected to the final circuit 140. Numerical signals are now transmitted by the originating sender OS1, through district circuit 110, low-pass filter 111, hybrid coil 112, modulator 114, amplifier 116, common medium CM11, line amplifier LA1, common medium CM12, and band-pass filter 147, to demodulator 148; and the demodulated signals are transmitted through hybrid coil 142, filter 141 and final circuit 140 to the terminating sender TS2, in which the identity of the called subscriber's station is thereby registered. For description of the sending of the seizure signal from the district 110, the connection of a terminating sender to the final circuit 140, and transmission of the numerical digits from the originating sender to the terminating sender, reference may be had to the aforementioned Hubbard-Matthies-Myers patent beginning on page 8, line 6, first column. The originating sender further transmits a signal indicative of

the frequency of the carrier source 119 which is connected to the demodulator 118 which is associated with hybrid coil 112 and district 110; and this signal operates register means in sender TS2. A terminating marker TM2 is thereupon connected to the sender TS2, the marker is connected to the modulator 144 and final switch FS2 which are associated with the final circuit 140, the variable frequency carrier source of modulator 144 is tuned to the same frequency as that of the source 119 associated with the demodulator 118 in office A, and the final switch FS2 is controlled by the marker TM2 to connect with the line L4 of the called station S4. The called line is tested and, if the line is idle, a signaling circuit is closed in the usual manner. When the call is answered, a two-way conversational connection is completed between stations S1 and S4, one way through media CM11 and CM12 and the other way through media CM13 and CM14. The originating marker OM1 is released as soon as the carrier source 115 has been tuned to the required frequency; the originating sender OS1 is released as soon as the numerical and channel frequency indicating signals have been transmitted to the called office; and the terminating sender TS2 and marker TM2 are released as soon as connection with the called line has been completed. Supervisory signals may be transmitted in both directions, release of the connection being effected when the subscriber at the calling station S1 restores the telephone set to normal. The line and final switches LS1 and FS2 are thereupon restored to normal; and the carrier sources 115 and 145 are disconnected from modulators 114 and 144.

In the offices C and D shown in Fig. 2, the district circuits 210 and 230 and final circuits 220 and 240 are individually connected through low-pass filters 211, 231, 221 and 241 to hybrid coils 212, 232, 222 and 242. The hybrid coils are further connected to line balancing networks 213, 233, 223 and 243, to modulators 214, 234, 224 and 244, and through channel amplifiers 219, 239, 229 and 249 to demodulators 217, 237, 227 and 247. Fixed frequency carrier sources 218, 238, 228 and 248 are connected to the demodulators; and carrier sources of desired frequency are selected and connected to the modulators under control of originating and terminating markers. The modulators are divided into groups, modulators 214 and 224 in office C being connected through individual isolating resistance pads 216 and 226 and through group filter GF1 to the multichannel transmission medium CM21; and modulators 234 and 244 in office D being individually connected through resistance pads 236 and 246 and through group filter GF3 to multichannel transmission medium CM23. The resistance pads and group filters are used instead of pentode amplifiers as in Fig. 1. The demodulators are also divided into groups, group filter GF2 connecting a group of demodulators 217, 227 to multichannel transmission medium CM24 and group filter GF4 connecting a group of demodulators 237, 247 to multichannel transmission medium CM22. Since the energy from one modulator, which feeds back into another modulator to cause cross-talk, is inversely proportional to the square of the number of modulators connected in parallel, the cross-talk due to intermodulation between channels will not be substantial with large numbers of modulators connected to each group filter. The loss which is introduced by the isolating resistance pads is made up in the line amplifiers.



A further modification introduced in the arrangement of Fig. 2 is the elimination of the demodulator filters shown in Fig. 1, the balance of the demodulators necessary to prevent cross-talk being obtained by the use of double-balanced copper-oxide modulators. The most serious cross-talk will be contributed by the third harmonic of the carrier modulating with energy approximately three times the frequency of the wanted signal; and this type of cross-talk is prevented by the group filters which pass a non-harmonically related group of carriers. The remaining serious distortion products involve the square and higher orders of the signal energy; and these are reduced by operating the demodulators at low level, single tube amplifiers being provided to raise the output volume of each demodulator to a satisfactory level.

In the arrangement shown in Fig. 3, a double stage of modulation is provided with single side-band transmission. Each district circuit 310 is connected by a low-pass filter 311 to a voice frequency hybrid coil 312; and each final circuit 330 is connected by a low-pass filter 331 to a voice frequency hybrid coil 332. The hybrid coil 312 is further connected to a line balancing network 313, a primary modulator 314 and a demodulator 321; and the hybrid coil 332 is further connected to a line balancing network 333, a primary modulator 334 and a demodulator 341. The primary modulator 314 is connected to fixed-frequency carrier source 315 and through a corresponding band-pass filter 316 to a secondary modulator 317; and the primary modulator 334 is connected to a fixed-frequency carrier source 335 and through a corresponding band-pass filter 336 to a secondary modulator 337. The channels are divided into groups, the same primary carrier frequency being used for all of the primary modulators in the group and a different secondary carrier frequency being used for each secondary modulator. The particular frequency of the carrier source 318 which is connected to the secondary modulator 317 on a given call is controlled by the originating marker under whose control the desired conversational connection is being established; and the particular frequency of the carrier source 338, which is connected to the secondary modulator 337 on a given call, is controlled by the terminating marker under whose control the desired conversational connection is being established. The frequency of the carrier connected to each primary modulator of a group of channels is greater than the band-width passed by the group filter; and the band-pass filter of each channel selects one of the side-bands of the primary carrier and passes it to the secondary demodulator. The frequency of the carrier source 318 which is selectively associated with the secondary modulator 317, lies within the band-width of the group filter 319 and determines the position of the modulated single side-band in the group band. And the frequency of the carrier source 338 which is selectively associated with the secondary demodulator 337, lies within the band-width of the group filter 339 and determines the position of the modulated single side-band in the group band. Since the unwanted side band of each channel is outside of the group band and is not transmitted, only a single stage of demodulation is required. Thus each group of secondary modulators is connected through a group filter 319 or 339 to a multichannel medium CM31 or CM33, thence through a line amplifier, a multichannel medium CM32 or CM34, and an

office filter 320 or 340 to all of the demodulators 321 and 341, each demodulator having a different fixed carrier frequency. While this arrangement requires the use of an additional modulator and filter for each channel, it greatly reduces the cost of the required carrier supply system, reduces the delay distortion, and increases the number of channels which may be provided through the common transmission media.

The carrier channel equipments may be arranged so that fixed carrier frequencies are assigned to both the modulator and demodulator associated with a final switch in which case the originating marker selectively controls the connection of carrier sources of required frequency to both the modulator and demodulator associated with the district through which a call is initiated. This and other modifications of the above-described arrangements may be made within the scope of the invention.

What is claimed is:

1. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units each comprising a modulator and a demodulator, means for individually connecting said units with subscribers' lines, amplifiers, one for each of said modulators, band-pass filters, one for each demodulator, for passing a different band of frequencies to each demodulator, a plurality of carrier current sources, a source of a different frequency for each demodulator, a multichannel transmission medium connected to a plurality of said amplifiers, a multichannel transmission medium connected to a plurality of said filters, an amplifier interconnecting said multichannel media, and means including control means common to said units for selectively connecting to the modulator of any unit connected with a calling line a carrier source of the same frequency as that of the carrier source connected to the demodulator of a unit adapted to be connected to the called line.

2. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units, means including electromechanical switching means for individually connecting said equipment units to subscribers' lines, each of said units comprising a modulator and a demodulator, multichannel transmission media common to said units, a plurality of carrier current sources, a source of a different frequency for each of said demodulators, and means including control means common to a plurality of said units for selectively effecting the connection of carrier sources of required frequency to said modulators, thereby to effect the completion of non-interfering two-way conversational connections through said common media between units connected to calling subscribers' lines and units adapted to be connected to called subscribers' lines.

3. In a telephone system, subscribers' lines, a plurality of carrier channel equipment units, each comprising a modulator and a demodulator, means for individually connecting said units with subscribers' lines, a multichannel transmission medium common to a plurality of said modulators, resistance pads one for each of said plurality of modulators, each of said pads connecting the associated modulator to said medium, a multichannel transmission medium common to a plurality of said demodulators, an amplifier interconnecting said media, a plurality of carrier current sources, a source of a different frequency for each of said demodulators, and means including control means common to said units for selectively connecting to the modulator of any unit connected to a calling subscriber's line a carrier source of the same frequency as that of the carrier source connected to the demodulator of a unit adapted to be connected to the called line.



4. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units, means for individually connecting said units with subscribers' lines, each of said units comprising a modulator and a demodulator, a multichannel transmission medium common to a plurality of said modulators, resistance pads one for each of said modulators connecting said modulators to said medium, a multichannel transmission medium common to a plurality of said demodulators, an amplifier interconnecting said media, a plurality of carrier current sources, a source of a different frequency for each of said demodulators, and means including control means common to said units for selectively connecting to the modulator of any unit adapted to be connected to a called subscriber's line a carrier source of the same frequency as that of the source connected to the demodulator of the unit connected to the calling subscriber's line.

5. In a telephone system, subscribers' lines, a plurality of carrier channel equipment units, each comprising a modulator and a demodulator, means for individually connecting said units with subscribers' lines, a multichannel transmission medium common to a plurality of said modulators, resistance pads one for each of said plurality of modulators, each of said pads connecting the associated modulator to said medium, a multichannel transmission medium common to a plurality of said demodulators, an amplifier interconnecting said media, a plurality of carrier current sources, a source of a different frequency for each of said demodulators, means including control means common to said units for selectively connecting to the modulator of any unit connected to a calling subscriber's line a carrier source of the same frequency as that of the carrier source connected to the demodulator of a unit adapted to be connected to the called line and for selectively connecting to the modulator of said unit adapted to be connected to a called subscriber's line a carrier source of the same frequency as that of the demodulator connected to the unit connected to the calling subscriber's line.

6. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units, means for individually connecting said units with subscribers' lines, each of said units comprising a modulator and a demodulator, said modulators and said demodulators being divided into groups, group filters, one for each group of modulators and one for each group of demodulators, resistance pads, one for each of said modulators, each of said pads connecting the associated modulator to the associated group filter, multichannel transmission media, the group filters of each of a plurality of groups of modulators being connected to one of said transmission media and the group filters of each of a pluraltiy of groups of demodulators being connected to another of said transmission media.

7. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units, means for individually connecting said units with subscribers' lines, each of said units comprising a modulator and a demodulator, said modulators and said demodulators being

divided into groups, group filters, one for each group of modulators and one for each group of demodulators, resistance pads, one for each of said modulators, each of said pads connecting the associated modulator to the associated group filter, multichannel transmission media, the group filters of each of a plurality of groups of modulators being connected to one of said transmission media and the group filters of each of a plurality of groups of demodulators being connected to another of said transmission media, a plurality of carrier current sources, a source of a different frequency for each of said demodulators, and means including control means common to said units for selectively connecting to the modulator of any unit connected to a calling subscriber's line a carrier source of the same frequency as that of the carrier source connected to the demodulator of a unit adapted to be connected to the called subscriber's line.

8. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units, means for individually connecting said units with subscribers' lines, each of said units comprising a modulator and a demodulator, said modulators and said demodulators being divided into groups, group filters, one for each group of modulators and one for each group of demodulators, resistance pads, one for each of said modulators, each of said pads connecting the associated modulator to the associated group filter, multichannel transmission media, the group filters of each of a plurality of groups of modulators being connected to one of said transmission media and the group filters of each of a plurality of groups of demodulators being connected to another of said transmission media, a plurality of carrier current sources, a source of a different frequency for each of said demoduators, and means including control means common to said units for selectively connecting to the modulator of any unit adapted to be connected to a called subscriber's line a carrier source of the same frequency as that of the source connected to the demodulator of the unit connected to the calling subscriber's line.

9. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units, said units divided into groups, means



for individually connecting said units with subscribers' lines, each of said units comprising a primary modulator, a secondary modulator and a demodulator, multichannel transmission media common to a plurality of said units, group filters, each of said filters connecting one of said media to the secondary modulator of a different group of said units, a plurality of sources of carrier current, a source of a different frequency being individually connected to each of said primary modulators and said demodulators, band-pass filters adapted to pass one of the voice frequency side-bands from the associated modulator to the associated secondary modulator, and means including control means common to said units for selectively connecting to the secondary modulator of a unit connected to a calling subscriber's line a carrier source of required frequency to establish a conversational connection through one of said media with the demodulator of a unit adapted to be connected with the called subscriber's line.

10. In a telephone system, subscribers' lines, a plurality of high frequency carrier channel equipment units, said units divided into groups, means for individually connecting said units with subscribers' lines, each of said units comprising a primary modulator, a secondary modulator and a demodulator, multichannel transmission media common to a plurality of said units, group filters, each of said filters connecting one of said media to the secondary modulator of a different group of said units, a plurality of sources of carrier current, a source of a different frequency being individually connected to each of said primary modulators and said demodulators, band-pass filters adapted to pass one of the voice frequency side-bands from the associated modulator to the associated secondary modulator, and means including control means common to said units for selectively connecting to the secondary modulator of a unit adapted to be connected to a called subscriber's line a carrier source of the required frequency to establish a conversational connection through one of said media with the demodulator of the unit connected to the calling subscriber's line.

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