

April 6, 1926.

1,579,256

E. H. SMYTHE

CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

Filed Nov. 9, 1923

12 Sheets-Sheet 1

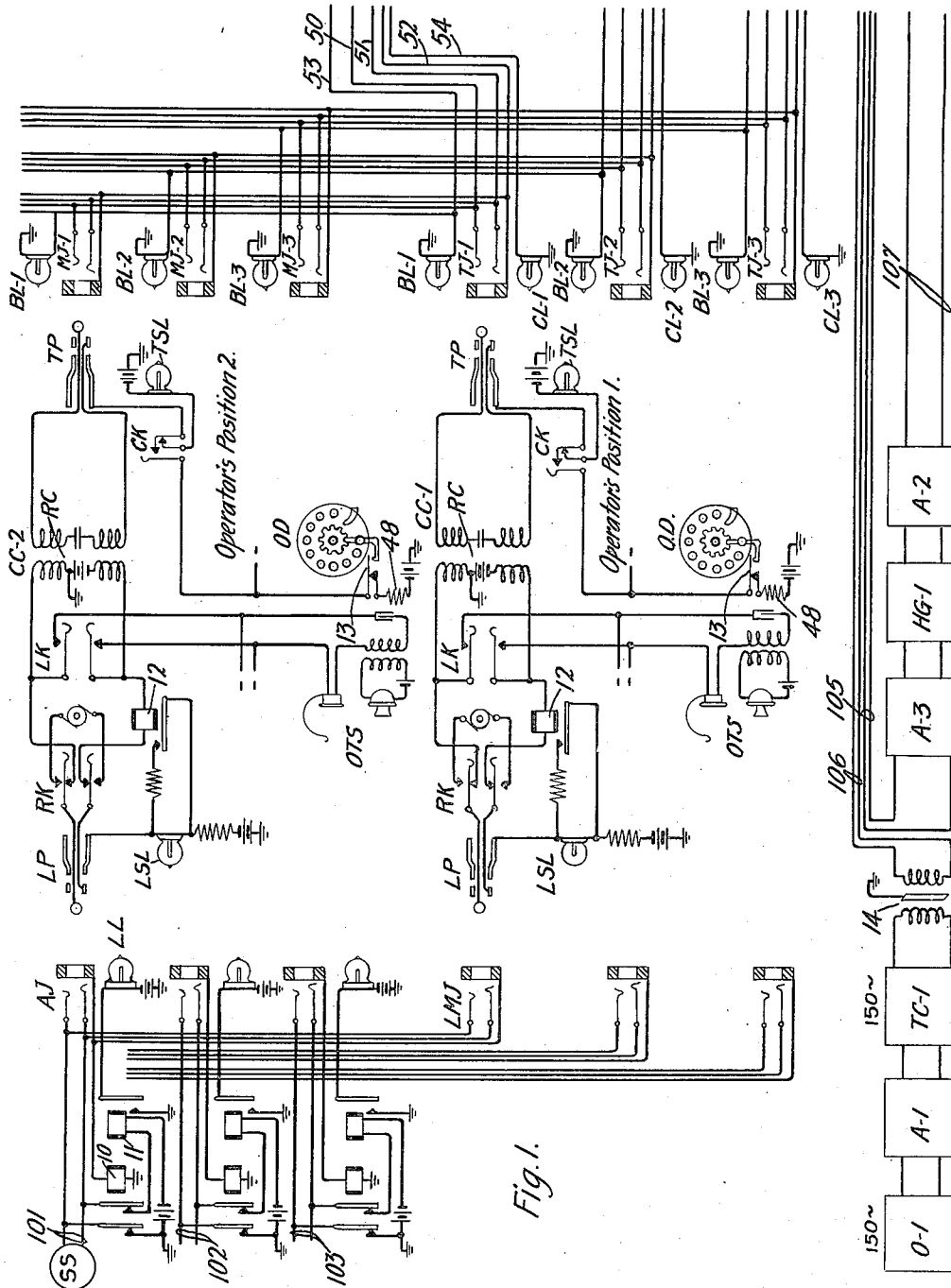


Fig. 1.

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April 6 , 1926.

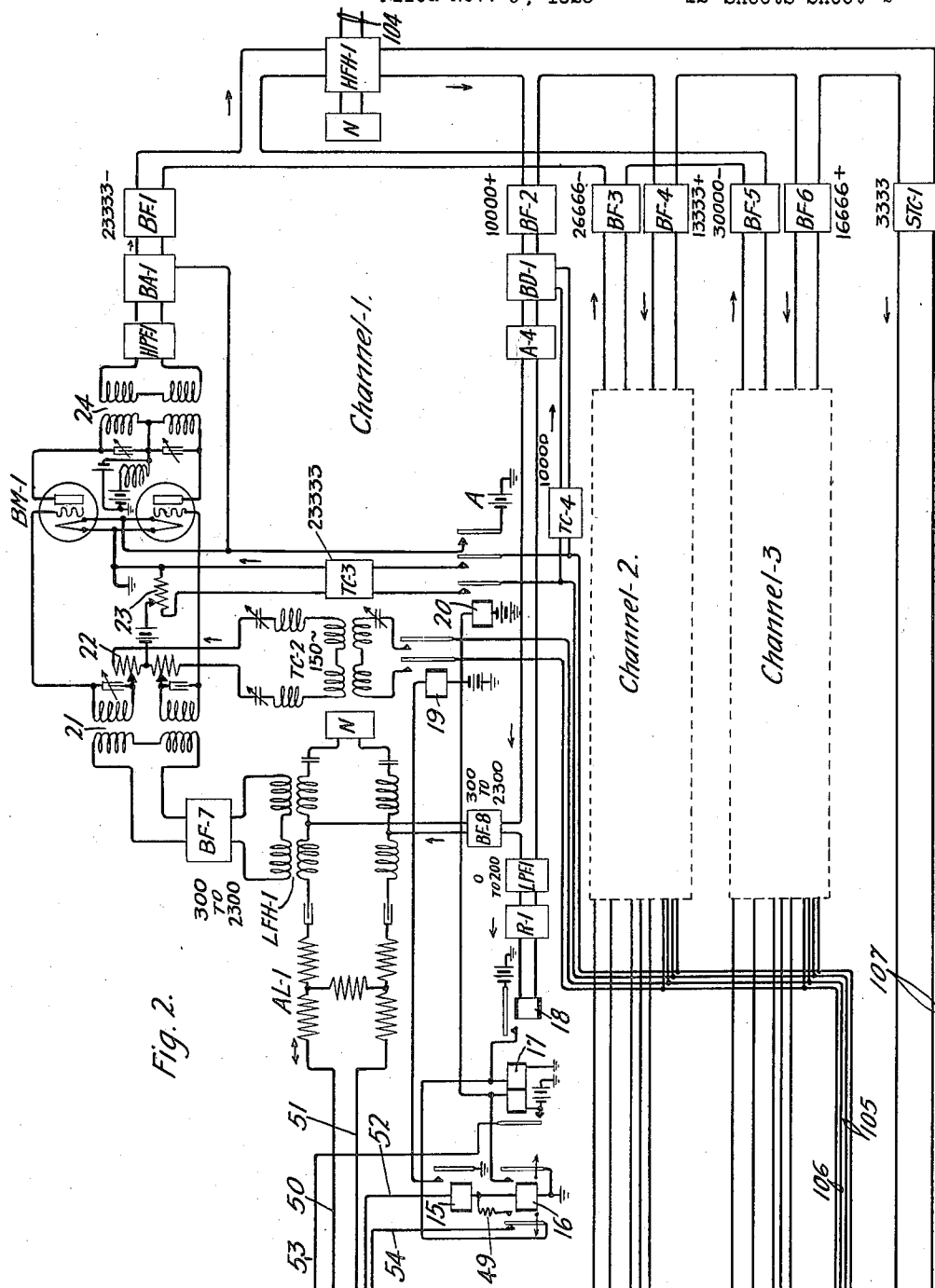
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12 Sheets-Sheet 2



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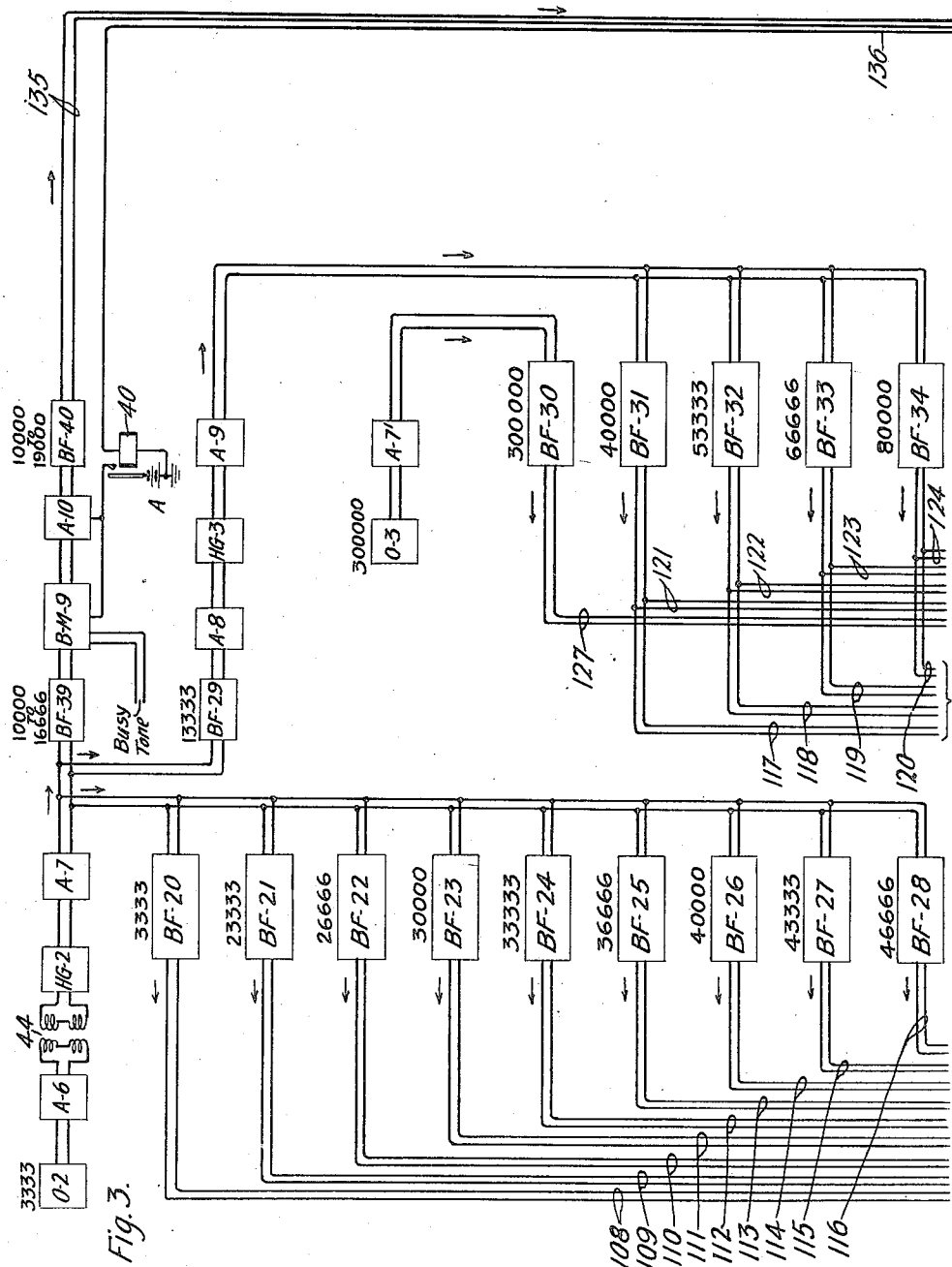
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12 Sheets-Sheet 3



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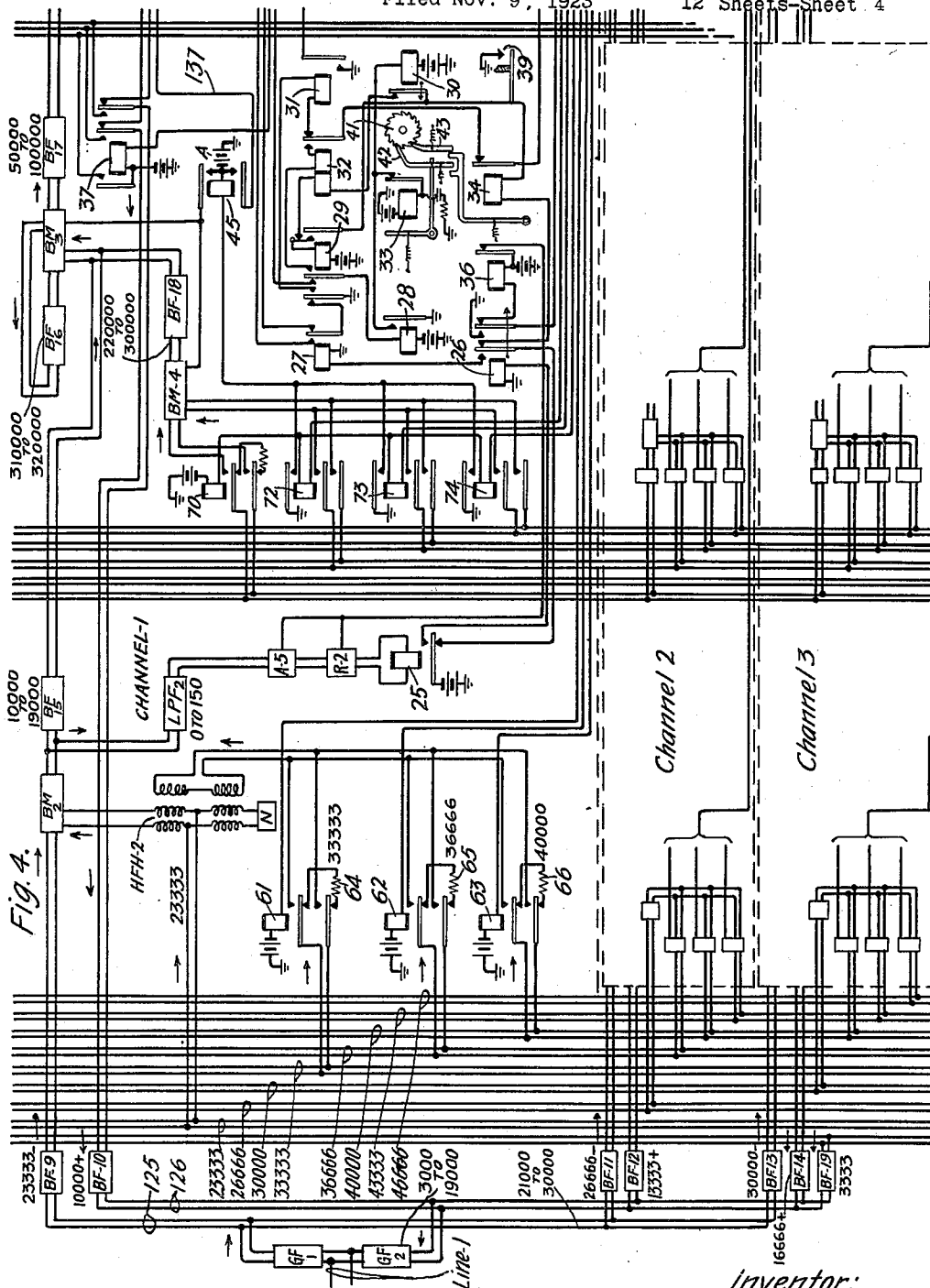
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12 Sheets-Sheet 4



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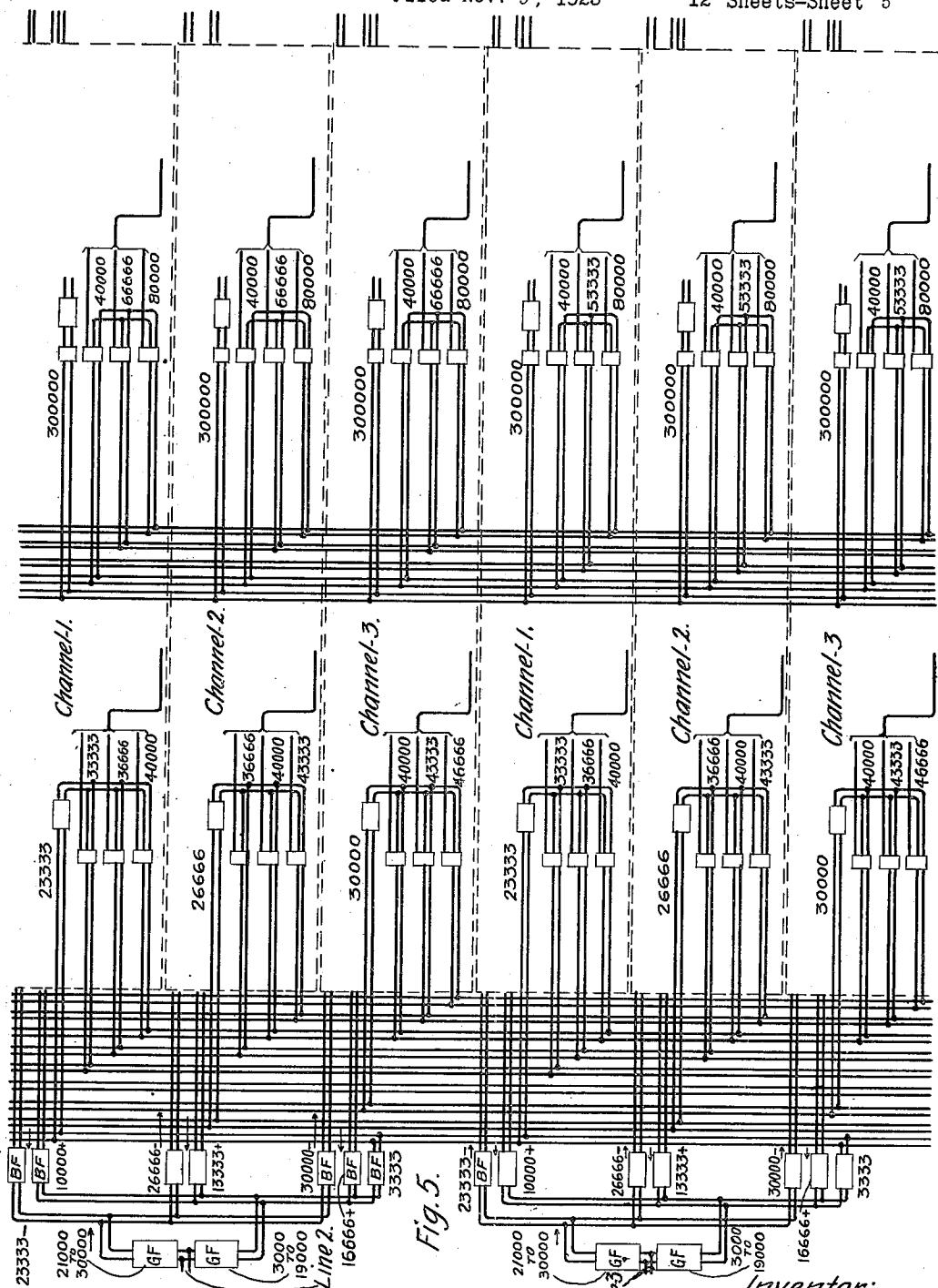
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

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12 Sheets-Sheet 5



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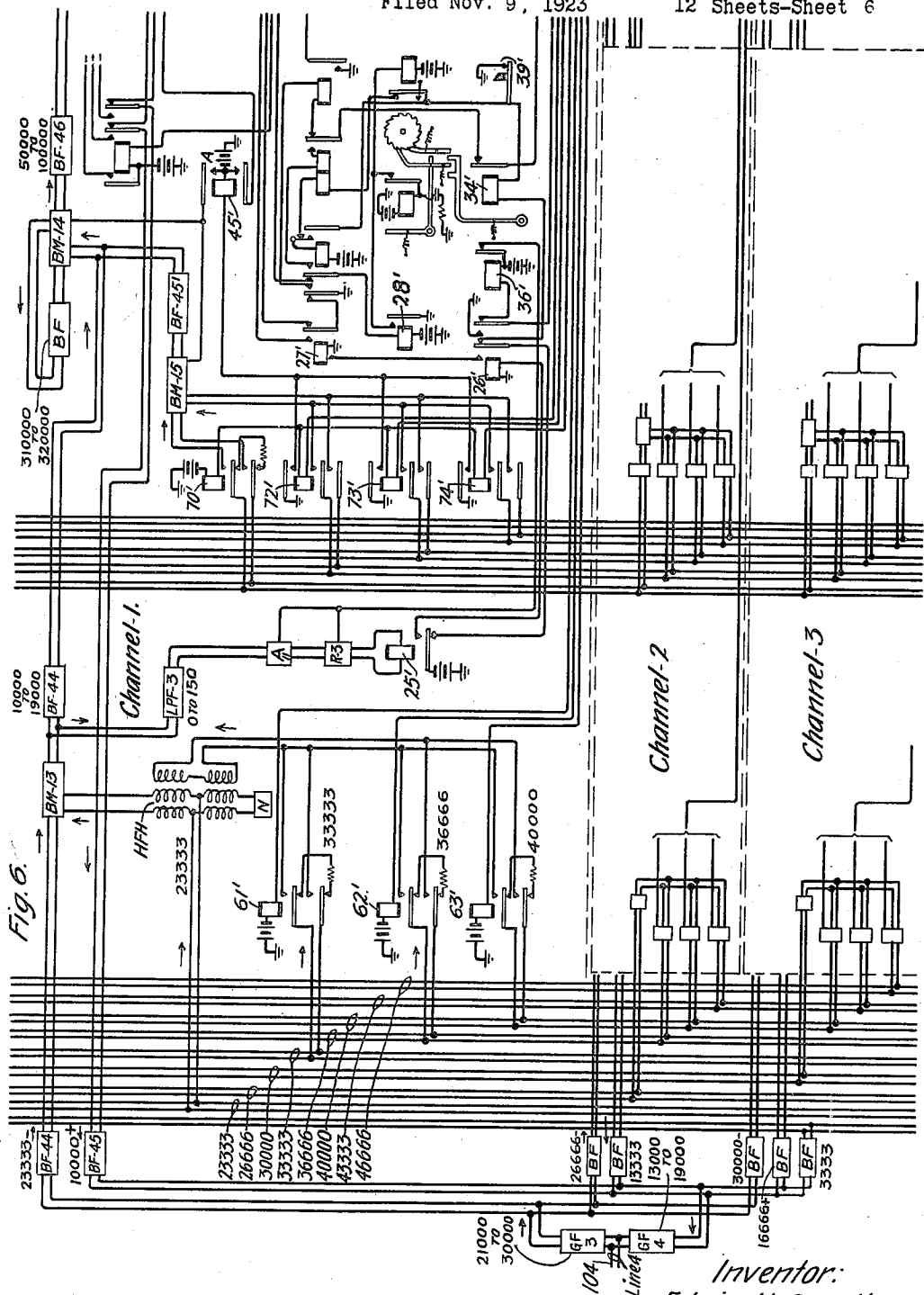
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

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12 Sheets-Sheet 6



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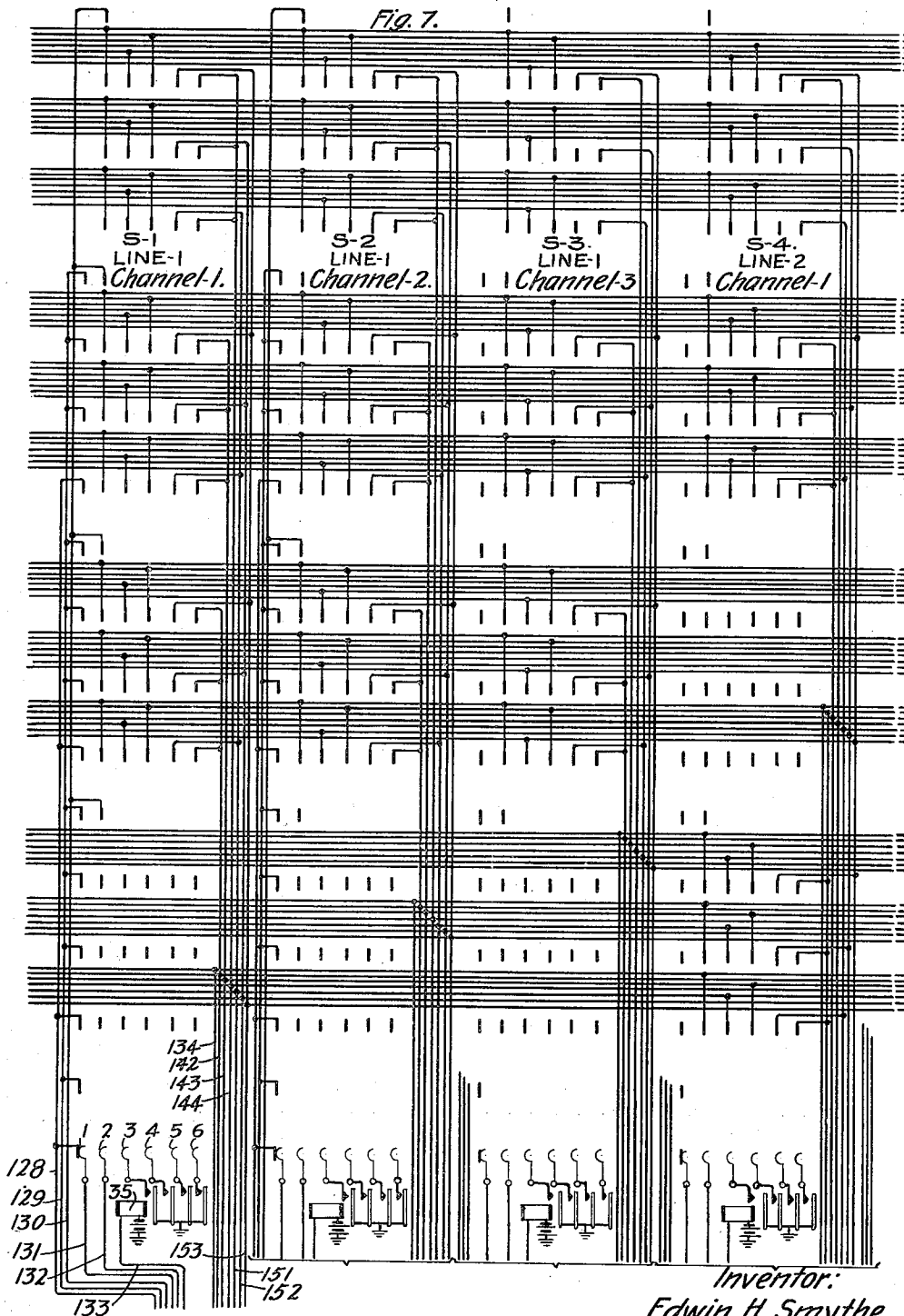
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

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12 Sheets-Sheet 7

Fig. 7.



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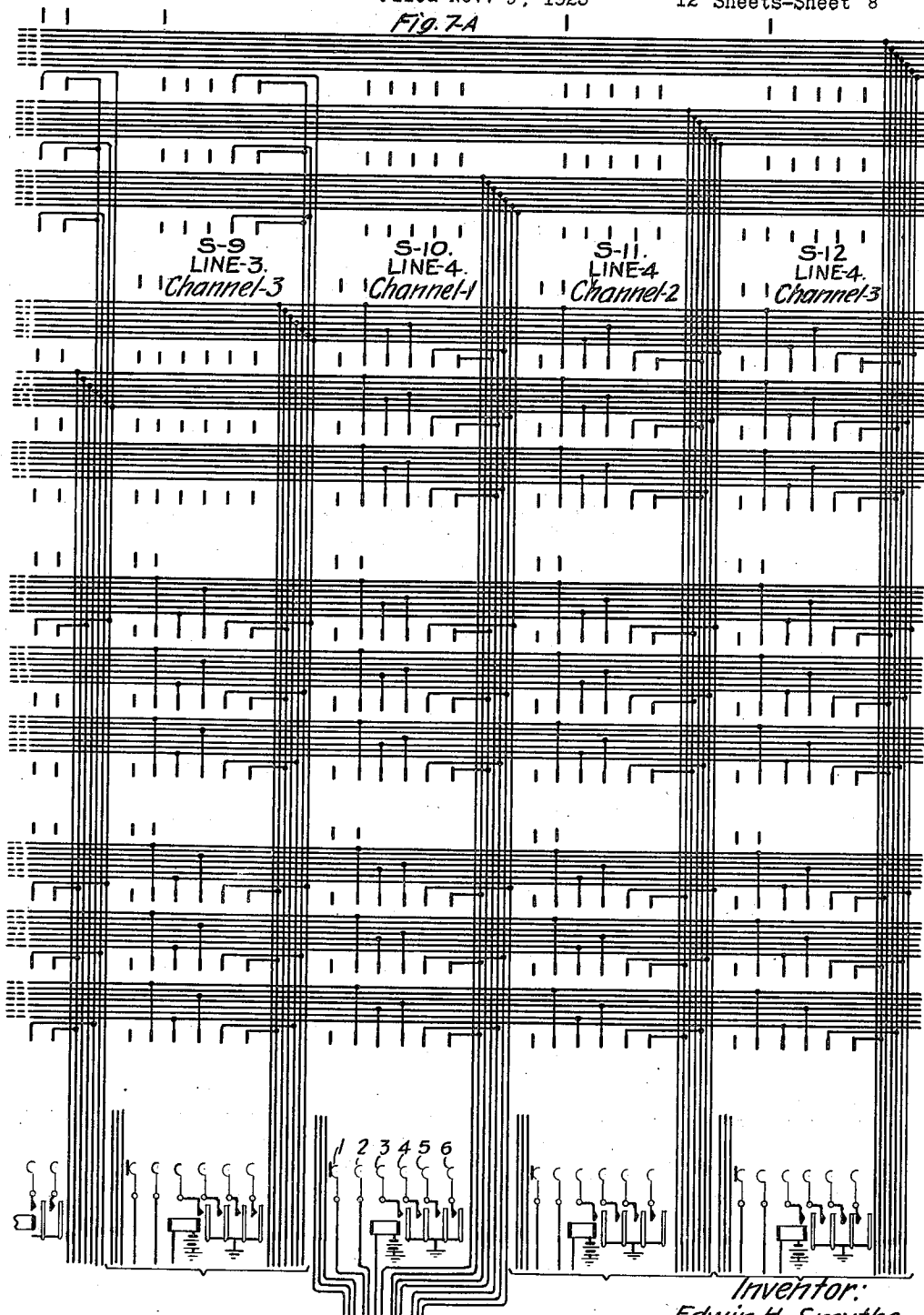
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

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12 Sheets-Sheet 8

FIG. 7A



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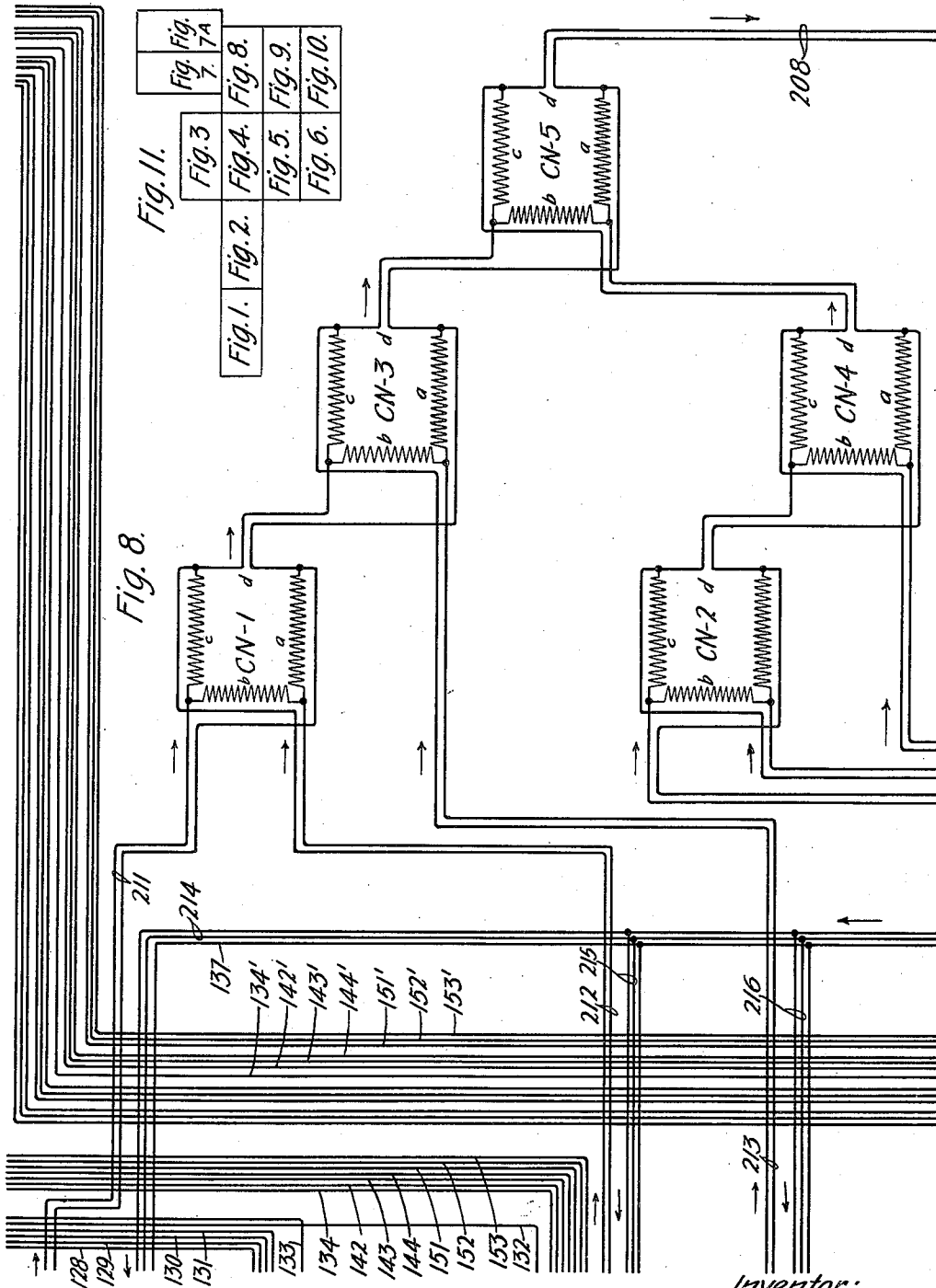
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

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12 Sheets-Sheet 9



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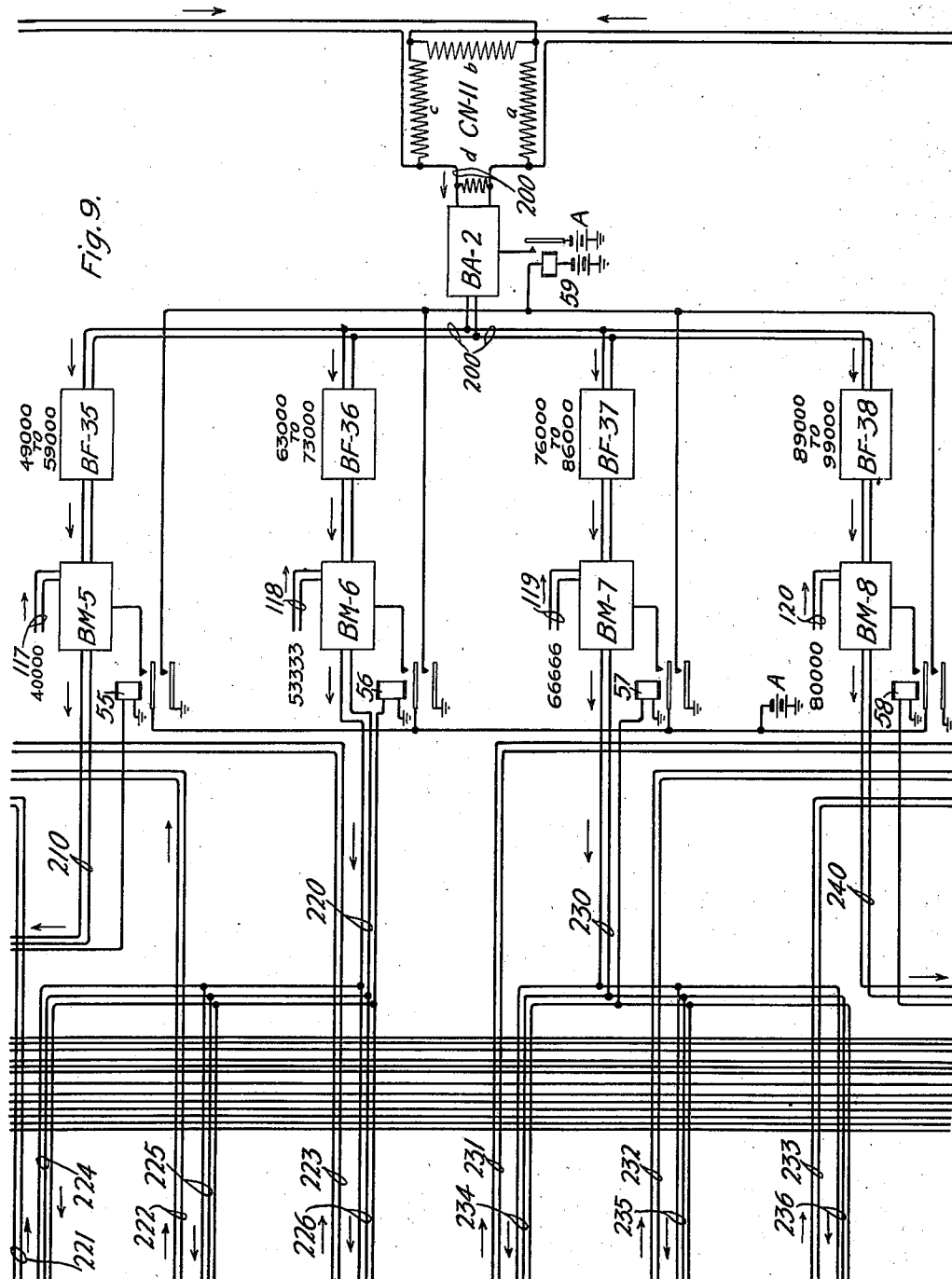
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

Filed Nov. 9, 1923

12 Sheets-Sheet 10



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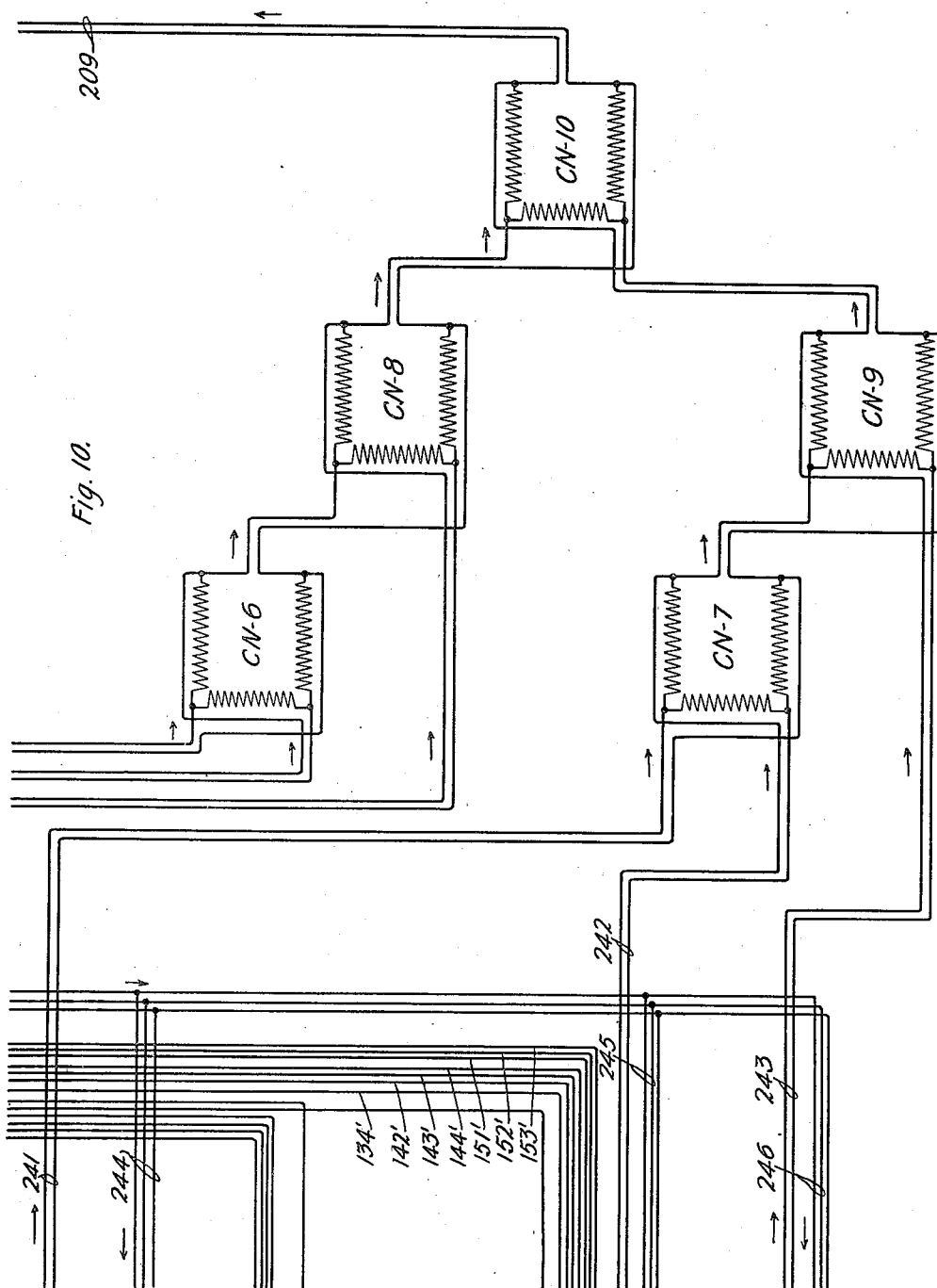
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM

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12 Sheets-Sheet 11



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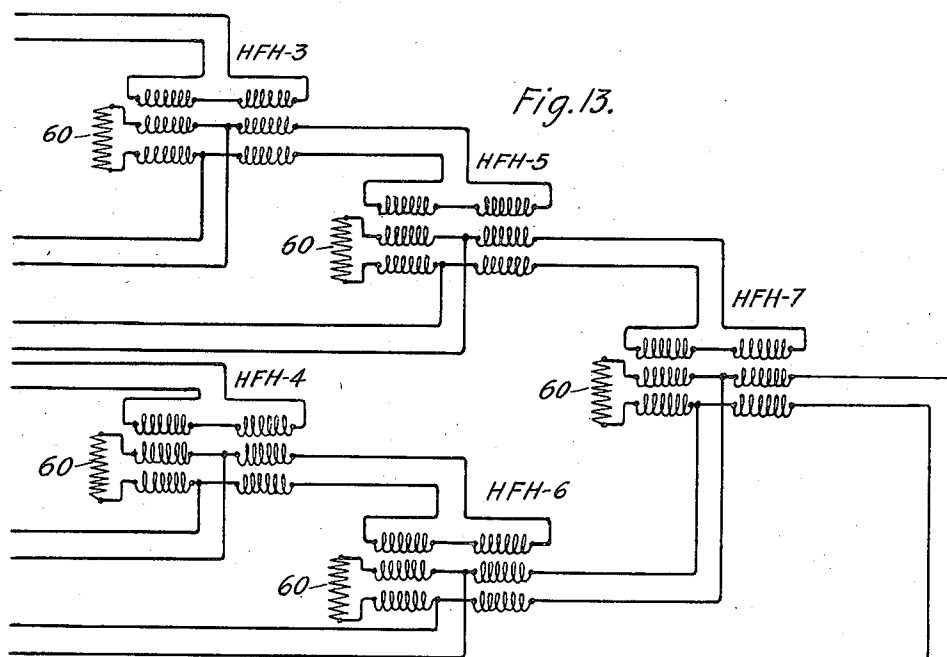
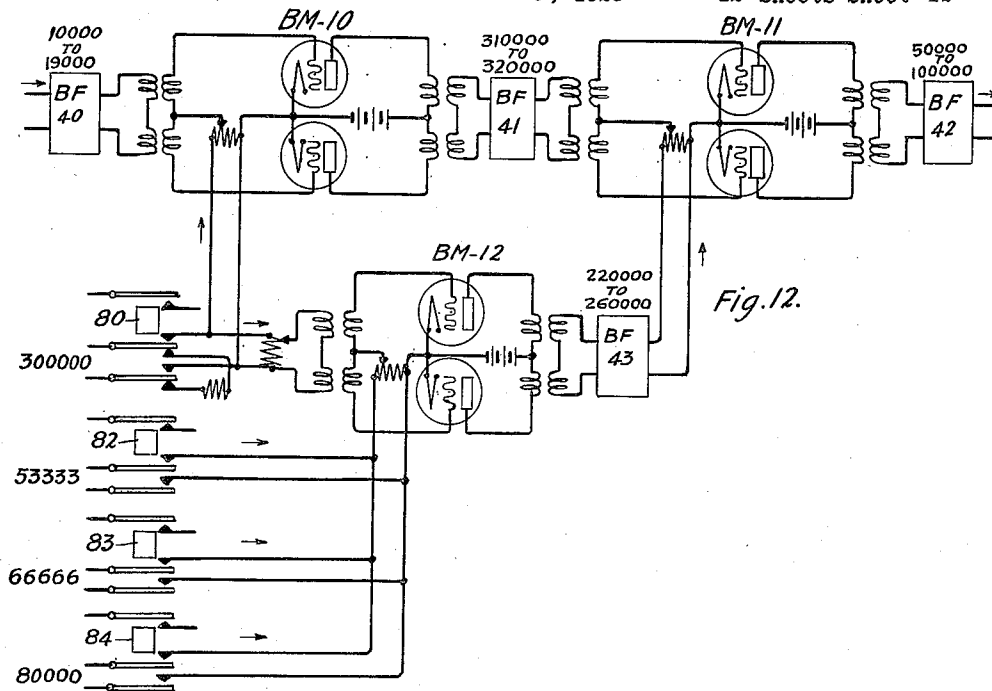
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CARRIER WAVE COMMUNICATING AND SWITCHING SYSTEM.

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12 Sheets-Sheet 12



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Patented Apr. 6, 1926.

1,579,256

UNITED STATES PATENT OFFICE.

EDWIN H. SMYTHE, OF EVANSTON, ILLINOIS, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

CARRIER-WAVE COMMUNICATING AND SWITCHING SYSTEM.

Application filed November 9, 1923. Serial No. 673,631.

To all whom it may concern:

Be it known that I, EDWIN H. SMYTHE, a citizen of the United States, residing at Evanston, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Carrier-Wave Communicating and Switching Systems, of which the following is a full, clear, concise, and exact description.

10 This invention relates to an improved interconnecting and communicating system, and more particularly to a system of the type in which carrier waves or oscillations, either free or guided, are employed as the medium for conveying energy for effecting the operation and control of the electrical switching, signaling and communicating apparatus located at separated points in the system. The invention especially relates to a system in which carrier currents in the form of high frequency waves guided upon wires are used as the medium of electrical connection between the electrical devices and apparatuses located at different points in the system. These carrier currents are assigned such frequencies that they are non-interfering with one another, so that each carrier serves as a connecting medium separate and distinct from the other carriers superposed upon the line or medium over which the carriers are transmitted. Each of the carriers is modulated in accordance with the voice currents or other signaling or controlling currents that are to be carried. The carriers thus modulated are transmitted over the toll or long distance line and are passed through individual arrangements each of which is selective of one carrier frequency to the exclusion of the others, and each of which may have associated with it apparatus that serves to reproduce from a modulated carrier the voice, signal or controlling currents with which the carrier was modulated at the distant station. The arrangement which is used to transmit and receive by means of any one high frequency wave as distinguished from that which is used for transmitting and receiving by means of a wave of a different frequency is commonly known as a high frequency or carrier channel, or as a frequency selective channel.

The present invention is directed particularly toward providing a system in which a connection may be established between two

or more toll or long distance stations, through an intervening switching station or toll center and the carrier multiplex lines that connect the long distance stations with the toll center, without the necessity of employing manually controlled switching or interconnecting agencies at the intermediate station; and toward providing a carrier multiplex interconnecting or switching system in which the switching or interconnecting of any channel of any calling line with any available channel of any desired other line may be effected merely by the shifting of the carrier frequencies at the intermediate station; and without the inclusion of any movable switch or relay contacts of any kind in the voice modulated carrier circuits. In the preferred embodiment of the invention herein disclosed, all of the transmitting and receiving branches of all of the channels of all of the carrier multiplex lines that center in the switching station are permanently connected together by way of frequency selective paths that normally prevent any channel from being in operative relation with any other channel; but which are able, when the proper frequency shifting operations occur under the control of the operators at the distant toll stations, to afford operative connection in any combination desired between the channels of the various lines.

The present invention has for its principal objects the provision of a carrier multiplex communicating system in which station selection is accomplished by shifting the carrier frequency; in which the shifting of the carrier frequency is employed for selecting a particular carrier multiplex line and also for selecting a particular available channel of the selected line; in which the line selecting shift of the carrier frequency is through a relatively slight range and is accomplished by the application of modulating frequencies of a frequency order that permits the ready suppression of undesired products of modulation; in which the modulating frequencies are applied and withdrawn locally in the intermediate or switching station and are not permitted to pass into the carrier multiplex lines extending to the distant toll stations; in which the carrier shifting frequencies are so chosen as to be relatively low in the frequency scale to permit proper

shielding and prevent undue radiation, while at the same time being high enough in the frequency scale to permit the ready suppression of undesired modulation products; in which the successive steps of carrier modulation to effect the desired frequency shift is accomplished with a minimum of modulating apparatus; in which the application of the modulating frequency at the switching station to shift the carrier frequency to select any desired line is accomplished by switching mechanism under the control of the operator at the calling station; in which said switching mechanism operates automatically to select an available channel extending to the called station; in which said switching mechanism acts automatically at the end of its line and channel selecting operation to adapt the incoming carrier frequency of the calling line to the outgoing channel of the called line, and the incoming carrier frequency of the called line to the outgoing channel frequency of the calling line; in which the incoming channel branches are permanently connected with and converge upon a common outlet from which frequency selective branches diverge to the outgoing channel branches of the various carrier multiplex lines; and in which the incoming channel branches are connected with the common outlet through the medium of a conjugate network that insures the uni-directional flow of the voice modulated carriers into the common outlet circuit and prevents the feeding back of the voice modulated carrier of any channel into the incoming paths of the other channels connected with the common outlet.

The foregoing are some of the principal objects that the system of the present invention attains. These and other features are all included in the present embodiment of the invention, but are capable of separate use in systems where it may be desirable to employ only part of the features herein disclosed. The manner in which the above mentioned and other objects and features are attained and realized will be explained in the following description of the preferred form of the invention, and the structures and combinations involved in the realization of the various novel features will be more particularly defined in the appended claims.

The preferred embodiment of the invention is illustrated in the accompanying drawings, in which Figs. 1 to 10, inclusive, taken together and arranged in the manner indicated in Fig. 11, show diagrammatically as much of the apparatus and circuits of the intermediate switching station and of one of the toll stations as is necessary to disclose the manner in which the apparatus and circuits of the entire system may be organized;

in which Fig. 12 shows a somewhat different arrangement of the line selection modulating circuit; and in which Fig. 13 shows a modified arrangement for preventing feedback between the incoming channel branches connected with the common outlet. More specifically, Fig. 1 illustrates the local line and carrier multiplex line terminals at one of the toll stations and the operator's cord circuits for interconnecting the terminals, together with apparatus for producing the required carrier and controlling frequencies; Fig. 2 illustrates the associated channel apparatus at the toll station; Fig. 3 shows the apparatus at the intermediate or switching station for producing the demodulating channel matching and station selecting frequencies, and for modulating certain of the frequencies with a busy tone in connection with the production and transmission of a return busy test signal; Fig. 4 shows the switching station channel apparatus associated with the carrier multiplex line extending to station 1, the organization of channel 1 being shown in full and that of channels 2 and 3 being indicated in outline; Fig. 5 shows in skeleton the switching station channel apparatus associated with the lines extending to station 2 and station 3; Fig. 6 shows the switching station channel apparatus associated with the line extending to station 4, the organization of channel 1 being shown in full and that of channels 2 and 3 being shown in skeleton form; Figs. 7 and 7^A illustrate diagrammatically the step-by-step switches and their circuits and the manner of their association with the twelve channels of the four carrier multiplex lines, which switches are controlled by the operators of the respective lines and in turn control the application of the channel matching and station selecting modulating frequencies; and Figs. 8, 9 and 10 illustrate the conjugate network connecting the incoming or receiving branches of the twelve channels with their common outlet circuit, and the frequency selective branches and frequency reducing apparatus that connect the common outlet with the transmitting or outgoing branches of the different channels of the four carrier multiplex lines.

Reference will first be made briefly to the general organization of the system as shown in the drawings, and then a more detailed description of the system will be given. In the preferred embodiment of the invention illustrated there are four carrier multiplex lines centering in an intermediate or switching station. These lines extend from station 1, station 2, station 3 and station 4, and each may be organized as illustrated in Figs. 1 and 2. At each of the toll stations local lines terminate, and provision is made for establishing connection between these local lines and the various channels of

the carrier multiplex line through the medium of operator's connecting cord circuits. The channel terminals, the local line terminals and the operator's connecting cord circuits all have associated with them appropriate calling and supervisory signals, and the cord circuits are equipped with switches and keys for controlling the connection establishing and disestablishing operations. From each terminal station a toll line extends to the intermediate or switching station; and, as shown in the present embodiment of the invention, each of these toll lines is provided with apparatus to constitute three non-interfering selective channels, which in each case are designated channel 1, channel 2 and channel 3. In the case of all of the toll lines entering the switching station from stations 1, 2, 3 and 4, channel 1 at the switching station in each case is arranged to transmit upon the upper side band of the 10,000 cycle carrier wave and to receive upon the lower side band of the 23,333 cycle carrier wave; channel 2 is arranged to transmit upon the upper side band of the 13,333 cycle carrier and to receive upon the lower side band of the 26,666 carrier; and channel 3 is arranged to transmit upon the upper side band of the 16,666 cycle carrier and to receive upon the lower side band of the 30,000 cycle carrier. At the distant end of each of the toll lines in the present embodiment of the invention, the frequency selective construction and adjustment of the channel apparatus is such that reception is effected upon the same frequency band which is used for transmission at the switching station while transmission at the distant station is effected over the same frequency band that is employed for reception at the switching station. That is, at each of the distant or terminal stations channel 1 receives over the upper side band of the 10,000 cycle carrier and transmits over the lower side band of the 23,333 cycle carrier, channel 2 receives over the upper side band of the 13,333 carrier and transmits over the lower side band of the 26,666 carrier, and channel 3 receives over the upper side band of the 16,666 carrier and transmits over the lower side of the 30,000 carrier.

At the intermediate or switching station, as represented in Figs. 3 to 10, inclusive, means are provided for bringing any channel of any one of the toll lines into communicating relation with any channel of any of the other three toll lines entering the switching station. All of the channels of all of the stations are permanently connected together at the switching station through the medium of an interconnecting network in which are interposed frequency selective devices that permit the establishment of operative relation between any two channels only when certain appropriate frequency changes

are made in the carriers of the two channels that are to be brought into operative relation. These frequency changes are made, in the present embodiment of the invention, through the agency of frequency shifting apparatus including in the receiving or incoming branch of each channel and controlled by the operators at the distant stations through the medium of the switches shown in Figs. 7 and 7^A of the drawing. As indicated there are twelve of these switches, one for each of the three channels of the four toll lines centering in the intermediate or switching station. Each of these switches is capable of being moved selectively into any one of a number of different positions; and in each of its selective positions it controls the energization of relays associated with the calling channel identified with the switch itself and the called channel corresponding to the position to which the switch is moved which relays operate to apply the appropriate modulating frequencies to the frequency shifting apparatus of the two channels. The carrier frequency of the incoming branch of the channel of each line is thus shifted to render it capable of passing through the frequency selective branch to the other line and to the outgoing branch of the proper channel of that line. The modulating frequencies for effecting the line selecting and channel matching shifting of the carriers are produced from a fundamental or base frequency by means of the harmonic generating apparatus illustrated in Fig. 3 of the drawing. The base frequency is applied to all of the carrier multiplex lines centering in the switching station and is thus made available at each of the outlying or toll stations for the harmonic production of identical modulating and demodulating frequencies at all points in the system.

Referring now more in detail to the organization of the system as illustrated in the drawing, the terminal toll station illustrated in Figs. 1 and 2, which may be regarded as typical of the other toll stations of the system, is assumed to have access to and to be accessible by the local telephone lines of an ordinary telephone exchange. These local lines are represented as being of the central energy type and as extending from the local subscribers' stations, as SS, by way of line circuits 101, 102 and 103 to terminal apparatus at the central office. The terminal apparatus of each line is represented as comprising the usual cut-off relay 10, line relay 11 and line lamp LL; and each line is further assumed to be provided with an answering spring jack AJ and one or more multiple spring jacks LMJ. The circuit arrangements of such lines are well known in the art and need not be specifically described. Obviously any other de-

sired type of line for establishing communication between the central office and the subscribers' stations may be substituted for the type of line particularly illustrated.

At the central office or toll station two operators' positions are indicated, and there may be as many operators' positions provided as are required to handle the local and long distance or toll traffic. Each of the two operators' positions illustrated is shown to be provided with a plurality of connecting cord circuits, one connecting circuit at each position being shown substantially complete and another merely indicated by branches from the common leads. Each of the connecting circuits is illustrated as terminating in a local plug LP and a toll plug TP the tip and ring contacts of which are united by means of a pair of talking conductors with an interposed repeating coil RC. Each connecting cord circuit has a local supervisory lamp LSL controlled by the connected local line through the medium of the supervisory relay 12, and a toll supervisory lamp TSL that is under control of the channel with which the associated toll plug TP is brought into connection. Each connecting cord circuit also is provided with a ringing key RK, a listening key LK and a calling key CK. These keys are respectively for the purpose of signaling the local subscribers' stations and bringing the operator's telephone set OTS and the operator's dial OD, common to the cord circuits of each position, into operative relation with the particular cord circuit with which the listening key LK and the calling key CK are associated. The operator's dial OD may be of the well known type disclosed in Patent 1,161,854, issued November 30th, 1915, to O. F. Forsberg. On account of certain speed limiting factors in the circuits controlled by the dial in the present embodiment of the invention, as will appear in the detailed description that follows, the speed governing mechanism of the dial is adjusted so as to retard the rate at which the dial in its operation opens and closes the circuit that it controls.

The carrier multiplex toll line through which the terminal station has communication with the other stations of the carrier multiplex system is generally of the type disclosed in Fig. 49 in the Colpitts and Blackwell paper entitled, "Carrier current telephony and telegraphy", published in the Journal of the American Institute of Electrical Engineers for April, May and June, 1921. Referring to Fig. 2 of the application drawing, the toll line comprises a pair of metallic conductors 104 that enter the terminal station by way of a high frequency hybrid coil HFH—1 provided with the usual network N for balancing the toll line and producing a conjugate relation between the

windings of the coil. From the hybrid coil there is connection by way of the apparatus of channel 1, channel 2 and channel 3 to springjack terminals associated with each of the three channels, these being designated respectively TJ—1, TJ—2 and TJ—3 at operator's position 1 and MJ—1, MJ—2 and MJ—3 at operator's position 2. All of the channel springjacks at the two positions have associated with them busy lamps, designated BL—1, BL—2 and BL—3, respectively, for the three channels; and each of the toll line terminal springjacks at operator's position 1 has also associated with it a calling lamp designated CL—1, CL—2 and CL—3, respectively, for the three channels. The busy lamps, as will be explained, are lighted whenever the corresponding channel is in use for either an outgoing or incoming connection, and the calling lamps CL are lighted by incoming calls over their respective channels.

Associated with each channel there are two relays 15 and 16 responsive to the insertion of a plug in one of the corresponding channel spring jacks and controlling the energization of the carrier channel and the application to the carrier of the low controlling frequency; a relay 17 that responds to the condition of use of the channel and causes the lighting of the associated busy lamps; a relay 18 that responds to the application of the calling frequency at the distant end of the channel and controls the calling, supervisory and busy lamps; and two relays 19 and 20 that operate under the control of the other relays to energize the transmitting branch of the channel and apply to it the carrier frequency and the low calling and controlling frequency. The high frequency hybrid coil HFH—1 of the toll line has a main transmitting branch and a main receiving branch, and from each of these main branches there is a sub-branch to each of the three channels. Interposed in each of these sub-branches is a band filter, BF—1, BF—2, BF—3, BF—4, BF—5 and BF—6, respectively, so constructed and adjusted as to pass the frequency bands comprising in each case the appropriate sideband of the modulated carrier wave of the frequency respectively indicated by the numerals associated with the rectangles representing these filters, the frequency bands for the various channels being in accordance with what has already been stated in connection with the general description of the drawing. These and other band filters designated as BF throughout the system are of the general type disclosed in Patent 1,227,113, issued May 22, 1917, to G. A. Campbell and also described with respect to the specific manner in which they are used in a carrier multiplex system of this type, in the Colpitts and Blackwell paper that has been

referred to. The organization of only one of the three channels, channel 1, is illustrated in Fig. 2. The other two channels are organized in the same manner as channel 1 excepting in the matter of the specific frequency values on which they are designed to operate, and are merely indicated by broken line rectangles. As specifically illustrated in the case of channel 1, the frequency band that passes through the band filter BF—2 included in the receiving branch is carried into the balanced detector BD—1 where it is joined by the corresponding carrier frequency selected from the common distributing circuit 105 by the tuned circuit TC—4. Demodulation takes place in the balanced detector BD—1, and the products of demodulation are amplified in the amplifier A—4 and are carried to the low pass filter LPF—1 and the band filter BF—8. The low pass filter LPF—1, in the present instance, is constructed and adjusted to have an upper cut-off limit of 200 cycles per second and the band filter BF—8 is constructed and adjusted to pass with substantially negligible attenuation a frequency band extending preferably from 300 to 2300 cycles per second. The relatively low calling and controlling frequency conveyed by the carrier passes through the low pass filter LPF—1, is rectified and amplified in the rectifier R—1 and energizes the relay 18. The essential voice frequencies pass through the band filter BF—8 and are carried to the mid-points of the line windings of the low frequency hybrid LFH—1. One end of the line windings of the low frequency hybrid coil is connected through condensers with a low frequency balancing network N and the other end is connected through condensers and through an artificial line AL—1 of the well-known H type by way of conductors 50 and 51 to the tip and ring or talking springs of springjack TJ—1, and also to the corresponding springs of such other multiple springjacks MJ—1 as may be associated with this particular channel.

The series winding of the low frequency hybrid LFH—1 is connected by way of the band filter BF—7 with the primary winding of the transformer 21. The band filter BF—7 is of the Campbell type previously referred to, and is constructed and adjusted to pass a band of frequencies ranging from 300 to 2300 cycles per second and to cut off frequencies below and above these limits. The outer terminals of the secondary winding of the transformer 21 are connected respectively with the grids of the two thermionic vacuum tubes of the balanced modulator BM—1, and the inner ends of the two halves of the secondary winding of the transformer are connected with movable contact points of the potentiometer 22, the mid-point of which is connected by way of the "C" bat-

tery and the potentiometer 23 with ground and the positive terminal of the filaments of the two thermionic tubes of the balanced modulator BM—1. The potentiometer 22 serves to apply to the grids of the balanced modulator tubes at the proper potential the 150 cycle calling and controlling frequency, and the potentiometer 23 serves to apply to the grids of the balanced modulator tubes at the proper potential the carrier frequency which this channel is adapted to employ for transmitting purposes, in the present instance of frequency of 23,333 cycles per second. The organization of the modulator BM—1 is in accordance with the disclosure of Patent 1,343,306, issued June 15, 1920, to J. R. Carson, the modulator being of what is commonly known as the balanced or carrier suppression type. That is, the effect of the potential variations in the divided input circuit of the modulator is balanced and neutralized in the output circuit excepting when the low frequency voice current fluctuations are impressed by way of the band filter BF—7 and the transformer 21 or when the low frequency calling or controlling current variations are impressed by way of the potentiometer 22. In either of these cases the fluctuations in the output circuit of the modulator are no longer balanced and consequently oscillations are produced in the output circuit having an amplitude proportional to the instantaneous value of the low frequency speech or low frequency controlling modulating currents. The movable points of the potentiometer 22 are so placed that the amplitude of the voltages impressed upon the grids by the low frequency controlling current are properly proportioned to the amplitudes of the other voltages impressed upon the grids, and also so that the voltages impressed upon the grids by the carrier current flowing in the potentiometer 23 are of equal value.

The 150 cycle control frequency is derived from the common distributing circuit 106 by way of a tuned circuit TC—2, the connection with the primary side of the tuned circuit being controlled by normally open contacts of the relay 19, and the secondary side of the tuned circuit being connected with the extremities of the potentiometer 22. The tuned circuit acts not only to insure the application to the balanced modulator BM—1 of the pure control frequency, but also to prevent the backing up into the common distributing circuit 106 of the other frequencies that are present in each of the balanced modulator circuits, namely, the carrier frequency of each of the various channels and the voice frequencies with which the carrier is to be modulated. The carrier wave employed in the transmitting branch of the channel is derived from the common

distributing circuit 105 by way of a tuned circuit TC—3 which is constructed and adjusted to be selective of the particular carrier frequency that the channel employs.

5 The connection with the primary side of the tuned circuit TC—3 is controlled by normally open contacts of the relay 20, and the secondary side of the tuned circuit has connection with the extremities of the potentiometer 23.

10 The output side of the balanced modulator BM—1 is connected by way of the windings of the transformer 24 and a high pass filter HPF—1 with the input side of the
15 balanced amplifier BA—1. The high pass filter HPF—1 acts to prevent the passage of the amplified and unmodulated low controlling and voice frequencies to the balanced amplifier BA—1 in order to prevent
20 these frequencies from overloading the amplifier. The balanced amplifier BA—1 is of the so-called "push-pull" type as illustrated and described in connection with Fig. 49 of the Colpitts and Blackwell paper here-
25 inbefore referred to, and the high pass filter HPF—1 is of the sort also illustrated and described in the Colpitts and Blackwell paper. The output of the balanced ampli-
30 fier BA—1 is connected by way of the band filter BF—1 with the main transmitting branch that joins the various channel trans-
mitting branches with the high frequency hybrid coil HFH—1.

35 As the tubes of the balanced modulator BM—1 and the balanced amplifier BA—1 are required to be active only when the associated channel is in use, the circuit of the A battery for heating the filaments of the tubes is controlled in contacts of the relay 20
40 which are normally open and are closed only when the relay 20 is energized by the taking of the channel for use. The circuit of the A battery is illustrated as extending in parallel branches to the filaments of the balanced
45 modulator and amplifier tubes; but it will be understood that this is merely a diagrammatic showing, and that the energizing circuits of the filaments of the tubes may be connected with each other and the associated
50 circuits in accordance with the standard practice of the wiring of these devices. Inasmuch as it is desirable that the receiving branches of the various channels be normally
55 in a responsive condition in order that they may constantly be in readiness to respond to a call originated at a distant station, it is assumed that the thermionic tubes associated with the receiving branches have their fila-
60 ments normally energized, and therefore the A battery circuit for these tubes and means for controlling it are not shown.

65 The apparatus by means of which the carrier frequencies for use in the various channels are produced is shown diagrammatically at the bottom of Fig. 1 of the drawing.

The receiving branch that extends from the high frequency hybrid coil HFH—1 to the receiving branches of the various channels also has another branch that has interposed in it a tuned circuit STC—1 which is tuned
70 to permit the passage through it of the base frequency of 3,333 cycles per second supplied over the carrier multiplex toll line from one of the remote stations, as will be described, and also includes a shunt made
75 anti-resonant to the 3,333 frequency and which therefore permits the substantially unattenuated passage of the other frequencies in the series circuit of the high frequency hybrid coil receiving branch. The
80 tuned circuit STC—1 is connected by way of conductors 107 with the input circuit of the amplifier A—2 (Fig. 3) and the output circuit of the amplifier is connected with the
85 input circuit of harmonic generator HG—1. The output circuit of the harmonic generator is connected with the input circuit of the amplifier A—3 and the output circuit of
90 amplifier A—3 is connected with the distributing circuit 105. This train of apparatus acts to generate and amplify a series of harmonics of the base frequency 3,333 in the manner described in the Colpitts and
95 Blackwell paper previously referred to, the nature and arrangement of the apparatus being in accordance with the disclosure contained in U. S. patent to Burton W. Kendall
1,446,752 dated February 27, 1923.

The low control frequency, 150 cycles per second in the present embodiment of the invention, is produced in the oscillator O—1 (Fig. 1), which oscillator may be of any usual and well known thermionic type with a feed back connection from its output into
into its input circuit. This sinusoidal oscillations produced in the oscillator O—1 are amplified in the amplifier A—1 and thence
pass through the tuned circuit TC—1, which serves to suppress the undesired frequencies, to the primary winding of the transformer
14. This transformer is provided with a grounded shield between the primary and secondary windings to prevent unbalance to
ground through the transformer of the two sides of the distributing circuit 106 which
is connected with the secondary winding of the transformer. The distributing circuit
106, as has been described, has branch connections with the different channels through
which the 150 cycle control frequency is supplied for the modulation of the channel
transmitting branch carriers under the control of relays such as relay 19 of channel 1.

The organization of the circuits and apparatus at the intermediate or switching station will now be described by reference to Figs. 3 to 10, inclusive, of the drawing. Fig. 4 shows in detail the organization at the switching station of channel 1 of the carrier multiplex line extending to station 1

and Fig. 6 shows in detail the organization at the switching station of channel 1 of the carrier multiplex line extending to station 4, only enough of the organization of the other two channels of each of these lines being shown to illustrate the connection of the carrier shifting modulating frequencies to the channel apparatus. In like manner Fig. 5 shows only enough of each of the three channels of each of the carrier multiplex lines extending to station 2 and station 3 to illustrate the connection of the carrier shifting modulating frequencies with these channels. Except in the matter of the particular carrier shifting frequencies that are made available for use in connection with each of the channels, the channels are all identical in their organization. Channel 1 of the line extending to station 1 and channel 1 of the line extending to station 4 are shown in full in order that a connection established between two stations may more readily be traced and understood. Inasmuch as the switching station organizations of the different carrier multiplex lines are the same excepting in the matter of the different carrier frequencies upon which the channels are adapted to operate and the carrier shifting modulating frequencies applied to them, a description of the organization of the carrier multiplex line illustrated in Fig. 4 and of channel 1 of this line will suffice for all of them.

The conductors 104 of the toll line are connected with the main receiving branch 125 and the main transmitting branch 126 by means of the group filters GF—1 and GF—2 respectively. The group filters GF—1 and GF—2 are of the type disclosed in the Campbell patent previously referred to. The filter GF—1 is constructed and adjusted to pass a frequency band extending from 21,000 to 30,000 cycles and the filter GF—2 is constructed and adjusted to pass a frequency band extending from 3,000 cycles to 19,000 cycles. Each group filter excludes the frequencies that the other group filter passes, thereby preventing any local communication of energy from the main transmitting branch to the main receiving branch by way of the group filters. If desired this result may be accomplished by the use of a high frequency hybrid coil with a balancing network, such as is shown in association with the other end of the carrier multiplex line in Fig. 2; or separating group filters as shown in Fig. 4 may be used at both ends of the line.

The main receiving branch conductors 125 are connected by way of band filters BF—9, BF—11 and BF—13 with the receiving branches of channels 1, 2 and 3 respectively; and the main transmitting branch conductors 126 have connection by way of band filters BF—10, BF—12 and

BF—14 with the transmitting branches of channels 1, 2 and 3 respectively. The main transmitting branch 126 also is connected through the medium of the band filter BF—19 with the apparatus illustrated in Fig. 3 that generates the base frequency of 3,333 cycles per second. All of these band filters are of the type disclosed in the Campbell patent previously referred to.

Referring now to the typical channel circuit arrangement illustrated in connection with channel 1 of Fig. 4, the receiving branch extends from the band filter BF—9 to the series input circuit of the balanced modulator BM—2. The balanced modulator BM—2 is of the type disclosed in Patent 1,343,306 to Carson previously referred to, in which the currents to be modulated are applied serially to the input circuit of the two thermionic tubes of the modulator and the modulating frequencies are applied by way of the common portion of the divided input circuit of the two tubes. In the case of channel 1 the currents that are communicated to the series input circuit of the balanced modulator BM—2 are the currents comprised in the lower side band of the 23,333 cycle carrier that passes through the receiving branch band filter BF—9; and the modulating currents supplied to the thermionic tubes of balanced modulator BM—2 in parallel are the harmonic modulating frequency of 23,333 cycles, corresponding to the carrier frequency of this particular receiving branch, and one or another of the harmonic modulating frequencies of 33,333 cycles, 36,666 cycles or 40,000 cycles, depending upon the particular called line channel the frequency of which is to be matched. The 23,333 cycle demodulating frequency and the particular desired one of the other three channel matching or carrier shifting frequencies are supplied to the parallel input circuit of the balanced modulator BM—2 through the medium of the high frequency hybrid coil HFH—2. One end of the line windings of the high frequency hybrid coil is connected with the parallel input circuit of the balanced modulator and the other end of the line windings is connected with a balancing net or impedance N the value of which is so chosen as to balance the impedance of the input circuit of the balanced modulator. The mid-points of the high frequency hybrid coil HFH—2 are connected with the 23,333 cycle distributing circuit 109, and the series winding of the high frequency hybrid coil is connected with a circuit having branches extending to normally open front contacts of the relays 61, 62 and 63. These three relays have their armatures connected respectively with the 33,333 cycle distributing circuit 112, the 36,666 cycle distributing circuit 113 and the

40,000 cycle distributing circuit 114. The back or resting contacts of each of the three relays 61, 62 and 63 are connected with the balancing impedances 64, 65 and 66 respectively, these impedances being of a magnitude to match the corresponding impedances introduced into the associated distributing circuits when the relays 61, 62 or 63 are operated to connect with their corresponding distributing circuits with the series windings of the high frequency hybrid coil HFH—2. This is in order that the impedance of each distributing circuit, looking out from the associated band filter of Fig. 3, may remain substantially constant regardless of the condition of use or disuse of the various distributing circuit branches. The interposition of the high frequency hybrid coil HFH—2 in the circuit between the parallel input circuit of the balanced modulator BM—2 and the two harmonic frequency modulating branches that are adapted simultaneously to feed modulating high frequency currents to the balanced modulator, maintains a conjugate relationship between the two branches so that while each branch feeds its particular frequency into the input circuit of the balanced modulator neither branch communicates its frequency in any substantial amount to the other branch.

The modulating action which takes place in the balanced modulator BM—2 may now be briefly considered. The lower side band of the 23,333 cycle carrier that is applied to the series input circuit of the balanced modulator BM—2 is modulated by the 23,333 cycle harmonic frequency and also by one or another of the three harmonic frequencies 33,333, 36,666 or 40,000, depending upon which of the relays 61, 62 or 63 is actuated to close its front contacts. Considering first the modulation of the lower side band of the 23,333 cycle carrier by the 23,333 cycle harmonic frequency supplied through the hybrid coil HFH—2, the products of modulation which appear in the output circuit of the balanced modulator are primarily the amplified 23,333 cycle side band and the sum and difference products of modulation of this side band with the 23,333 cycle harmonic frequency. The sum product of modulation is the lower side band of the 46,666 cycle frequency. The difference product of modulation is the relatively low frequency with which the 23,333 cycle carrier was modulated at the distant toll station to produce the side band that is passing through the band filter BF—9. In the output circuit of the balanced modulator BM—2 are the Campbell type band filter BF—15 and low pass filter LPF—2, filter BF—15 being constructed and adjusted to pass a band of frequencies ranging from 10,000 to 19,000 cycles and the filter LPF—2

being constructed and adjusted to pass a band of frequencies ranging from 0 to 150 cycles inclusive. Therefore, the controlling frequency of 150 cycles with which the carrier during the use of the channel is modulated at the distant toll station, is reproduced by demodulation in the balanced modulator BM—2 and flows from the modulator output circuit by way of the low pass filter LPF—2. All of the other products of modulation produced in the balanced modulator BM—2 by the modulation of the 23,333 cycle lower side band with the 23,333 cycle harmonic frequency are above and outside the range of both the filters BF—15 and LPF—2 connected with the modulator output circuit. Furthermore, the speech frequencies produced by this modulating action are limited to a range between 300 cycles and 2300 cycles, and are therefore above the upper cut-off limit of low pass filter LPF—2 and are below the lower cut-off limit of band filter BF—15. Therefore, the only frequencies resulting from modulation by the 23,333 cycle frequency that can pass from the output circuit of the modulator BM—2 is the 150 cycle controlling frequency.

Substantially the same action as that described above occurs in each of the switching station receiving channel branches of all of the carrier multiplex lines when the corresponding channels are in use, as each channel has constantly applied to the parallel input circuit of its associated balanced modulator BM—2, the harmonic demodulating frequency corresponding to the carrier frequency of that channel. Therefore, in each case, the application of the 150 cycle controlling frequency at the toll terminal station of the channel results in the reproduction of that frequency in the output circuit of the associated balanced modulator BM—2 at the switching station, and the passage of the reproduced 150 cycle controlling frequency through the associated low pass filter LPF—2.

After passing through the low pass filter, the reproduced 150 cycle controlling frequency is amplified in the amplifier A—5, and after rectification in the rectifier R—2 is effective to control the operation of the relay 25 for purposes that will hereinafter appear.

Returning now to a consideration of the action that occurs in balanced modulator BM—2 as a result of the modulation of the 23,333 cycle carrier lower side band by the harmonic frequencies applied under the control of relays 61, 62 and 63, it may be said in the first place that if the modulator carrier of channel 1 is to be matched with the frequency of channel 1 of another line, relay 61 is operated to apply the 33,333 cycle harmonic frequency; if the modulated car-

rier of channel 1 is to be matched with channel 2 of another line, relay 62 is operated to apply the 36,666 cycle harmonic frequency; and if the modulated carrier of channel 1 is to be matched with channel 3 of another line, relay 63 is operated to apply the 40,000 cycle harmonic frequency. Assuming in the first place that the modulated 23,333 cycle lower side band of channel 1 is to be matched with channel 1 of another line, it is necessary to change the lower side band of the 23,333 cycle carrier to the upper side band of the 10,000 cycle carrier, the latter being the side band that the outgoing or transmitting branch of each of the channels 1 is adapted to pass by way of its band filter BF—10. In this case, as indicated above, the relay 61 is operated to apply the 33,333 cycle harmonic frequency to the parallel input circuit of the balanced modulator BM—2. The sum and difference products of modulation of the lower side band of the 23,333 cycle carrier with the 33,333 cycle harmonic frequency appear in the output circuit of the balanced modulator. The upper side band based upon the 10,000 cycle frequency appears as the difference product of modulation in the output circuit of the modulator and this modulation product is within the frequency range of the band filter BF—15 connected with the modulator output circuit, and therefore passes through the filter. The sum production of modulation is the lower side band based upon a frequency of 56,666 cycles, which is outside the frequency range of the filter BF—15, and is therefore suppressed. All other products of modulation that appear in the output circuit of the modulator in any substantial amount are also outside the range of the filters connected with the output circuit and are therefore suppressed, so that the upper side band based upon the 10,000 cycle frequency is the only modulation product that is able to pass.

If it is assumed that the lower side band of the 23,333 cycle carrier of channel 1 is to be matched with channel 2 of the other line, then relay 62 is operated to apply the 36,666 cycle harmonic frequency to the balanced modulator. The difference produce of modulation of the 23,333 cycle lower side band and the 36,666 cycle harmonic frequency is the upper side band based upon the 13,333 cycle frequency. This corresponds with the frequency that the band filter BF—12 in the transmitting branch of channel 2 of the other line is constructed and adjusted adapted to pass, and is also within the range of the band filter BF—15 connected with the output circuit of balanced modulator BM—2. Therefore, this modulation product with its speech or voice frequency component passes through the band filter BF—15, while all of the other modulation products that

appear in any substantial amount in the output circuit of the balanced modulator are outside the range of the filter BF—15 and are suppressed.

If the lower side band of the 23,333 cycle carrier of channel 1 is to be matched with channel 3 of the other line, relay 63 is operated to apply the 40,000 harmonic frequency to the balanced modulator BM—2. The difference product of modulation of the lower side band of the 23,333 cycle carrier and the 40,000 harmonic modulating frequency is the upper side band based upon the 16,666 cycle frequency. This is the frequency that the band filter BF—14 of the transmitting branch of each of the channels 3 of the various lines is adapted to pass, and is also within the frequency range of the band filter BF—15 connected with the output circuit of balanced modulator BM—2. All of the other modulation products that appear in the modulator output circuit in substantial amounts are outside of the frequency range of filter BF—15, and are therefore suppressed.

The same principle as that outlined in the foregoing applies in the case of the matching of the receiving branch carrier side bands of channel 2 with the transmitting branches of channels 1, 2 and 3 of other lines, and in the matching of the receiving branch carrier side band of channel 3 with the transmitting branches of channels 1, 2 and 3 of the other lines. That is, in each case the particular one of the relays corresponding with the previously mentioned relays 61, 62 and 63 is operated which applies that harmonic frequency, the difference modulation product of which with the receiving branch carrier side band is such as to result in the production of a side band corresponding with the frequency that the band filter in the transmitting branch of the matched channel of the other line is adapted to pass. Thus in the case of channel 2, the receiving branch carrier side band of which is the lower side band of the 26,666 cycle frequency, the matching of the 26,666 lower side band with channel 1 of another line is accomplished by applying the 36,666 cycle harmonic frequency to the balanced modulator to give the upper side band based on the 10,000 cycle frequency; the matching of channel 2 with channel 2 of the other line is accomplished by applying the 40,000 cycle harmonic frequency to produce the upper side band based upon the 13,333 cycle frequency, and the matching of channel 2 with channel 3 is accomplished by applying the 43,333 cycle harmonic frequency to produce the upper side band based upon the 16,666 cycle frequency. In the case of channel 3 in which the lower side band of the 30,000 cycle carrier is employed in the receiving branch of the channel, the match-

ing with channel 1 is effected by applying the 40,000 cycle harmonic frequency to the balanced modulator to produce in the output circuit the upper side band based upon the 10,000 frequency, the matching of channel 3 with channel 2 is effected by applying the 43,333 cycle harmonic frequency to produce the upper side band based upon the 13,333 cycle frequency, and the matching of channel 3 with channel 3 of the other line is effected by applying the 46,666 cycle harmonic frequency to produce in the output circuit of the modulator the upper side band based upon the 16,666 cycle frequency.

In each case the application of these carrier shifting or changing harmonic frequencies to the balanced modulator of the receiving branch of the associated channel is accomplished under the control of three relays corresponding with relays 61, 62 and 63 of Fig. 4, one or another of which is energized to apply its corresponding harmonic frequency, depending upon the particular channel that is to be matched with the channel with which the relays are associated. These three relays for each of the channels of each of the carrier multiplex lines and their relationship with the harmonic frequency distributing circuits are shown in full in connection with channels 1 of the lines extending to station 1 and station 4, and are indicated in connection with all of the other channels of the four lines on Figs. 4, 5 and 6 of the drawing.

Continuing the description of the organization of channel 1 shown on Fig. 4 of the drawing, which channel may be regarded as typical of the other channels, the particular upper side band based on the 10,000 cycle, the 13,333 cycle or the 16,666 cycle carrier produced by modulation in the balanced modulator BM—2 and transmitted through the band filter BF—15, flows to the parallel input circuit of the balanced modulator BM—3. The balanced modulator BM—3 is of the carrier suppression type disclosed in the Carson patent previously referred to, and the parallel input circuit of the two thermionic tubes of this device is adapted to receive current not only by way of the band filter BF—15 mentioned above, but also by way of the band filter BF—18. The band filter BF—18 is of the Campbell type and is constructed and adjusted to pass a band of frequencies extending from 220,000 to 300,000 cycles inclusive. Inasmuch as the frequency range of the band filter BF—15 is from 10,000 to 19,000 cycles, each filter excludes from its associated circuits the frequencies that the other filter passes.

The frequencies that the band filter BF—18 is adapted to carry are produced in the balanced modulator BM—4, which is also of the Carson carrier suppression type. The

modulation products generated in the balanced modulator BM—4 are produced, in the present instance, by the combination of a 300,000 cycle frequency supplied from the distributing conductors 127 with one or another of the three frequencies 53,333 cycles, 66,666 cycles or 80,000 cycles supplied from the distributing circuits 122, 123 and 124, respectively, the particular one of the three last mentioned frequencies that is combined with the 300,000 cycle frequency depending upon which one of the controlling relays 72, 73 and 74 is operated at the time when relay 70 controlling the application of the 300,000 cycle frequency is operated. The 300,000 cycle frequency is applied to the series input circuit of the balanced modulator BM—4, and the particular one of the other three frequencies that is chosen for use is applied to the parallel input circuit of the balanced modulator. The adjustment of the band filter BF—18 is such that the difference products of modulation of the 300,000 frequency with the particular other frequency will pass through it together with the amplified 300,000 frequency itself; and these frequencies, together with the frequency that flows through the band filter BF—15 associated with balanced modulator BM—2 are applied to the parallel input circuit of balanced modulator BM—3. The parallel output circuit of balanced modulator BM—3 has connection by way of band filter BF—16 with the series input circuit of the balanced modulator BM—3, the band filter BF—16 being constructed and adjusted to pass a band of frequencies with a lower cut-off limit of approximately 310,000 cycles and an upper cut-off limit of approximately 320,000 cycles. The frequencies that are applied to the series input circuit of balanced modulator BM—16 by way of band filter BF—16 intermodulate with the frequencies applied to the parallel input circuit by way of band filter BF—15 and band filter BF—18, and among the products of modulation are certain voice modulated frequencies that are within the range of 50,000 to 100,000 cycles inclusive of the band filter BF—17 connected with the series output circuit of balanced modulator BM—3. These voice modulated frequencies pass into the network illustrated in Figs. 8, 9 and 10 of the drawing, from which they are directed into the proper channels of the various lines by means of frequency selective apparatus which will be described hereinafter.

The function of the apparatus including the balanced modulators BM—3, BM—4 and the band filters BF—16, BF—17 and BF—18 is to effect a frequency changing or shifting of the voice modulated carriers such as to direct the speech side band into the particular frequency selective branch associated with the particular carrier multiplex line with which

interconnection is desired. It may be well at this point to describe how this function is performed. In a previously filed application of the present applicant, Serial No. 621,635, filed February 27, 1923, the interconnection of a plurality of carrier multiplex lines centering in a common switching station was accomplished by means of switches under the control of the distant toll line operators, upon the stationary and movable contacts of which switches the transmitting and receiving branches of each of the channels of the various lines terminated, so that in the operation of the switches the channels were brought directly into connection with each other in any combination desired. In the system of the present application one of the objects of the invention, as hereinbefore stated, is to provide for the interconnection of the channels of the various lines in any way desired without the use of switches or moving contacts of any sort in the direct communicating circuits of the channels. To this end, as will hereinafter appear, communication with the outgoing channel branches of each carrier multiplex line can be established at the switching station only at a certain frequency level which is different from the frequency level at which communication is established with the outgoing channel branches of each other carrier multiplex line. Therefore, the selection of any line by any other line in establishing intercommunication between them is accomplished by stepping up the voice modulated carrier of each of the two lines that are to be interconnected to the frequency level that permits it to pass into the outlet path to the other line, after which the frequency level is reduced by an equal amount to bring the frequency of the voice modulated carrier within the range of the filters in the transmitting branches of the various channels of the other line.

In order to avoid the difficulties that arise from energy radiation and attendant cases and interference effects when the higher frequencies are employed in circuits in close physical relation with each other, it is desirable to accomplish the frequency shifting of the carrier bands by means of modulating frequencies that are as low as possible consistent with the avoidance of other complications attendant upon the necessary selection of certain modulation products and the exclusion of other modulation products generated in the output circuits of the modulators. Obviously it is possible to effect the line selection by means of carrier side band elevation within a rather wide range of frequencies, and still come within the requirements outlined above with respect to the avoidance of objectionable energy dissipation and interference and the ability to suppress undesired modulation products. In the present embodiment of the invention, line selection by carrier side band frequency shifting is accomplished in a range of frequencies extending between 50,000 cycles and 100,000 cycles per second. In the system as disclosed, the frequency range of the band filter which admits the carrier side bands to the channels of line 1 is 49,000 to 59,000 cycles. The frequency range of the filter that admits the carrier side bands to the channels of line 2 is 63,000 to 73,000 cycles; the frequency range of the filter that admits the carrier side bands to the channels of line 3 is 76,000 to 86,000 cycles; and the range of the filter that admits the carrier side bands to the channels of line 4 is 89,000 to 99,000 cycles. These filters are shown in Fig. 9 of the drawings and are designated BF-35, BF-36, BF-37 and BF-38, respectively. In the present embodiment of the invention, therefore, in order to direct a particular carrier side band to the channels of a particular line, it is necessary to modulate the side band by means of a modulating frequency so chosen that one of the modulation products with a speech or voice frequency component shall lie within the frequency range of the particular one of the band filters BF-35, BF-36, BF-37 or BF-38 associated with the desired line. Take, for instance, the case of channel 1 of line 1 illustrated in Fig. 4 of the drawing, if the carrier side band that enters balanced modulator BM-3 by way of band filter BF-15 is to be directed into the channels of line 2, the necessary modulating frequencies are produced by causing the operation of the associated relays 70 and 72; if it is to be directed to the channels of line 3 the necessary modulating frequencies are produced by causing the operation of relays 70 and 73; and if it is to be directed to the channels of line 4 the necessary modulating frequencies are produced by causing the operation of relay 70 and 74. Obviously, in the present embodiment of the invention, it never is necessary to direct the carrier side band of any channel of a given line back into another channel of the same line, and consequently no provision is made for raising the carrier side band of any line channel to the frequency elevation corresponding to the range of the selecting filter of that line.

In order to explain the modulating actions which occur in directing a carrier side band to a particular line by shifting its position in the frequency scale, we may consider the specific case where channel 1 of line 1 (Fig. 4) is to be connected with channel 1 of line 4 (Fig. 6). As the transmitting or outgoing branch of channel 1 of line 4 is adapted for operation upon the upper side band of the 10,000 cycle carrier, the lower side band of the 23,333 cycle car-

rier flowing in the incoming or receiving branch of channel 1 of line 1 is first acted upon in the balanced modulator BM—2 as hereinbefore described, to change it to the
 5 upper side band of the 10,000 cycle carrier, which side band then passes through band filter BF—15 to the parallel input circuit of balanced modulator BM—3. Here it is joined by the products of
 10 modulation which pass from the output circuit of balanced modulator BM—4 through the band filter BF—18. Inasmuch as the carrier side band is to be directed to one of the channels of line 4, relays 70
 15 and 74 associated with balanced modulator BM—4 are operated. Relay 70 in operating applies the 300,000 cycle frequency to the series input circuit of modulator BM—4, and relay 74 in operating applies the 80,000
 20 cycle frequency to the parallel input circuit of modulator BM—4. Consequently there appear in the output circuit of the modulator the amplified 300,000 cycle frequency applied to the series input circuit and the
 25 sum and difference modulation products of the 300,000 frequency and the 80,000 frequency. The sum product of modulation of these two frequencies is 380,000 cycles, which is outside the range of band filter
 30 BF—18 which is constructed and adjusted to pass frequencies from 220,000 to 300,000, inclusive. But the difference modulation product of the two frequencies applied to the input circuit is 220,000 cycles, which
 35 is within the range of and therefore passes through the band filter BF—18. The amplified 300,000 cycle frequency also passes through filter BF—18, and the other modulation products are outside the range of the
 40 filter and are therefore suppressed. As a result, under the conditions assumed, three frequencies are applied to the parallel input circuit of balanced modulator BM—3, these frequencies being the 220,000 and
 45 300,000 cycle frequencies that flow through band filter BF—18, and the upper side band of the 10,000 cycle carrier that flows to the input circuit by way of filter BF—15. These three frequencies now all inter-modulate, and produce in the output circuit of the balanced modulator BM—3 a multiplicity
 50 of modulation products. Inasmuch as the transformer windings in the series output circuit of balanced modulator BM—3 are opposed or differential with respect to each other, the modulation products produced by the three frequencies simultaneously applied to the parallel input circuit of balanced
 55 modulator BM—3 balance or neutralize each other. However, their exclusion from the path leading from the series output circuit of balanced modulator BM—3 is not entirely due to the neutralizing or balancing action within the modulator, for the reason
 65 that all of the products of modulation in

this first stage of the modulating action are outside the range of band filter BF—17 interposed between the modulator series output circuit and the continuation of the channel conductors. That is, all of the
 70 modulation products of the three frequencies referred to, even though they are not perfectly balanced or neutralized in the output circuit of the modulator, are below the lower cut-off limit of 50,000 or above the
 75 upper cut-off limit of 100,000 of the band filter BF—17.

With respect to the parallel output circuit of the two thermionic tubes of the balanced modulator BM—3, the products of
 80 the three frequencies referred to are additive or cumulative. But interposed in the parallel output circuit of the modulator is a band filter BF—16 constructed and adjusted to pass a range of frequencies from 310,000
 85 to 320,000 cycles, inclusive. Of all the multiplicity of modulation products produced in any substantial quantity in the first stage of modulation of balanced modulator BM—3, there is in the case assumed, only one
 90 frequency which is within the frequency range of band filter BF—16, this frequency being the upper speech side band based upon a frequency of 310,000 cycles. The upper side band of the 310,000 cycle frequency
 95 therefore is applied to the series input circuit of balanced modulator BM—3, and a second stage of modulation occurs in which the upper side band of the 310,000 cycle frequency intermodulates with the
 100 three frequencies that are being applied to the parallel input circuit of the modulator, namely, with the 220,000 cycle frequency, the 300,000 cycle frequency and the upper side band of the 10,000 cycle carrier. Another
 105 multiplicity of modulation products results in the output circuit of the balanced modulator BM—3. Of these modulation products a part are balanced out or neutralized in the parallel input circuit of the modulator, and those which are not thus neutralized in this circuit are outside the frequency range of the band filter BF—16 and are suppressed in that filter. Others of the
 115 modulation products are neutralized in the differential or opposed transformer windings in the series output circuit of the balanced modulator, and of the products that are not thus neutralized in the series output circuit all with a single exception are outside the 50,000 to 100,000 cycle range of the band filter BF—17 interposed in the series
 120 output circuit. This single exception is the upper speech frequency side band based upon the 90,000 cycle frequency. Therefore, the effect of the operation of the group of apparatus including the balanced modulators BM—3 and BM—4 and the band filters BF—16, BF—17 and BF—18 is, under
 125 the particular conditions assumed, to shift

the upper speech frequency side band that enters by way of band filter BF—15 from the 10,000 cycle to the 90,000 cycle elevation and to permit its passage through the band filter BF—17. The frequency of the speech side band is thus raised to a level where it is capable of passing through the 89,000 to 99,000 cycle band filter BF—38 associated with line 4 (Fig. 9) and is excluded from the band filters BF—35, BF—36 and BF—37 of the other lines. The frequency transforming sub-combination the operation of which has just been described is specifically claimed in the co-pending joint application of J. F. Farrington and myself, Serial No. 654,104, filed July 27, 1923.

If the interconnection is to be between channel 1 of line 1 and channel 2 of line 4, the transmitting branch of which latter channel is adapted to operate on the upper side band of the 13,333 cycle carrier, the action is the same as that described above, excepting that it is the 13,333 cycle carrier side band that intermodulates with the 300,000 cycle and 220,000 cycle modulating frequencies in balanced modulator BM—3, the upper side band of the 13,333 cycle frequency which passes back into the series input circuit of the balanced modulator by way of band filter BF—16, and the upper side band of the 93,333 cycle frequency which passes out by way of the band filter BF—17. Similarly if channel 1 of line 1 is to be interconnected with channel 3 of line 4, it is the upper side band of the 16,666 cycle carrier that enters the parallel input circuit of balanced modulator BM—3 together with the 300,000 and 320,000 cycle modulating frequencies, the upper side band of the 316,666 cycle frequency which re-enters the modulator by way of band filter BF—16, and the upper side band of the 96,666 cycle frequency which passes out by way of band filter BF—17. In each case all of the other products of modulation are neutralized in the modulator or suppressed in the band filters or both.

It will be observed that in the modulating action that has been described the effect is to raise the carrier side band in the first stage of modulation in balanced modulator BM—3 by an additional 300,000 cycles in the frequency scale, and then immediately, in the second stage of modulation in the same modulator, to depress it by an amount that leaves its net elevation in the frequency scale at a point where the side band is capable of passing through the line selecting band filter associated with the particular line with which communication is to be established. The net elevation of the carrier side band where, as in the present instance, communication is to be established with line 4, is the difference between the 300,-

000 cycles and the 220,000 cycles applied to the parallel input circuit of balanced modulator BM—3, or 80,000 cycles, which is the frequency determined by the operation of relay 74 associated with balanced modulator BM—4. Where it is line 3 with which connection is to be established, relay 73 is operated to effect the modulation in modulator BM—4 of the 300,000 cycle frequency with the 66,666 cycle frequency supplied by distributing circuit 123. In this case the two modulating frequencies that are applied to the parallel input circuit of balanced modulator BM—3 by way of band filter BF—18 are 300,000 cycles and 233,333 cycles, respectively, and the net elevation of the carrier side band that is effected in balanced modulator BM—3 is the difference between 300,000 cycles and 233,333 cycles, or 66,666 cycles. Therefore, in this case the 10,000 cycle carrier upper side band applied to balanced modulator BM—3 becomes the upper side band of the 76,666 cycle frequency, the upper side band of the 13,333 cycle carrier applied to balanced modulator BM—3 becomes the upper side band of the 80,000 cycle frequency, and the upper side band of the 16,666 cycle carrier applied to the balanced modulator BM—3 becomes the upper side band of the 83,333 cycle frequency. These frequencies, it will be noted, are the frequencies that are adapted to pass through band filter BF—37 associated with the outgoing or transmitting branches of the channels of line 3 (Fig. 9).

In case it is line 2 with which connection is to be established, the frequencies applied to balanced modulator BM—4 are the 300,000 cycle frequency determined by the operation of relay 70 and the 53,333 cycle frequency supplied by distributing circuit 122 and determined by the operation of relay 72. The intermodulation of these two frequencies in balanced modulator BM—4 causes the 300,000 cycle frequency and the 246,666 cycle frequency to be applied to the parallel input circuit of balanced modulator BM—3, together with the carrier side band admitted by way of the band filter BF—15. The resultant net frequency elevation of the carrier side band by the operation of balanced modulator BM—3 in this case is by an amount equal to 53,333 cycles. Therefore in the output circuit of the balanced modulator BM—3 the 10,000 cycle carrier upper side band becomes the upper side band of the 63,333 frequency, the upper side band of the 13,333 cycle carrier becomes the upper side band of the 66,666 cycle frequency, and the upper side band of the 16,666 cycle carrier becomes the upper side band of the 70,000 cycle frequency. These frequencies, it will be noted, are the frequencies which are adapted to pass through the band filter

BF-36 associated with the outgoing or transmitting branches of the channels of line 2 (Fig. 9).

The particular frequencies that are used for the elevation of the carrier side bands in the line selecting operation are the same in the case of all of the carrier multiplex lines centering in the switching station. In each case, in addition to the 300,000 cycle frequency, the 40,000 cycle frequency supplied by distributing circuit 121 is used to effect the selection of the channels of line 1, the 53,333 cycle frequency supplied by distributing circuit 122 is used to select the channels of line 2, the 66,666 cycle frequency supplied by distributing circuit 123 is used to effect the selection of the channels of line 3, and the 80,000 cycle frequency supplied by distributing circuit 124 is used to effect the selection of the channels of line 4. In each case, however, the frequency required for the selection of a particular line is not supplied to the modulating apparatus of the channels of that line, for the reason that it is never necessary for a channel to establish connection with another channel of the same line. The distribution of the line selecting modulating frequencies to the various channels of the different lines is indicated with respect to each of the lines in Figs. 4, 5 and 6 of the drawing.

It might be thought that a single stage of modulation would suffice to elevate the carrier side bands to the particular part of the frequency range between 50,000 and 100,000 cycles necessary to correspond to the frequency range of the line selecting filter associated with the line with which connection is to be established. But this is not feasible on account of the fact that the direct use of the 40,000, 53,333, 66,666 or 80,000 line selecting modulating frequencies gives rise to a large number of other modulation products containing speech frequency components that lie within the range of line selecting filters other than the filter associated with the particular line that is to be selected, with a resultant production of cross-talk between the various lines. By effecting the line selecting carrier side band elevation by the use of two relatively high modulating frequencies differing from each other by the frequency through which the carrier side band is to be elevated, all of the undesired modulation products are thrown well outside of the range of the filters associated with the modulator output circuit and the desired modulation product alone is permitted to pass. Furthermore, it will be noted that only one relatively high frequency, namely, the 300,000 cycle frequency, is required to be distributed throughout the system, the complementary high frequency modulating currents of

200,000, 233,333, 246,666 and 260,000 cycles being developed locally in the particular groups of apparatus in which they are to be used from the relatively low 40,000, 53,333, 66,666 and 80,000 cycle frequencies, and not being required to be distributed throughout the system. The line selecting frequency modulation system is such that all of the relatively high modulating frequencies are applied and, after having performed their function, are immediately withdrawn in a single group of apparatus in each channel, so that none of the individual channels in the system is required to carry speech modulated currents at such high frequencies as would introduce difficulties arising from energy dissipating and interference effects.

While the line selecting modulation of the carrier side bands is under discussion, reference may be made briefly to the alternative modulating arrangement illustrated in Fig. 12 of the drawing. In the alternative form illustrated in Fig. 12, instead of effecting the two stages of high frequency modulation of the carrier side band in a single balanced modulator, as described in connection with the arrangement illustrated in Fig. 4, each of the two high frequency stages of modulation is arranged to take place in a separate balanced modulator. In the portion of the circuit illustrated in Fig. 12, the band filter BF-40 corresponds to band filter BF-15 of Fig. 4, band filter BF-41 corresponds to band filter BF-16, band filter BF-42 corresponds to band filter BF-17 and band filter BF-43 corresponds to band filter BF-18, except that in the case of the last mentioned band filter BF-43 the frequency range is 220,000 to 260,000 cycles, inclusive, instead of 220,000 to 300,000 cycles, inclusive, which is the frequency range of band filter BF-18 in Fig. 4. Balanced modulator BM-12 of Fig. 12 corresponds to balanced modulator BM-4 of Fig. 4, and balanced modulators BM-10 and BM-11 of Fig. 12 together to perform the function that is performed by balanced modulator BM-3 of Fig. 4. Relays 80, 82, 83 and 84 of Fig. 12 correspond to relays 70, 72, 73 and 74 of Fig. 4.

In the alternative circuit illustrated in Fig. 4 the upper side bands based upon the 10,000, 13,333 and 16,666 carrier frequencies enter the series input circuit of balanced modulator BM-10 and there intermodulate with the 300,000 cycle frequency applied to the parallel input circuit by way of the contacts of relay 80. The carrier side band is raised to a level within the frequency range of the band filter BF-41 connected with the output circuit of modulator BM-10 and is applied to the series input circuit of balanced modulator BM-11. At the same time the 300,000 cycle frequency is applied by the

operation of relay 80 to the series input circuit of balanced modulator BM—12, and one or another of the 53,333, 66,666 and 80,000 cycle frequencies is applied by the operation of the associated relay 82, 83 or 84 to the parallel input circuit of modulator BM—12. The filter BF—43 connected with the output circuit of balanced modulator BM—12 is constructed and adjusted to pass the lower side bands resulting from the modulation of the 300,000 cycle frequency with whichever of the other three frequencies is applied to the parallel input circuit of the modulator. The frequency range of the band filter BF—43 need be only broad enough to pass the three lower side bands, and may exclude the 300,000 cycle frequency, as that frequency performs its modulating function directly in balanced modulator BM—10. The particular lower side band that is produced, depending upon which of the three relays 82, 83 or 84 is operated, passes through band filter BF—43 and is applied to the parallel input circuit of balanced modulator BM—11, where it intermodulates with the carrier side band that has been produced in balanced modulator BM—10 and raised to the frequency elevation that permits it to pass through band filter BF—41. The effect of the modulation which now takes place in balanced modulator BM—11 is to lower the frequency level of the carrier side band elevated in balanced modulator BM—10 to an extent that leaves it elevated by a net frequency corresponding to that which permits it to pass through band filter BF—42 and to be directed to the particular line with which connection is to be established.

We may now consider the portion of the system which permanently links all of the channels of all of the carrier multiplex lines together in such a way that while each channel is potentially connected with every other channel, no channel is operatively associated with any other channel until the proper carrier side band frequency shifting operations have been performed. The incoming or receiving branches of the twelve channels of the four carrier multiplex lines that center in the switching station converge through a conjugate network upon a single common pair of conductors 200 (Fig. 9); and from this common pair of conductors 200 diverge the frequency selective branches that connect ultimately with the outgoing or transmitting branches of the twelve channels of the four carrier multiplex lines. All of the paths that converge upon and diverge from the common conductors 200 are permanently established paths, and include no movable switch or relay contacts of any sort. In the drawing the receiving or incoming channel branches of line 1 are designated 211, 212 and 213; those of line 2 are des-

ignated 221, 222 and 223; those of line 3 are designated as 231, 232 and 233; and those of line 4 are designated as 241, 242 and 243. The transmitting or outgoing channel branches of line 1 are designated 214, 215 and 216; those of line 2 are designated 224, 225 and 226; those of line 3 are designated 234, 235 and 236; and those of line 4 are designated 244, 245 and 246. As heretofore described each of the receiving or incoming channel branches has a band filter BF—17 interposed between the associated balanced modulator BM—3 and the connection of the channel branch with the network that converges upon the common conductors 200. But inasmuch as the incoming channel branch beyond the balanced modulator BM—3 will have occasion to pass at one time or another the entire range of frequencies corresponding with the selective branch frequencies of the different lines with which each channel may have occasion to be interconnected, the frequency range of the band filters BF—17 interposed in the modulator output circuit is such that it cannot act to suppress the frequencies of the elevated carrier side bands that may be generated in the incoming or receiving branches of the other channels that have connection with the common conductors 200 upon which all the branches converge, these frequencies being the same for all channels. In order to prevent the intermingling and feasible intermodulation in the balanced modulator plate circuits of the different carrier side bands that may simultaneously be present in the common circuit, a network is provided which acts to permit the receiving branches of all of the channels to feed into the common circuit 200, but prevents any feed-back from the receiving or incoming branch of any channel to the receiving or incoming branch of any other channel. This network, in the form in which it is illustrated in Figs. 8, 9 and 10 of the drawing, is based upon the principles of the Wheatstone bridge. The incoming branches of carrier multiplex lines 1 and 2 have connection with the common circuit 208 by way of the nets CN—1, CN—2, CN—3, CN—4 and CN—5, as shown in Fig. 8. The incoming or receiving branches of carrier multiplex lines 3 and 4 have connection with the common circuit 209 through the medium of nets CN—6, CN—7, CN—8, CN—9 and CN—10. The two common circuits 208 and 209 are connected with the common outlet 200 through the medium of net CN—11. Each of the nets enumerated above is made up of four impedances *a*, *b*, *c* and *d* permanently connected together to constitute in effect the four arms of a Wheatstone bridge. The impedance of the four arms may be of any convenient sort as long as they satisfy the fundamental condition of proportion-

ality between the arms required to constitute a condition of balance between the diagonally related sets of junction points of the impedances for the particular character of current that is to be transmitted through the nets. A simple arrangement satisfying the necessary conditions is one where the impedances in the four arms are pure resistances, and this is the sort of impedance which is represented in the drawings in the present instance. When the fundamental condition of balance of the Wheatstone bridge is satisfied by the impedances in the four arms, there is zero difference of potential between each pair of diagonally related junction points with respect to any electromotive force impressed upon the other diagonally related pair of junction points. It therefore follows that by thus relating the receiving or incoming branches of two channels, the varying potentials in each are non-effective to produce any variation of potential in the other. But the output circuit of each bridge network is associated with or constitutes, only one arm of the bridge, and therefore potential differences impressed upon either of the diagonal pairs of junction points by the associated incoming channel branch cause corresponding variations of potential across the output circuit associated with the single arm.

The fundamental conditions of conjugacy described above are extended in the present system to embrace all of the incoming or receiving channel branches of the carrier multiplex lines of the system. The pairs of receiving branch conductors 211 and 212 of channels 1 and 2 of line 1 are connected in balanced or conjugate relation with respect to each other by being connected with the two sets of diagonally related junction points of network CN—1. The output circuit from the net CN—1 constitutes the impedance element or arm d , and has connection with one of the diagonal pairs of junction points of the net CN—3. The other pair of diagonal junction points of the net CN—3 has connection with the receiving branch conductors 213 of channel 3 of line 1; and therefore these conductors of channel 3 and the output circuit of the two pairs of receiving branch conductors 211 and 212 that are conjugately connected with the net CN—1 are in balanced relation with respect to each other. The output circuit from the net CN—3 constitutes the impedance element or arm d of the bridge and therefore is in unbalanced relation with respect to potential variations impressed upon the net by the channel conductors 213 and by the output circuit of net CN—1 representing the channel conductors 211 and 212. The three pairs of incoming or receiving branch channel conductors 221, 222 and 223 of line 2 are similarly related through the

medium of the nets CN—2 and CN—4; and the output circuits of the net CN—3 representing line 1 and the net CN—4 representing line 2 are connected in conjugate or balanced relation with the two pairs of diagonal junction points of the net CN—5. The nets CN—6 and CN—8 (Fig. 10) serve the incoming channel branches of line 3, the nets CN—7 and CN—9 serve the incoming channel branches of the line 4, and the net CN—10 associates the output circuits of the nets CN—8 and CN—9 of the respective lines in balanced or conjugate relation in exactly the same way as has been described above in connection with lines 1 and 2. The output circuit 208 of net CN—5 of lines 1 and 2 and the output circuit 209 of net CN—10 of lines 3 and 4 are associated in conjugate or balanced relation by their connection with the two pairs of diagonally opposite junction points of the net CN—11 shown in Fig. 9, and the common output circuit 200 constitutes the impedance element or arm d of the net CN—11. In this way all of the incoming or receiving branches of the twelve channels of the four carrier multiplex lines feed unidirectionally toward the common conductors 200 and are prevented from feeding back into each other.

Assuming that the impedances of the four arms of each of the conjugate nets are desired to have the same value, each of the arms a , b and c of each net may have an impedance equal to the impedance of the common output circuit 200. Thus if the output circuit 200 connected with the arm d of the net CN—11 is arbitrarily given or assumed to have an impedance of 10,000 ohms, each of the other three arms a , b and c of net CN—11 may also conveniently be assigned an impedance value of 10,000 ohms to preserve the relation of balance between the two pairs of diagonally related junction points. If the above mentioned impedance values are assigned to the four arms of the net CN—11, the impedance offered to currents traversing the bridge by way of the series parallel paths between diagonally opposite junction points will have a value of 10,000 ohms, being the resistance of two 20,000 ohm paths in parallel. This being the case, the balance of each of the nets CN—5 and CN—10 is maintained by giving each of the arms a , b and c of each of these nets an impedance value of 10,000 ohms, and so on back through the series.

If the impedance of the common output circuit 200 is greater or less than the amount assumed above, the impedance of each of the bridge arms of each of the nets of the conjugate network will be correspondingly varied in order to maintain the desired condition of balance. If the impedance of the common output circuit 200 has

inductive or capacitive reactance characteristics, these reactance characteristics may be simulated in the bridge arms of the network in order that the condition of balance may be maintained; and, of course, if desired the conjugate relationship of the circuits or channel branches feeding into the network may be maintained by employing nets in which the bridge arms are properly chosen inductances or capacities instead of the pure resistances indicated.

A modified form of conjugate network for permitting the independent feeding of a plurality of incoming into a common outgoing circuit is illustrated in Fig. 13. In this modified form, which shows only a representative part of the complete organization required, the conjugate relationship is effected by the employment of high frequency hybrid or conjugate coils the windings of which are in inductive relation with each other in the usual way. Two of the three incoming or receiving channels of one of the carrier multiplex lines are connected respectively with the series winding and the mid-points of the line windings of the high frequency hybrid coil HFH—3. One end of the line windings is connected with a balancing impedance 60 and the other end is connected with an output circuit extending to the series winding of another hybrid coil HFH—5 with the mid-points of the line windings of which the incoming or receiving branch of the third channel of the carrier multiplex line is connected. The hybrid coil HFH—5 also has a balancing impedance 60 connected with one end of the line windings of the coil and the output circuit extends from the other end of the line windings. The three incoming or receiving branches of another carrier multiplex line are similarly associated by means of the high frequency hybrid coils HFH—4 and HFH—6, and the output circuits from the hybrid coils HFH—5 of the first carrier multiplex line and the hybrid coil HFH—6 of the second carrier multiplex line are conjugately related by means of the high frequency hybrid coil HFH—7. Two such systems of hybrid coils as that shown in Fig. 13 may have their output circuits conjugately related by means of still another high frequency hybrid coil (not shown) to permit the feeding independently of each other of the four carrier multiplex lines of the present system into the common output circuit 200 of Fig. 9 of the drawing.

The feeding of the plurality of incoming branches of a number of carrier multiplex line channels into a common output circuit by means of a conjugate network such as that indicated in Fig. 13 would entail smaller energy losses than are encountered

in the use of the conjugate network illustrated in Figs. 8, 9 and 10 of the drawing; but whatever the energy losses are, they of course may be compensated and the desired energy values reestablished by the interposition of amplifiers wherever required. Such interposed amplifiers would be of the straight line or nondistorting type in order to prevent intermodulation of the plurality of different carrier side bands that they would be called upon to amplify simultaneously. As indicated in Fig. 9, a balanced amplifier BA—2 of such capacity and so arranged as to operate in a nondistorting manner upon the carrier side bands impressed upon its input circuit, is interposed in the common outlet 200, and acts to raise the energy values of the simultaneously impressed carrier side band, without intermodulation, to the required amount for the proper operation of the system.

It may be noted that channel 3 of each of the carrier multiplex lines is connected to the conjugate network at such a point that its energy suffers less attenuation than in the case of the energy of channels 1 and 2, the currents in which last mentioned channels pass through an additional net in the network. The energy output of the channels may be equalized either by increasing the amplification in the incoming branches of channels 1 and 2 or by properly reducing the energy output of channel 3 by the use of a potentiometer, or in any desired way. After amplification in the balanced amplifier BA—2, the carrier side bands are distributed from the common outlet circuit 200 to the four band filters BF—35, BF—36, BF—37 and BF—38. The band filter BF—35 has a lower cutoff limit of 49,000 cycles and an upper cut-off limit of 59,000 cycles and is adapted to pass with substantially negligible attenuation the upper side bands based upon the 50,000, 53,333 and 56,666 cycle frequencies, and to suppress all of the other speech modulated frequencies that have access through the network to the common output circuit 200. The band filter BF—36 has a frequency range of from 63,000 to 73,000 cycles, and is adapted to pass the upper side bands based upon the 63,333, 66,666, and 70,000 cycle frequencies. The band filter BF—37 has a range of from 76,000 to 86,000 cycles, and is adapted to pass the upper side bands based upon the 76,666, 80,000 and 83,333 cycle frequencies. The band filter BF—38 has a range of from 89,000 to 99,000 cycles, and is adapted to pass the upper side bands based upon the 90,000 the 93,333 and the 96,666 cycle frequencies. Each of the band filters BF—35, BF—36, BF—37 and BF—38 thus automatically selects the particular group of carrier side bands that is identified by its

frequency elevation as being directed toward the outgoing channel branches of the particular carrier multiplex line with which the particular band filter is associated. The carrier side bands of the group selected by each of the band filters are applied to the series input circuit of an associated balanced modulator, and to the parallel input circuit of each balanced modulator is applied a modulating frequency of the same value as that by which the particular carrier side bands applied to the series input circuit of the modulator have been elevated above their normal carrier frequencies in the process of line selecting modulation. Thus a frequency of 40,000 cycles is applied to balanced modulator BM—5 included in the frequency selective outlet to the transmitting branches of the channels of line 1; a frequency of 53,333 cycles is applied to balanced modulator BM—6 associated with the outlet to the channels of line 2; a frequency of 66,666 cycles is applied to balanced modulator BM—7 associated with the outlet to the channels of line 3; and a frequency of 80,000 cycles is applied to balanced modulator BM—8 associated with the outlet to the channels of line 4.

Taking first the case of the action in balanced modulator BM—5 associated with the outlet to line 1, the three bands of frequencies that are admitted to the series input circuit of this modulator by way of band filter BF—35 are the upper side bands based upon the 50,000, 53,333 and 56,666 cycle frequencies respectively. When these frequency bands intermodulate with the 40,000 cycle frequency applied to balanced modulator BM—5, the result is to produce a plurality of modulation products including the upper side bands of the 10,000 cycle, 13,333 cycle and 16,666 cycle carriers. This is upon the assumption that the 50,000 cycle 53,333 and 56,666 cycle side bands are simultaneously present in the input circuit of the modulator, as would be the case if all three channels of line 1 were simultaneously in use. The modulating action would be the same if only one, or less than all, of the channels of line 1 were in use at the same time, the effect of the application of the 40,000 frequency to balanced modulator BM—5 being in effect to subtract 40,000 cycles from the basic frequency of as many of the carrier side bands as are being applied to the input circuit of the modulator, thus reducing the applied side band frequencies to frequencies corresponding with the frequency ranges of the band filters BF—10, BF—12 and BF—14 interposed in the outgoing or transmitting channel branches of line 1. The modulating action of the balanced modulator results in the production of a large number of other fre-

quencies; but all of these other frequencies are above the upper cut-off limits of the band filters in the outgoing or transmitting channel branches.

Similarly balanced modulator BM—6 associated with line 2 operates to reduce by 53,333 cycles the frequency level of the 63,333 cycle, the 66,666 cycle and the 70,000 cycle carrier bands that are applied to the input circuit of the modulator by way of band filter BF—36; balanced modulator BM—7 associated with line 3 operates to reduce by 66,666 cycles the frequency level of the 76,666 cycle, the 80,000 cycle and the 83,333 cycle carrier bands applied to the input circuit of the modulator by way of band filter BF—37; and balanced modulator BM—8 associated with line 4 operates to reduce by 80,000 cycles the frequency level of the 90,000 cycle, the 93,333 cycle and the 96,666 cycle carrier bands applied to the input circuit of the modulator by way of band filter BF—38. In each case the effect is to reduce the carrier side bands, respectively, to the 10,000 cycle, 13,333 cycle or 16,666 cycle frequency levels so that they may be selected by the band filters in the outgoing or transmitting branches of the corresponding channels of their respective lines. As may be seen by reference to the drawing, the output circuit 210 of balanced modulator BM—5 is connected with the outgoing branches 214, 215 and 216 of channels 1, 2 and 3, respectively, of line 1; the output circuit of balanced modulator BM—6 is connected by way of conductors 220 with the outgoing branches 224, 225 and 226 of channels 1, 2 and 3, respectively, of line 2; the output circuit of balanced modulator BM—7 is connected by means of conductors 230 with the outgoing branches 234, 235 and 236 of channels 1, 2 and 3, respectively, of line 3; and the output circuit of balanced modulator BM—8 is connected by way of conductors 240 with the outgoing branches 244, 245 and 246 of channels 1, 2 and 3, respectively, of line 4. Thus the action of the balanced modulators BM—5, BM—6, BM—7 and BM—8 is to subtract from the side bands selectively directed to the modulators by way of the associated band filters the line selecting modulating or elevating frequency, and to reduce the side bands to frequencies within the frequency ranges of the band filters in the outgoing channel branches of the associated lines.

We may now consider briefly the apparatus illustrated in Fig. 3 for generating the base frequency that is to be transmitted to the other stations of the system and the harmonic frequencies that are used at the switching station for effecting the frequency changes and modulations to which reference has hereinbefore been made; also the ap-

paratus for producing a busy tone modulation of certain of the carriers to be employed in case all of the channels of a selected group are found to be in use. The
 5 base frequency of 3,333 cycles, in the present instance, is generated in the oscillator O—2, which is preferably of any usual and well known thermionic type with a feedback connection from its output into its
 10 input circuit. The sinusoidal oscillations produced in the oscillator O—2 are amplified in the amplifier A—6, have the magnitude of their voltages greatly increased in the transformer 44 and are then impressed upon
 15 the input circuit of the harmonic generator HG—2. The magnitude of the impressed oscillations is such as greatly to overload the thermionic tube of the harmonic generator, with the result that the repeated oscillations are distorted into an extended
 20 series of currents the frequencies of which are the harmonics of the base frequency current. The above described action is in accordance with the disclosure contained in the Kendall Patent 1,446,752 above referred to.

The harmonics thus produced consist of an extended series having relatively uniform energy values. After further amplification
 30 of these harmonic frequencies in amplifier A—7, the base frequency of 3,333 cycles is separated out by means of band filter BF—20 and is applied to the distributing circuit 108 from which it is supplied through
 35 the medium of band filters, such as band filter BF—19 associated with line 1, to the main transmitting branches of the different carrier multiplex lines centering in the switching station. The harmonic frequencies of 23,333 cycles, 26,666 cycles and 30,
 40 000 cycles are separated out by means of the band filters BF—21, BF—22 and BF—23, respectively, and are then applied to the distributing circuits 109, 110 and 111
 45 from which they are supplied to the balanced modulators BM—2 of the various channels of the different carrier multiplex lines. As has been described the 23,333 cycle frequency is supplied to the balanced
 50 modulators in the receiving branches of channels 1, the 26,666 cycle frequency is supplied to the balanced modulators in the receiving branches of channels 2, and the 30,000 cycle frequency is supplied to the balanced modulators in the receiving branches
 55 of channels 3 of the various lines, these frequencies acting in each case to demodulate the received carrier band and reproduce the lower controlling frequency with which the carrier is modulated at the distant toll station. The 33,333, 36,666, 40,000,
 60 43,333 and 46,666 cycle frequencies are separated out by means of band filters BF—24, BF—25, BF—26, BF—27 and BF—28 and
 65 are supplied by means of the distributing

circuits 112, 113, 114, 115 and 116 for the channel matching modulating operation under the control of the relays 61, 62 and 63 of the various channels, as has been described.

The 13,333 cycle frequency is separated out by means of band filter BF—29, is amplified in amplifier A—8, and is then impressed upon the input circuit of the harmonic
 70 generator HG—3. The harmonic generator HG—3 is of the same type as the harmonic generator HG—2, previously described, and acts to distort the repeated oscillations into an extended series of currents the frequencies of which are the harmonics of the base
 75 frequency 13,333. These harmonic frequencies are amplified in the amplifier A—9, and the 40,000, 53,333, 66,666 and 80,000 cycle harmonics are separated out by means of the band filters BF—31, BF—32, BF—33 and
 80 BF—34, respectively, and are then supplied to the corresponding distributing circuits 121, 122, 123 and 124 to be employed for effecting the line selecting shifting or elevation of the side bands in the receiving branches of
 85 the various channels, as has already been described. The 300,000 cycle frequency that cooperates with the four last mentioned harmonic frequencies in effecting the line selecting shifting of the side bands is generated in the oscillator O—3, after which it is
 90 amplified in the amplifier A—7' and passed to the distributing circuit 127 by way of the band filter BF—30. The branches 117, 118, 119 and 120 of the distributing circuits 121, 122, 123 and 124, respectively, supply the
 95 corresponding frequencies of 40,000, 53,333, 66,666 and 80,000 cycles to the balanced modulators BM—5, BM—6, BM—7 and BM—8 (Fig. 9) for effecting the frequency reduction of the side bands after their selection by means of the associated band filters, as has previously been described.

The production of the busy tone modulation is effected in the balanced modulator
 100 BM—9 (Fig. 3) by the modulation of the 10,000, 13,333 and 16,666 cycle frequencies by a busy tone current supplied from any suitable source. The busy tone modulation of the three carriers referred to is amplified in amplifier A—10 and is applied by way of
 105 band filter BF—40 having a frequency range of from 10,000 to 19,000 cycles to the distributing circuit 135, from which circuit it is supplied when needed to the outgoing or transmitting branch of each channel under the control of the relay 37. The busy tone is supplied as a modulation of the three carriers of 10,000, 13,333 and 16,666 cycle
 110 frequencies so that it may be furnished over a single distributing circuit to all of the outgoing channel branches and may be capable of passing through the transmitting branch filter of any channel to which it may be applied.
 115
 120
 125
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We may now consider the controlling switches that are represented in Figs. 7 and 7^A of the drawing. Under the conditions that have been assumed in the present embodiment of the invention, there are at the switching station twelve switches, each one acting under the control of a different one of the twelve channels of the four carrier multiplex lines, when the associated channel is the calling channel, to control the application of the channel matching and line selecting frequencies to both the calling and the called channels. For the sake of simplifying the showing, some of the twelve switches are not illustrated in detail since it will be clear from the switches that are shown, how the switches are associated with one another and with the respective channels. In Figs. 7 and 7^A these switches and their circuit inter-relationship are diagrammatically illustrated, the switches being designated S—1 to S—12, inclusive, and being associated with the different channels of the different lines in the manner indicated by the words appearing in connection with the reference characters that designate each switch. Each of the switches may conveniently be of the single motion rotary type in which brushes or wipers, designated in the present instance 1, 2, 3, 4, 5 and 6, respectively, are moved by electromagnetically driven step-by-step mechanism over corresponding rows of stationary contacts or terminals, and are spring returned to their normal position upon the withdrawal of a holding pawl by the associated release magnet. Such mechanism is diagrammatically illustrated in Fig. 4 in which the stepping magnet 53 operates the brush moving ratchet wheel 41 through the medium of the stepping pawl 42, and the release magnet 34 when energized lifts the holding pawl 43 and also at the same time disengages the stepping pawl 42 from the teeth of the ratchet wheel. Rotary switches of this type are well known in the art and require no special description or illustration. Obviously, if it is desired to do so, one ordinarily skilled in the art may readily and without the exercise of invention substitute another of the well known types of switches for the single motion step-by-step rotary switch that is indicated.

Each of the brushes 1 to 6, inclusive, of the switch is adapted in its movement to engage a corresponding series of contact terminals. The relation between brushes 1 and 2 and the contact terminals which they are adapted to engage is such that the brush engages each succeeding contact of the series before it disengages the preceding contact. In the case of the brushes 3, 4, 5 and 6 the relationship is such that each brush disengages one contact before it comes into engagement with the next contact of the series.

In the first or resting position of the switch brushes, as also in the second position, only brush 1 engages a stationary terminal. In their 3rd, 4th and 5th positions the brushes are in engagement successively with three groups of contacts that control the application of the channel matching and line selecting modulating frequencies to both the calling and called channels when the channel with which this particular switch is associated establishes connection with channels 1, 2 and 3, respectively, of line 1. In the 6th position the switch brush 2 engages a terminal that controls the transmission of a busy tone signal to the calling operator in case all of the channels of line 1 are in use. The 7th, 8th, 9th and 10th groups of stationary contact terminals serve similar purposes in connection with the channels of line 2 when the channel with which the particular switch is associated initiates a call for line 2. The 11th, 12th, 13th and 14th groups of stationary contact terminals serve like purposes in connection with the initiation of a call by the associated channel for an available channel of line 3; and the 15th, 16th, 17th and 18th groups of terminals engaged by the set of switch brushes serve like purposes in connection with a call initiated for an available one of the channels of line 4. As it is never necessary for any of the channels to complete connection with another channel of the same carrier multiplex line, the stationary contact terminals in each switch that correspond with the channels of the line with which that switch is associated do not have any connections with the circuits that control the application of the channel matching and line selecting modulating frequencies.

The row of contact terminals engaged by brush 1 has to do with the selection, under the control of the operator at the remote calling station, of the particular carrier multiplex line or group of channels to which it is desired to extend connection; and the stationary contacts engaged by brush 2 have to do with the automatic selection of a particular available or non-busy channel of the group that the distant operator has selected, and with the application of the busy tone to the calling channel in case all of the channels of the called line are in use. The row of stationary contact terminals engaged by switch brush 3 has to do with the application to the selected channel of the called line of the particular modulating frequency necessary to match the incoming branch of the called line channel with the outgoing branch of the calling line channel, that is, the channel with which the particular switch in question is associated. The row of stationary contact terminals engaged by the switch brush 4 has to do with the application to the called line channel of the particular modulating frequency neces-

sary to elevate the called line channel carrier band to the level where it may pass through the selective filter in the common outlet to the outgoing channel branches of the calling line. The row of contacts engaged by switch brush 5 have to do with the application to the incoming branch of the calling line channel, that is the channel with which the particular switch in question is associated, of the modulating frequency necessary to match the incoming frequency of this channel with the outgoing frequency of the selected channel of the called line. The row of contacts engaged by switch brush 6 have to do with the application to the incoming branch carrier side band of the calling line channel of the modulating frequency necessary to raise the side band to the level where it may pass through the selective filter in the common outlet circuit to the outgoing channel branches of the called line.

The energizing circuits of the channel matching control relays 61, 62 and 63 (Fig. 4) of each channel extend to the corresponding controlling switch shown in Fig. 7 by way of the conductors 151, 152 and 153, respectively; and the energizing circuits of the relays 72, 73 and 74 that control the application of the line selecting modulating frequencies extend to the corresponding switch of Fig. 7 by way of the conductors 142, 143 and 144, respectively. Each of these six conductors has a vertically extending branch with appropriate connections to the stationary contacts engaged by switch brushes 5 and 6 of the associated switch, and with a horizontally extending branch having appropriate connections with certain of the stationary contacts of the channel switches of the other lines that are adapted to be engaged by brushes 3 and 4 of these other switches. When the line and channel selecting operation of the switch is completed and the brushes 3, 4, 5 and 6 have been brought to rest upon the corresponding terminals of the horizontal bank of contacts associated with the selected channel of the selected line, the relay 35 (Fig. 7) is operated to connect the brushes 3, 4, 5 and 6 to ground and thus complete the energizing circuits of the modulation controlling relays associated with the calling and called channels. Prior to the completion of the selecting operation of the switch the circuits extending from the switch brushes 3, 4, 5 and 6 are held open in contacts of the associated relay 35.

Broadly stated, the effect of the selecting operation of the switch is to bring about the operation of the called channel modulation controlling relays corresponding to the line and channel number of the calling channel, and to bring about the operation of the calling channel modulation controlling relays corresponding to the line and channel num-

ber of the selected called line channel. The particular two relays associated with the calling channel that are operated depends upon the extent of vertical movement of the calling line switch, and the particular two called channel relays that are operated depends upon the position of the calling switch in the horizontal row of switches that have access to the selected channel of the line. For example the conductors 151, 152 and 153, representing the energizing circuits of the channel matching controlling relays 61, 62 and 63, respectively, of channel 1 of line 1, have horizontally extending branches with a connection from conductor 151 to the stationary contacts engaged by brush 3 of the channel 1 switches of lines 2, 3 and 4, a connection from conductor 152 to the stationary contacts engaged by brush 3 of the channel 2 switches of lines 2, 3 and 4, and connections from conductor 153 to the stationary contacts engaged by brush 3 of the channel 3 switches of lines 2, 3 and 4. As a result, when a channel 1 switch of another line operates to establish connection between its associated channel and channel 1 of line 1, the circuit of conductor 151 is closed to energize relay 61 of channel 1 of line 1 and thus match this channel with channel 1 of the calling line; when a channel 2 switch of another line is operated to establish connection between its channel and channel 1 of line 1, the circuit of conductor 152 is closed to energize relay 62 of the selected channel 1 of line 1, and thus match this channel with the calling channel 2; and when a channel 3 switch of another line operates to establish connection between its associated channel and channel 1 of line 1, the circuit of conductor 153 is closed to energize relay 63 and match the selected channel 1 of line 1 with the calling channel 3 of the other line.

The vertically extending branches of conductors 151, 152 and 153 through which the energizations of relays 61, 62 and 63, respectively, are brought about are involved when the associated channel 1 of line 1 is the calling channel. The vertically extending branches of conductors 151, 152 and 153 are connected with the contacts engaged by the switch brush 5, conductor 151 being connected with the contacts in the horizontal banks representing channels 1 of lines 2, 3 and 4, conductor 152 being connected with the contacts in the horizontal banks representing channels 2 of lines 2, 3 and 4, and conductor 153 being connected with the contacts in the horizontal banks representing channels 3 of lines 2, 3 and 4. Consequently when switch S—1 of channel 1 selects channel 1 of the called line, channel matching relay 61 is operated; when it selects channel 2 of the called line channel matching relay 62 is operated; and when it selects channel 3

of the called line the channel matching relay 63 is operated.

A similar plan of connection is followed with respect to the energizing conductors 142, 143 and 144 associated respectively with the line selecting modulation control relays 72, 73 and 74. Conductor 142 associated with relay 72 has connection with stationary contacts of the channel 1, channel 2 and channel 3 switches of line 2; conductor 143 associated with relay 73 has connection with stationary contacts of the channel 1, channel 2 and channel 3 switches of line 3; and conductor 144 associated with relay 74 has connection with stationary contacts of the channel 1, channel 2 and channel 3 switches of line 4. Consequently when channel 1 of line 1 is selected by a line 2 switch, relay 72 operates to shift the carrier band frequency of channel 1 of line 1 to match the frequency of the selective branch to the outgoing channel branches of calling line 2; and similarly when channel 1 of line 1 is selected by a switch of line 3 or line 4, relay 73 or 74, as the case may be, of channel 1, line 1 is operated to effect the corresponding elevation of the carrier side band.

Conductor 142 associated with relay 72 also has connection with a stationary contact in each of the three contact banks of switch S—1 corresponding to the three channels respectively of line 2, conductor 143 associated with relay 73 has connection with a contact terminal in each of the three banks of contacts of switch S—1 corresponding to the three channels of line 3, and conductor 144 associated with relay 74 has connection with a stationary contact in each of the three contact banks of switch S—1 corresponding to the three channels of line 4. As a result, when channel 1 of line 1 is the calling channel, and switch S—1 is operated to select one of the channels of line 2, the relay 72 of the calling channel is energized; when switch S—1 is operated to select one of the channels of line 3, relay 73 is operated, and when switch S—1 is operated to select one of the channels of line 4, relay 74 is operated. In each case, as has hereinbefore been described, the relay 72, 73 or 74 in operating applies the modulating frequency required to elevate the carrier side band of the receiving branch of the associated channel to the frequency level required to select the common outlet to the outgoing channel branches of the called line with which connection is being established.

The same scheme of interconnection that has been described above is followed throughout the switches of Figs. 7 and 7^A with respect to the energizing conductors of the channel matching and line selecting control relays of all of the channels of all of the lines. Inasmuch as the interconnecting

scheme is rather completely illustrated in Figs. 7 and 7^A, it is thought that no further description will be required in order to make the matter clear to those skilled in the art.

The operation of the system will now be described in detail. It will be assumed that connection is to be established between one of the local lines centering in station 1 and one of the local lines centering in station 4. Assuming that it is the local subscriber at station SS (Fig. 1) that initiates the call for a subscriber at a distant station, when the telephone receiver at station SS is taken off of its switch hook a conductive path is established over line wires 101, and the line relay 11 operates to cause the illumination of the associated line lamp LL in the usual manner. As the line lamp LL is located at operator's position 2, the operator at that position inserts the local plug LP of one of her pairs of connecting cords CC—2 into the answering jack AJ associated with the illuminated line lamp and operates the corresponding listening key LK. This act connects the operator's telephone set OTS with the calling subscriber's telephone, and the operator then learns the distant toll station with which connection is desired and the particular desired called subscriber's station at the distant toll station.

Having obtained the necessary information from the calling subscriber the toll operator first ascertains the condition of use or disuse of the channels of the carrier multiplex line by observing the illuminated or unilluminated condition of the lamps BL—1, BL—2 and BL—3 corresponding with the different channels of the line, and then inserts the toll plug TP of the connecting circuit CC—2 into the multiple springjack of one of the channels that is not at the time in use. It may be assumed that this is the spring jack MJ—1 associated with the busy lamp BL—1. When the plug is inserted in the spring jack a circuit is completed that extends from battery by way of the toll supervisory lamp TSL, resting contacts of the calling key CK, registering sleeve contacts of the toll plug TP and multiple channel jack MJ—1, conductor 52, winding of relay 15 and winding of slow release relay 16 to ground. This causes the illumination of the lamp TSL and the energization of relays 15 and 16. Relay 16 in operating closes a circuit that extends from battery through the winding of relay 20 and right hand front contact and armature of relay 16 to ground. The resultant operation of relay 20 applies current from the A battery for the energization of the tube filaments of the balanced modulator BM—1 and the balanced amplifier BA—1 of the transmitting branch of channel 1, and also connects the

harmonic distributing circuit 105 with the tuned circuit TC—3 so that the 23,333 cycle carrier frequency appropriate to channel 1 is applied to the balanced modulator BM—1 for modulation by the voice frequencies and the low controlling frequency. Relay 16 in operating also closes a circuit that extends from battery through the left hand winding of relay 17 and the right hand front contact and armature of relay 16 to ground. This energizes relay 17 which thereupon operates to connect battery with the conductor 53 for the illumination of the busy lamps BL—1 associated with all of the springjack terminals of the channel that has been taken for use. The illuminated condition of the busy lamps guards the channel from intrusion. Relay 16 in operating also deprives relay 18 of control over the calling lamp CL—1 of the associated channel and gives it control over the toll supervisory lamp TSL of the cord circuit CC—2 now connected with the channel, for a purpose that will hereinafter appear. As has been stated, relay 15 is also energized by the insertion of the toll plug TP into the channel multiple springjack MJ—1. Relay 15 in operating energizes relay 19; and relay 19 in operating connects the control frequency distributing circuit 106 with the tuned circuit TC—2 to cause the application of the 150 cycle control frequency to the balanced modulator BM—1 of the transmitting branch of the channel that has been chosen for use.

It therefore appears that as a result of the insertion of the toll plug TP into the springjack MJ—1 the transmitting branch of channel 1 is energized, and that the 23,333 cycle carrier frequency of this channel and the 150 cycle control frequency are both applied to the balanced modulator BM—1. The modulation of the carrier frequency by the control frequency takes place in the balanced modulator, and after amplification in the balanced amplifier BA—1 the modulated lower side frequency of the 23,333 cycle carrier passes by way of the band filter BF—1 into the common transmitting branch and thence by way of the high frequency hybrid coil HFH—1 to the carrier multiplex line 104.

At the switching station the lower side band of the 23,333 cycle carrier wave passes through the group filter GF—1 (Fig. 4) into the receiving branch 125 common to the various channels of the line, and thence by way of the band filter BF—9 into the incoming or receiving branch of channel 1. After passing through the band filter BF—9 the modulated lower side band of the 23,333 cycle carrier passes to the input circuit of the balanced modulator BM—2 where it is joined by the corresponding 23,333 cycle frequency derived from the common distributing circuit 109 by way of the high

frequency hybrid HFH—2. Demodulation takes place in the balanced modulator BM—2 and the 150 cycle control frequency is separated out of the other demodulation products by the low pass filter LPF—2, is amplified in the amplifier A—5, rectified in the rectifier R—2 and causes the energization of relay 25. Relay 25 in operating energizes the slow release relay 26. Therefore the instant that the channel is appropriated at the calling terminal station by the insertion of the toll plug TP into the channel springjack MJ—1 the relay 25 and the slow releasing relay 26 of the corresponding channel of the carrier multiplex line at the distant switching station are energized, and the relay 26, on account of its slow release construction and adjustment, remains energized until disconnection finally takes place.

When relay 26 operates it breaks at its outer right hand back contact and armature the path that normally exists for the energization of relay 36 by way of conductor 134 and the multiple test terminals of this channel that appear upon the interconnecting switches associated with the channels of the other carrier multiplex lines. At the same time the outer right hand armature of relay 26 closes at its front contact a circuit from conductor 134 to ground that creates a busy test condition upon the busy test terminals of this channel in the other interconnecting switches.

The circuits of channel 1 at the terminal station and at the intermediate or switching station are now in condition for the transmission of the impulses that control the interconnecting operation at the switching station. Referring to Fig. 1, the operator at position 2 now operates the calling key CK of the connecting cord circuit CC—2. This has the effect of disconnecting the branch to battery by way of the toll supervisory lamp TSL and substituting a normally closed branch to battery by way of the normally closed contacts 13 of the operator's dial OD and a protective resistance 48. This substitution of one branch to battery for the other is effected without breaking the circuit, as the calling key is constructed so as to close one of the branches before breaking the other. The operator at position 2 now inserts her finger in the finger-hole of the dial OD corresponding with the digit representing the arbitrarily assigned call number of the distant terminal or toll station to which the connection is to be extended. In the present instance it is assumed that the distant terminal station is station 4, and that the calling number for this station is the number "4". The dial OD is rotated until the operator's finger comes into contact with the stop and is then released. In returning to normal the dial causes the as-

sociated contacts 13 to break and make the circuit in which they are included four times. The speed of operation of the dial is so regulated that each break is for a short interval and each succeeding make is for a long interval, the circuit remaining closed after the last break.

At the first interruption of the circuit at the dial contacts 13 the relay 15 included in the circuit of sleeve conductor 52 (Fig. 2) is released, but the relay 16 included in the same conductor, being of the slow release type, remains energized. Relay 16 remaining operated maintains the transmitting branch of channel 1 energized and the 23,333 cycle carrier wave applied. But relay 15 in releasing releases relay 19 and disconnects the 150 cycle control frequency from the balanced modulator BM—1. The effect of the operation of the dial OD therefore is to withdraw the 150 cycle control frequency from the carrier wave of channel 1 as many times as the dial contacts 13 are opened, which, in the present instance, is assumed to be four times.

Referring now to the effects that are produced at the distant end of the carrier multiplex line as illustrated in Fig. 4, each withdrawal of the 150 cycle control frequency from the transmitting branch of channel 1 causes a corresponding deenergization of relay 25 which is being held energized by the presence of the control frequency modulation of the carrier; and as the slow acting characteristics of relay 26 are such that this relay is not released by the brief interruptions of its energizing circuit at the front contact of relay 25, each deenergization of relay 25 closes a circuit that extends from battery through the armature and back contact of relay 25, inner armature and front contact of relay 26 and winding of relay 27 to ground. Therefore the relay 27 is energized during the interruption of the operator's dial contacts 13 at the calling station and is deenergized upon the subsequent closure of the dial contacts.

It has been assumed that it is station 4 that is being called and that the dial contacts 13 are interrupted and then closed four times. At the first interruption of the dial contacts, and consequent energization of relay 27 (Fig. 4), a circuit is closed that extends from battery through the winding of the stepping control relay 28, inner left hand armature and back contact of relay 29, conductor 131, brush 1 of switch S—1 and the stationary contact terminal upon which it normally rests, conductor 128, front contact and armature of relay 27 and outer left hand back contact and armature of relay 29 to ground. The closure of this circuit operates relay 28, and closes a circuit that extends from battery through the energizing winding of the slow release relay 30 and the

stepping magnet 33 in parallel and is completed to ground at the front contact and armature of relay 28. The stepping magnet 33 has self-interrupting contacts in its energizing circuit to cause the rapid energization and deenergization of the magnet as long as the contacts of relay 28 are closed. Stepping magnet 33 is also provided with the usual shunt of its energizing winding including a condenser and a resistance for suppressing the spark at the self-interrupting contacts and stabilizing the vibratory action of the magnet. The first energization of the stepping magnet 33 attracts the left hand armature of the magnet, and the subsequent deenergization of the stepping magnet 33 causes the pawl 42 to advance the associated ratchet wheel 41 one step. The relationship between the ratchet wheel 41 and the set of brushes of the switch S—1, as has been described, is such that this has the effect of advancing the brushes 1, 2, 3, 4, 5 and 6 from their normal resting positions to the second of the positions that they are adapted to occupy. Brush 1 is therefore moved out of engagement with the contact terminal upon which it normally rests and is moved into engagement with the second contact terminal of the associated series. The movement of brush 1 from its normal resting contact interrupts the previously traced circuit that includes the energizing winding of relay 28, and that relay thereupon is deenergized and breaks the energizing circuit that extends in parallel branches through the windings of slow release relay 30 and stepping magnet 33. Stepping magnet 33 is therefore deenergized after it has caused the associated switch brushes to advance one step; but the release of the armature of relay 30 is delayed on account of the slow release characteristics of that relay. It may also be noted that the first step in the advance of the brushes of the switch S—1 permits the closure of the off-normal contact 39 which is associated with the moving parts of the switch in a manner well known in the art. The closure of the off-normal contacts 39, however, does not complete any circuit at this time.

The brief interruption of the contacts 13 of the calling operator's dial OD is followed by a closure of these contacts of somewhat longer duration and the consequent deenergization of the relay 27 at the switching station. When relay 27 releases its armature it closes a circuit that extends from battery through the winding of relay 28, inner left hand armature and back contact of relay 29, conductor 131, switch brush 1 and the second contact terminal of the series upon which it is now resting, conductor 129, back contact and armature of relay 27 and outer left hand back contact and armature of relay 29 to ground. Relay 28 is thus again

energized to complete the energizing circuits of slow release relay 30 and stepping magnet 33. Relay 30 has not released its armature during the brief deenergization of relay 28, and now continues to hold it attracted; and stepping magnet 33, under the control of its self-interrupting contacts, causes the switch brushes to take another step to bring them into engagement with the first set of six contact terminals in the third position of the switch movement. As brush 1 moves out of engagement with the second contact terminal of its associated series it breaks the energizing circuit of relay 28, which in turn breaks the energizing circuits of slow release relay 30 and stepping magnet 33. This condition of the circuits continues until relay 27 is again energized by the second interruption of the contacts 13 of the calling operator's dial OD. During this interval the slow releasing characteristics of the relay 30 maintain the associated contacts of relay 30 open. The relay 30 is merely conventionally represented, and, if necessary to secure the interruption of the associated contacts for a sufficiently long period of time after the relay magnet is deenergized, this device may be generally of the character of the device disclosed in Patent No. 1,337,680, granted April 20, 1920, to Samuel B. Williams, Jr. and Walter P. Albert. The construction and adjustment are such that the slow release relay 30 is adapted to hold its associated contacts open during the interval which elapses between successive interruptions of the circuit controlled by the contacts 13 of the operator's dial OD.

In the present instance it is assumed that the dial opens its associated circuit four times. Upon the second interruption of the dial circuit and accompanying energization of relay 27 the previously traced energizing circuit of the stepping control relay 28 is again completed, this time by way of switch brush 1 and the third stationary terminal of the series adapted to be engaged by brush 1. Relay 28 again operates to cause the energization of slow acting relay 30 and stepping magnet 33, the stepping magnet 33 again causes the associated switch brushes to take an additional step under the control of the self-interrupting contacts of magnet 33. This carries the brushes into engagement with the set of contacts in the fourth of the positions adapted to be occupied by the brushes in their movement, and again effects the breaking of the energizing circuit of relay 28. A moment later the contacts 13 of the dial OD are again closed and the relay 27 deenergized. When this occurs the energizing circuit of relay 28 is again closed, this time by way of brush 1 and the fourth stationary terminal in the series that it is adapted to engage. The energizing circuit of the stepping magnet

33 is now maintained closed long enough for the switch brushes to be advanced three steps, for the reason that the fourth, fifth and sixth stationary terminals in the series engaged by brush 1 are connected to conductor 129 which extends to ground by way of the back contact of relay 27 and the outer left hand back contact of relay 29. Therefore during the closure of the contacts 13 of dial OD that follows the second interruption of these contacts the switch brushes are advanced through their fourth, fifth and sixth positions and are left in engagement with the set of stationary terminals in the seventh position of the switch. When the relay 27 is again energized in response to the third interruption of the circuit at contacts 13 of the dial OD, the switch brushes are advanced from the seventh to the eighth position of their movement, and during the succeeding closure of the dial contacts 13 the switch brushes are advanced through their eighth, ninth and tenth positions, in the manner that has been described, and come to rest in their eleventh position. As it is line 4 that is being called, there is a fourth interruption at the contacts 13 of the operator's dial that effects the movement of the switch brushes from their eleventh to their twelfth position, and the succeeding closure of the dial contacts causes the switch brushes to move through their twelfth, thirteenth and fourteenth positions and come to rest in their fifteenth position. In this position they are in engagement with the set of stationary terminals identified with channel 1 of station 4, the station that is being called.

No further interruptions of the dial contacts 13 follow and consequently the circuit controlled by the contacts now remains closed and relay 27 remains deenergized. Therefore, as the switch brush 1 is in engagement with a contact terminal that is connected by way of conductor 128 with the front contact of relay 27, the energizing circuit of relay 28 remains interrupted; and when the contacts of relay 28 have remained interrupted for an interval in excess of that which normally elapses between successive interruptions of the dial contacts 13, the relay 30 releases its armature and closes its associated contacts. When this occurs a circuit is closed that extends from battery through the winding and right hand switch spring and resting contact of relay 29, left hand winding of relay 32, back contact and armature of relay 30 and off-normal contacts 39, now closed, to ground. Relays 29 and 32 both operate. Relay 29 locks up by way of a circuit that extends to ground at the off-normal contact 39 through the right hand switch spring and armature of relay 29. At the same time relay 29 at its inner left hand arma-

ture shifts the energizing circuit of the stepping control relay 28 from the path that extends by way of conductor 131 to switch brush 1 to the path that extends by way of the right hand winding and front contact and armature of relay 32, right hand armature and resting contact of release magnet 34 and conductor 132 to test brush 2 of the switch. Relay 29 also disconnects the ground controlled at its outer left hand armature from the circuits controlled by the armature of relay 27 and brings this ground into connection with a path that extends through the energizing winding of relay 31 in readiness to bring about the energization of relay 31 upon the release of relay 32, as will presently be described. As may be seen from the foregoing the control of the energizing circuit of stepping control relay 28 is now no longer dependent upon the path by way of switch brush 1 and the contacts of relay 27 controlled by the distant calling operator, but is governed over a path that extends by way of switch brush 2 to the stationary test terminals that brush 2 is adapted to engage.

For the purpose of this description it will be assumed that channel 1 of station 4 is idle and available for connection. The condition of the test terminal that marks the channel as available for connection may perhaps more readily be understood by first outlining briefly the busy test condition which exists when the channel is not available as a result of being in use either as a calling channel or as a called channel. Referring to Figs. 4, 7 and 7^A and more conveniently to the wiring of channel 1 of line 1 as being representative of the wiring of all the channels, it may be seen that the test terminal of the channel is connected by way of conductor 134 with the outer armature of relay 26. This armature is normally connected by way of its back contact to battery by way of the winding of relay 36; but when relay 26 is energized it is connected directly with ground at the front contact of the armature. It follows consequently that when the channel is in use as a calling channel the energization of relay 26 that continues during the entire period of use of the channel applies ground directly to conductor 134, and therefore to the multiplied test terminals to which this conductor extends.

Again referring to the channel circuit as illustrated in detail in Figs. 4, 7, and 7^A, it may be seen that when any channel is in use as a called channel the switch brush 2 of the calling switch is resting in engagement with the corresponding test terminal of the called channel. Under these circumstances all of the multiplied test terminals of the called channel are connected by way of brush 2 of the calling switch, conductor 132, back con-

tact and armature of release magnet 34, armature and back contact of relay 32, winding of relay 31 and outer left hand front contact and armature of relay 29 to ground. The actions that result in the completion of the path to ground just traced upon the seizure of an idle channel will subsequently be described. It is sufficient for the present to state that this path to ground from the test terminals of the called channel exists, and that the resistance of the relay 31 is relatively low so that the potential impressed upon the test terminals under these circumstances is substantially the ground potential.

Returning now to a description of the manner in which channel 1 of line 4 assumed to be idle is seized; at the moment relays 29 and 32 are energized by the release of relay 30 the energizing path for the stepping control relay 28 is extended by way of the inner left hand armature and front contact of relay 29, right hand locking winding and front contact and armature of relay 32, right hand armature and back contact of release magnet 34 and conductor 132 to the switch test brush 2. If channel 1 of line 4 were busy either as a calling or as a called channel, the test terminal upon which test brush 2 is resting would be connected to ground, as has been described. As a result relay 28 of the calling channel would be energized and relay 32 would remain energized. Relay 28 in operating would energize slow release relay 30 and stepping magnet 33 as hereinbefore described. The operation of relay 30 would not produce any result, as the path through the lower winding of relay 32 is now held open at the right hand back contact and switch spring of relay 29. Stepping magnet 33, however, acting under the control of its self-interrupting contacts, would advance the switch brushes one step into engagement with the group of terminals representing channel 2 of station 4. As has heretofore been pointed out, the relationship between test brush 2 and the row of contacts that it traverses is such that the brush makes contact with each succeeding terminal before it breaks contact with the preceding terminal. Therefore the brush 2 is shifted from the test terminal of one channel to the test terminal of the next channel without interrupting the continuity of the energizing path of relays 28 and 32. Thus if channel 1 of line 4 were busy the switch brushes would automatically be advanced to the stationary contacts of the next channel in the group, and so on over the contacts of unavailable channels.

But it has been assumed in the present instance that channel 1 is idle and available for use. Therefore after the initial energization of relay 32 upon the termination of the switch stepping impulses, there is no cir-

cuit for maintaining the energization of the relay as there is no path to ground by way of the conductors 132 or 134 extending from the multiplied test terminals of the channel such as exists when the channel is busy. Therefore relay 32 is immediately deenergized and releases its armature, thus completing the previously traced path from brush 2 to ground by way of the armature and back contact of relay 32, the winding of relay 31 and the outer left hand front contact and armature of relay 29. As the holding circuit of the relay 32 is now open and the initial energizing circuit of the relay by way of its lower winding is held open at the right hand back contact of relay 29 locked up to ground at the off-normal contact 39, the relay 32 plays no further part in the control of the circuits. Relay 31 in operating, as a result of battery applied from brush 2 and the contact with which it is engaged, and to which a conductor corresponding to 134 is connected, closes a circuit that extends from battery through the winding of relay 35 (Fig. 7) conductor 133 and the armature and front contact of relay 31 to ground. Relay 35 in operating extends a connection from ground to the brushes 3, 4, 5 and 6 of the corresponding switch, S—1, and thus applies ground to the stationary contact terminals upon which brushes 3, 4, 5 and 6 are resting. It may be noted that the grounding of the brushes 3, 4, 5 and 6 does not occur until the switch S—1 has completed its selecting operation and has brought its brushes to rest upon the terminals associated with the channel with which connection is to be established. Therefore, the passage of the brushes over the contact terminals associated with other channels on their way to the selected channel is without effect upon the circuits of the channels traversed.

The effect of the grounding of brushes 3, 4, 5 and 6 of switch S—1 upon the completion of the station and channel selecting operation, as has been described, is to close the energizing circuits of a pair of modulation frequency controlling relays associated with the calling channel and another pair of modulation frequency controlling relays associated with the called channel. Each of these pairs of relays includes a particular relay in the group of relays 61, 62 and 63 that control the application of the channel matching modulating frequencies, and a particular relay in the group 72, 73 and 74 that control the application of the line or station selecting modulating frequencies. As the brushes of switch S—1 have come to rest in engagement with the fifteenth set of contact terminals, that is the contact terminals associated with channel 1 of line 4, the result of the operation of relay 35 (Fig. 7) is to ground conductors 151 and 144 extending to the controlling relays of calling channel 1 of line 1

and conductors 151¹ and 142¹ extending to the controlling relays associated with called channel 1 of line 4. The grounding of conductor 151 of the calling channel energizes relay 61, which thereupon operates to apply the 33,333 modulating frequency to balanced modulator BM—2 of the calling channel. As the incoming or receiving branch of the calling channel is operating on the lower side band of the 23,333 carrier, the application of the 33,333 cycle modulating frequency to balanced modulator BM—2 results in the production in the output circuit of the balanced modulator of the upper side band of the 10,000 cycle carrier as the difference product of modulation. The upper side band of the 10,000 cycle carrier thus produced passes through the band filter BF—15 to the input circuit of the balanced modulator BM—3, where it is met by the modulating frequency produced by the modulation that occurs in the associated balanced modulator BM—4. As the conductor 144 is one of the two calling channel control conductors grounded by the operation of the selecting switch S—1 of the calling channel, the corresponding relay 74 is energized; and also the relay 70, the winding of which is included in series in a common portion of the circuit from which the energizing circuits of relays 72, 73 and 74 are branched. Relay 70 in operating applies the 300,000 cycle modulating frequency to modulator BM—4 and relay 74 in operating applies the 80,000 cycle frequency to this same modulator. The difference product of modulation of these two frequencies is the 220,000 cycle frequency; and this together with the 300,000 modulating frequency passes through band filter BF—18 and joins the upper side band of the 10,000 cycle carrier at the parallel input circuit of the balanced modulator BM—3. As the modulating operation in the group of apparatus including the balanced modulator BM—3 has already been described, it is only necessary to say that as a result of the intermodulation of the 220,000 and 300,000 cycle frequencies with the upper side band of the 10,000 cycle carrier there is produced in the output circuit of balanced modulator BM—3 the upper side band of the 90,000 cycle frequency. This 90,000 cycle upper side band passes through the band filter BF—17, thence by way of receiving branch conductors 211, conjugate net CN—1, conjugate net CN—3, conjugate net CN—5, conductors 208 and conjugate net CN—11 to the common outlet conductors 200. At this point the 90,000 cycle upper side band is amplified in the common balanced amplifier BA—2, passes selectively through band filter BF—38 associated with the outgoing channel branches of line 4 and adjusted for the 89,000 to 99,000 cycle frequency band, and thence passes to the input

circuit of balanced modulator BM—8 in the common outlet to the channels of line 4. At this point the 90,000 frequency upper side band is met by the 80,000 cycle frequency applied by way of conductors 120 to the parallel input circuit of balanced modulator BM—8. As a result of the modulation that now occurs the upper side band based upon the 90,000 cycle frequency is stepped down by 80,000 cycles and becomes the upper side band based upon the 10,000 cycle frequency. This side band now passes by way of the common outgoing branch conductors 240 and is selectively diverted into the particular branch of the common circuit 240 that is provided with a band filter of a corresponding frequency range; that is it is diverted into the outgoing or transmitting branch 244 of channel 1 that includes the band filter BF—45 adapted to pass the upper side band of the 10,000 cycle carrier. Thus by the energization of relays 61 and 74 of calling channel 1 as a result of the selective operation of switch S—1, the carrier side band of channel 1 of line 1 is so modulated that, after passing into the common network, it is selectively diverted into the common outlet associated with called line 4 and into the outgoing or transmitting branch of selected channel 1 of line 4.

A complementary action similar to that described above takes place in connection with matching the incoming or receiving branch of the called line channel with the outgoing or transmitting branch of the calling line channel. As hereinbefore stated, the grounding of brushes 3 and 4 of switch S—1 upon the completion of the selecting operation, applies ground to the terminals of conductors 151' and 142' associated with channel 1 of called line 4. The grounding of conductors 151' brings about the energization of relay 61' associated with channel 1 of line 4, and the grounding of conductor 142' causes the energization of relay 72' and common relay 70' associated with channel 1 of line 4. Relay 61' in operating applies the 33,333 cycle frequency for the modulation of the lower side band of the 23,333 cycle carrier in balanced modulator BM—13 of the incoming or receiving branch of channel 1 of line 4 (Fig. 6). This modulation converts the lower side band of the 23,333 cycle carrier into the upper side band of the 10,000 cycle carrier, thus matching the carrier side band of the incoming branch of the called line with the carrier side band frequency for which the outgoing branch of the calling channel is adjusted. The upper side band of the 10,000 cycle frequency thus produced then passes through band filter BF—44 to balanced modulator BM—14 where it is met by the modulating frequencies determined by the operation of the associated relays 70' and

72' of the called line channel. As the relay 70' applies the 300,000 cycle frequency and the relay 72' applies the 40,000 cycle frequency to balanced modulator BM—15, the 300,000 cycle frequency and the 260,000 cycle frequency are present in the output circuit of balanced modulator BM—15 and pass through band filter BF—45' to the parallel input circuit of balanced modulator BM—14. The effect of the intermodulation of the upper side band of the 10,000 carrier with the 300,000 and 260,000 cycle frequencies in balanced modulator BM—14, as has hereinbefore been described, is to produce in the output circuit of balanced modulator BM—14 the speech modulated upper side band based upon the 50,000 cycle frequency. The 50,000 cycle upper side band passes through the band filter BF—46, and by way of conductors 241, conjugate net CN—7, conjugate net CN—9, conjugate net CN—10 and conjugate net CN—11 to the common outlet conductors 200 (Fig. 9). After amplification in balanced amplifier BA—2, the upper side band of the 50,000 cycle frequency passes selectively through band filter BF—35 to the series input circuit of balanced modulator BM—5 in the common outlet to the transmitting branches of the channels of line 1. The 40,000 cycle frequency is applied by way of conductors 117 to the parallel input circuit of balanced modulator BM—5, and as a result of the modulation that takes place, the upper side band based upon the 50,000 cycle frequency is stepped down by 40,000 cycles to the upper side band based upon the 10,000 cycle frequency. The upper side band of the 10,000 cycle carrier therefore appears in the output circuit of the modulator BM—5, flows through the common outlet conductors 210 of the channels of line 1 and is diverted into the outgoing or transmitting branch conductors of the particular channel of line 1 that is provided with the 10,000 cycle carrier side band filter in its outgoing circuit; that is it is diverted into the transmitting branch 214 of channel 1 of line 1, which is the transmitting branch of the calling channel. Thus the selecting operation of the calling channel switch S—1 causes the application to the called channel of the particular modulating frequencies required to match the called channel carrier with the carrier frequency for which the transmitting branch of the calling channel is adjusted, and to elevate the called channel carrier side band to the proper frequency for securing its selective diversion into the outgoing channels of the line with which the calling channel is associated.

It may be noted that when any one of the relays 72, 73 and 74 controlling the application of the line selecting frequencies is oper-

ated, a circuit is closed that extends from battery through the winding of relay 45 (Fig. 4), and to ground by way of the upper front contact and armature of whichever of the relays is operated. Relay 45 in operating closes the circuit of the A battery for the heating of the filaments of the associated balanced modulators BM—3 and BM—4, thus rendering the modulators operative to perform their line selecting frequency modulation. Relay 45 in operating also closes a circuit that extends from battery through the lower front contact and armature of the relay, conductor 137 and the winding of relay 55 (Fig. 9) to ground. Relay 55 in operating applies current from the A battery for heating the filaments of the balanced modulator BM—5. It also closes a circuit that extends from battery through the winding of relay 59 and outer lower front contact and armature of relay 55 to ground. Relay 59 in operating applies current from the A battery for the heating of the filaments of balanced amplifier BA—2. Thus the completion of the selecting operation by the switch S—1 of the calling channel brings about the energization of the receiving branch balanced modulators BM—3 and BM—4 of the calling channel, the energization of the balanced modulator BM—5, common to the outgoing or transmitting branches of the channels of calling line 1, and also the energization of the balanced amplifier BA—2 interposed in the common outlet circuit to the transmitting branches of all of the lines. At the same time the operation of relay 72' (Fig. 6), which is assumed to have been operated in the called channel 1 of line 4, brings about the application, in the same way, of current from the A battery for energizing balanced modulators BM—14 and BM—15 of the called channel 1 of line 4, and the operation of relay 58 for the energization of balanced modulator BM—8 (Fig. 9) associated with the common outlet to the transmitting branches of the channels of line 4, and for the energization of balanced amplifier BA—2 interposed in the outlet circuit 200, to all of the lines. It will be observed that the balanced modulators BM—5, BM—6, BM—7 and BM—8 of the four lines have associated with them the relays 55, 56, 57 and 58, respectively, for controlling the respective energizing circuits of the associated balanced modulators, and for controlling the energizing circuit of the common relay 59 associated with the common balanced amplifier BA—2.

When the brushes of switch S—1 of the calling channel become connected with the set of stationary terminals identified with channel 1 of station 4, as described, a circuit is completed that extends from battery by way of the winding of relay 36' of channel 1 (Fig. 6), outer left hand back

contact and armature of relay 26', conductor 134', the multiple wire that joins all the test terminals of channel 1 of station 4, the test terminal of this channel in switch S—1, test brush 2 which now rests upon this test terminal, conductor 132, lower back contact and armature of release magnet 34, armature and back contact of relay 32, winding of relay 31, and outer left hand front contact and armature of relay 29 to ground. The effect of the resultant operation of relay 31 has already been described. The operation of relay 36' which also results from the completion of this circuit opens at the lower back contact and armature of relay 36' the path over which the A battery is normally supplied to the amplifier A—11 and rectifier R—3 of channel 1 of called line 4 to maintain them in their responsive condition. Therefore the instant the channel is seized by the switch of a calling channel the receiving branch of the seized channel is rendered inert and the associated relay 25' is rendered unresponsive. This prevents the 150 cycle control frequency that is subsequently transmitted over the receiving branch of called channel 1 for the control of the signaling apparatus of calling channel 1 at the calling station from effecting the operation of the switching apparatus associated with called channel 1 at the intermediate or switching station.

The interconnecting operation of the two channels at the switching station is now complete and there is no further change in the condition of the switching apparatus associated with these channels until disconnection takes place at the end of the conversation. After the operator at the calling station has operated the dial OD to effect the interconnection of the channels at the switching station, as described above, she returns the calling key CK of connecting cord circuit CC—2 to its normal position. This reconnects toll supervisory lamp TSL in the sleeve circuit of the connecting cord and disconnects the common operator's dial OD. As relay 15 (Fig. 2) is now steadily energized, the 150 cycle control frequency is steadily applied to modulate the 23,333 cycle carrier wave of channel 1. The lower side band of this modulated wave passes through the band filter BF—1, the high frequency hybrid coil HFH—1, the carrier multiplex toll line conductors extending from calling station 1 to the switching station, the group filter GF—1 at the switching station, the band filter BF—9 of the receiving branch of channel 1 of this line at the station, thence through the frequency changing devices of the receiving branch of channel 1 of line 1, the conjugate network, the common outlet circuit with its frequency sorting or selecting devices, and into the transmitting or outgoing branch of

selected channel 1 of called line 4. Thence it passes through band filter BF—45 and group filter GF—4 to the conductors 104 of line 4.

5 As the organization of the carrier multiplex circuit at called station 4 may be exactly the same as the organization of the circuits at calling station 1 shown in Figs. 1 and 2, the circuits illustrated in these two
10 figures may now be assumed to represent the circuits of the station to which the connection is being extended.

Proceeding now upon this assumption, the upper side band of the 10,000 cycle carrier
15 frequency with its 150 cycle control frequency modulation passes through the band filter BF—2 to the balanced detector BD—1 where demodulation takes place. The 150
20 cycle control frequency product of demodulation is amplified in amplifier A—4 and passes through the low pass filter LPF—1 to rectifier R—1, being kept out of the
25 branch extending from the band filter BF—8 by the low frequency suppressing characteristics of this filter. After rectification and amplification in rectifier R—1 the uni-directional current produced causes the operation
of relay 18 connected with the output circuit of rectifier R—1.

30 The result therefore is that as soon as interconnection of the channels at the switching station has taken place, relay 18, associated with the seized channel at the called station operates. When relay 18 operates
35 it closes an energizing circuit by way of the right hand winding of relay 17 and also closes an energizing circuit for calling lamp CL—1 by way of the left hand armature and back contact of relay 16 and conductor
40 54. Relay 17 in operating closes a circuit that extends from battery through the front contact and armature of relay 17 and thence by way of conductor 53 to ground
45 by way of the busy lamps BL—1 of this channel. These lamps are thus illuminated to guard the channel as soon as it is seized at the switching station. The illumination of calling lamp CL—1 indicates to the operator
50 at the answering position, operator's position 1, that there is a call incoming over this channel. The operator therefore answers the call by inserting the toll plug TP of one of her pairs of connecting cords
55 CC—1 into the associated channel springjack TJ—1. This closes a circuit that extends from battery through the toll supervisory lamp TSL of the cord circuit that is being employed, resting contacts of calling
60 key CK, registering sleeve contacts of the toll plug TP and channel springjack TJ—1, conductor 52, winding of relay 15 and winding of slow release relay 16 to ground. The closure of this circuit operates
65 both relays 16 and 15. Relay 16 in operating operates relay 20, and that relay ap-

plies current from the A battery to energize the transmitting branch of the corresponding channel and applies the appropriate carrier wave, in the present instance assumed to be the 23,333 cycle wave, to balanced modulator BM—1 by way of tuned
7 circuit TC—3. Relay 15 in operating operates relay 19 and applies the 150 cycle control frequency to the balanced modulator BM—1 for modulating the 23,333 cycle
75 carrier wave. Relay 16 in operating also closes an energizing circuit by way of the left hand winding of relay 17, so that the illumination of the busy lamps BL—1 is assured as long as a plug TP remains in a
80 springjack of the associated channel. Relay 16 in operating also opens at its left hand armature and back contact the circuit over which calling lamp CL—1 was illuminated, thus extinguishing the lamp, and closes at
85 its left hand armature and front contact a circuit that extends from battery through the armature and front contact of relay 18, resistance 49 and winding of relay 16
90 to ground. The circuit thus closed through resistance 49 is in shunt of the branch extending from battery by way of supervisory lamp TSL, conductor 52 and winding of relay 15, and the value of resistance 49
95 is such as to shunt out and extinguish lamp TSL, but without effecting such a reduction of current flow as to release the relay 15 included in series with lamp TSL. Assuming an electromotive force of approximately
100 24 volts for the battery that supplies current for this circuit, this result may be effected by making the resistance of relay 16 approximately 100 ohms, the resistance of relay 15 approximately 20 ohms, the hot
105 resistance of lamp TSL approximately 120 ohms and the value of resistance 49 approximately 40 ohms.

At the stage of operation that has now been reached the operator at operator's position 2 of the calling station is in connection with channel 1 by way of connecting
110 circuit CC—2 and multiple jack MJ—1 of the channel, the 23,333 cycle carrier wave with its 150 cycle control frequency modulation is applied to calling channel 1 at the calling station, the connection between channel 1 of station 1 and channel 1 of station 4
115 is established at the intermediate or switching station, the 23,333 cycle carrier with its 150 cycle control frequency modulation is holding the intermediate station switch S—1 in its operated position and is also being transformed to the 10,000 cycle carrier with
120 an accompanying 150 cycle control frequency modulation for passage, after line selecting modulation and demodulation, through the transmitting branch of channel 1 of line 4 at the switching station, this modulated carrier is being received in channel 1 of station 4 and is holding the relay
125
130

18 associated with the receiving branch of that channel operated, the operator at operator's position 1 at the called station 4 has made connection by means of connecting circuit CC—1 with the channel over which the call is being received, calling lamp CL—1 and toll supervisory lamp TSL at the called station 3 are extinguished and the 23,333 cycle carrier wave with the 150 cycle frequency modulation is being applied to the transmitting branch of channel 1 at called station 4. The 23,333 cycle carrier wave with the 150 cycle control frequency modulation applied at the called station is transmitted back over the carrier multiplex line extending between the switching station and called station 4, and passes into the receiving branch of channel 1 (Fig. 6) by way of band filter BF—44. The modulated 23,333 carrier is applied to the input circuit of the balanced modulator BM—13, and after demodulation the 150 cycle component passes through low pass filter LPF—3 to amplifier A—11. But as the seizure of channel 1 and the accompanying operation of relay 36' (Fig. 6) has disconnected the normally connected A battery from the filaments of the thermionic tubes of amplifier A—11 and rectifier R—3, these devices are inert and the 150 cycle component of the modulated 23,333 cycle carrier has no effect upon relay 25', and the switching apparatus associated with channel 1 of line 4 remains therefore in its normal condition. The modulated 23,333 cycle carrier, however, passes into the frequency changing apparatus of the receiving branch of the channel, where it is modulated, in the manner that has already been described, to match the incoming carrier side band of the called line with the 10,000 cycle side band frequency at which the transmitting branch of the channel of the calling line is adapted to operate, and to elevate the frequency of the changed carrier side band to the frequency level that will cause it to pass selectively into the common outlet circuit of the transmitting branches of the calling line channels. Thence the frequency matched and elevated side band passes through the conjugate network to the common outlet conductors 200 with their associated sorting or frequency selective branches, into the common outlet conductors 210 of the outgoing branches of the channels of line 1, through transmitting branch 214 and associated band filter BF—10 of channel 1 of calling line 1, and through the group filter GF—2 of line 1 to the conductors 104 of that line that extend between the intermediate or switching station and calling station 1.

The modulated 10,000 cycle carrier produced as described then passes over the conductors 104 of carrier multiplex line 1, through high frequency hybrid coil HFH—

1 (Fig. 2), band filter BF—2 of the receiving branch of channel 1 of the calling station and thence to balanced detector BD—1 where demodulation occurs. The 150 control frequency product of demodulation is amplified in amplifier A—4 and passes selectively through low pass filter LPF—1 to rectifier R—1, and the amplified and rectified current that results, causes the operation of relay 18 of the receiving branch of channel 1 at the calling station. When relay 18 at the calling station operates it closes the branch circuit to battery by way of resistance 49 and the left hand front contact and armature of relay 16, the latter relay being operated at the calling station as a result of the presence of toll plug TP of connecting circuit CC—2 in the channel springjack MJ—1. The completion of the branch path by way of resistance 49 has the effect of shunting and extinguishing the toll supervisory lamp TSL at the calling station. Therefore the response of the operator at called station 4 to the call received over channel 1 from station 1 is indicated to the operator at calling station 1 by the darkening of the toll supervisory lamp TSL of the connecting cord circuit CC—2. The carrier circuit between calling station 1 and called station 4 is now complete, and the operators at these stations may carry on the conversation incidental to the establishment of the further extension of the connection to the desired local line at called station 4. Assuming that the connection is to be extended to local station SS at called station 4, this is effected by the insertion of plug LP of connecting circuit CC—1 into the multiple jack LMJ of the line extending to this local station and the pressing of ringing key RK.

When the subscribers are in conversation the voice currents pass by way of conductors 50 and 51 (Fig. 2) through the artificial line AL—1 to the line windings of the low frequency hybrid coil LFH—1 and thence by way of the series winding of the hybrid coil, the band filter BF—7 and the transformer 21 to the series input circuit of the two thermionic tubes of balanced modulator BM—1. The band filter BF—7, as heretofore stated, is constructed and adjusted to pass the essential voice frequencies lying between the limits of 300 cycles and 2300 cycles per second; and as the band filter BF—7 is interposed between the low frequency talking circuit of the station and the point of application of the 150 cycle control frequency to the balanced modulator, it serves to prevent the backing up of the continuously applied 150 cycle frequency into the low frequency talking circuit. As a result of the action which takes place in the balanced modulator BM—1 the carrier wave, 23,333 cycles at both the calling and the called stations, is modulated simultaneously by the

150 cycle control frequency and the 300 to 2300 cycle band of the voice frequencies, and in each case the lower modulation side band is transmitted. The lower side band of the 23,333 cycle carrier transmitted from calling station 1 is modulated at the switching station, as has been described, to convert it into the upper side band of the 10,000 cycle frequency and to direct it to the channels of line 4; and the lower side band of the 23,333 cycle carrier transmitted from called station 4 is modulated at the switching station to convert it into the upper side band of the 10,000 cycle frequency and to direct it to the channels of line 1. The converted frequency side band produced at the switching station by the modulation of the side band transmitted from each station is then transmitted to the other station, received in the receiving branch of the channel at that station, and demodulated in the balanced detector BD—1. The 150 cycle control frequency product of demodulation is then selected by low pass filter LPF—1 to effect the energization of relay 18 in the manner hereinbefore described and the voice frequency products of demodulation lying between 300 cycles and 2300 cycles per second are selected by band filter BF—8 and applied to the mid-points of the line windings of the low frequency hybrid coil LFH—1. The voice currents then pass equally through the line windings of the hybrid coil to the balancing network N and to the conductors 50 and 51 extending to the line springs of the springjack into which the toll plug TP of the connecting circuit is inserted, and thence in the usual way to the connected local line.

If after the connection is established it is necessary for the operator at either station to signal the operator at the other station, this may conveniently be done by throwing the calling key CK of the associated connecting circuit to connect the common dial OD with the sleeve circuit, and then operating the dial to cause a series of interruptions of the circuit at the dial contacts 13. As has been stated, the dial OD is so adjusted that the interruptions of the circuit at dial contacts 13 are of sufficient duration to cause the operation of the quick acting relays, but of insufficient duration to cause the release of the slow acting relays controlled by the dial. As a result when the operator operates dial OD to signal the distant operator, the armature of relay 15 is intermittently released and attracted to cause corresponding intermissions in the application of the 150 cycle control frequency, but the circuit of relay 16 is not interrupted for a sufficient length of time to permit relay 16 to release its armatures and deenergize the transmitting branch of the channel. The effect of the intermissions of

the 150 cycle control frequency at the switching station is to cause a corresponding series of retractions and attractions of the armature of relay 25 (Fig. 4), the interruptions of the energizing circuit of associated relay 26, however, being of insufficient duration to permit relay 26 to release its armatures. The intermittent operation of relay 25 causes a corresponding intermittent operation of the relay 27; but as relay 29 is at this time energized and locked up by way of the off-normal contacts 39 of switch S—1, the operation of relay 27 is without effect on the circuits of the channel. However, the withdrawal of the 150 cycle control frequency results in a corresponding disappearance of the 150 cycle modulation from the carrier side bands that are transmitted through the channel interconnections at the intermediate or switching station. As a result of the intermissions of the 150 cycle control frequency at the distant station the relay 18 at the station that is being signaled is caused intermittently to release and attract its armature, and there, therefore, is a corresponding breaking and making of the shunt circuit including the resistance 49 and the left hand front contact and armature of relay 16. The breaking and making of this shunt circuit causes the flashing of the toll supervisory lamp TSL of the operator's connecting cord circuit, and this constitutes an indication to the operator that the distant operator is signaling her.

When the connected subscribers have concluded their conversation the replacing of the telephone receivers upon the respective switch hooks breaks the circuits of the associated supervisory relays 12 of the connecting cord circuits and causes the illumination of the associated lamps LSL. The operators, after supervising the connection by means of their cord circuit listening keys LK, withdraw the plugs LP and TP from the springjacks into which they have been inserted. When the operator withdraws toll plug TP from the channel springjack into which it has been inserted the circuit that has been maintaining relays 15 and 16 energized is broken. Relay 15 immediately releases its armature, and the resultant deenergization of relay 19 withdraws the 150 cycle control frequency from the balanced modulator BM—1. Shortly thereafter the slow release relay 16 releases its armatures, and the resultant deenergization of relay 20 disconnects the A battery from the filaments of the thermionic tubes of balanced modulator BM—1 and balanced amplifier BA—1 to render the channel transmitting branch inert, and also withdraws the carrier wave from the input circuit of the balanced modulator BM—1.

The withdrawal of the toll plug TP from the channel springjack at the called station

is without effect upon the switching apparatus at the intermediate or switching station, for the reason that the high frequency responsive switch control apparatus, associated with the receiving branch of the seized channel at the intermediate or switching station is maintained inoperative by the interruption at the lower back contact and armature of relay 36' (Fig. 7) of the circuit over which current from the A battery is supplied to the filaments of the amplifier A-11 and rectifier R-3. The restoration of the switching apparatus at the intermediate or switching station is under the control of the calling station. When the 150 cycle control frequency is withdrawn from the carrier wave of channel 1 of the calling station as a result of the withdrawal of toll plug TP from the channel springjack, relay 25 of the receiving branch of the channel at the switching station (Fig. 4) is immediately released and shortly thereafter the slow release relay 26 releases its armatures. When relay 26 releases it breaks at its outer front contact and armature the path to ground that has been maintaining the test potential on conductor 134 connected with the test terminals of this channel throughout the switches, thus removing the busy test condition from the channel. Relay 26 in releasing also, at its outer armature and back contact, reconnects to the test conductor 134 the branch from battery including the relay 36, so that relay 36 is again under the control of conductor 134 extending to the test terminals. Relay 26 in releasing also closes a circuit that extends from battery through the armature and back contact of relay 25, inner armature and back contact of relay 26, winding of release magnet 34 of the switch S-1 and to ground by way of the closed off-normal contacts 39 of switch S-1. The completion of this circuit causes release magnet 34 to attract its armature and remove the holding pawl 43 from ratchet wheel 41 of associated switch S-1, at the same time acting to lift the stepping pawl 42 out of engagement with the teeth of the ratchet wheel. The energizing circuit of release magnet 34 remains closed throughout the return movement of the switch wipers or brushes, and as the brushes reach their normal position the energizing circuit is broken by the opening of the off-normal contacts 39. The opening of the off-normal contacts also serves to break the locking circuit of relay 29, which thereupon releases to restore the normal condition of the associated circuits. When the release magnet 34 operates it not only releases and permits the return to normal of the associated switch brushes, but also opens at its lower armature and resting contact the circuit extending from ground by way of outer armature

and front contact of relay 29, winding of relay 31, back contact and armature of relay 32, right hand armature and back contact of release magnet 34, and conductor 132 to test brush 2 of the switch. This has the effect of opening the circuit to ground of test brush 2 and thus preventing unintended actions which might otherwise occur as a result of test brush 2 passing over corresponding test terminals of other channels during the return movement of the brushes.

It also has the effect of immediately breaking the energizing circuit through relay 31 thus causing relay 31 to break the energizing circuit of relay 35 as a result of which brushes 3, 4, 5 and 6 are immediately disconnected from ground and are maintained disconnected during the return movement of the brushes. The result of this is immediately to open the energizing circuits of the two modulating frequency controlling relays 61 and 74 associated with calling channel 1 of line 1, and of the two modulating frequency controlling relays 61' and 72' associated with called channel 1 of line 4. The deenergization of these relays withdraws from their respective channels the modulating frequencies that the relays control and operatively disconnects the calling and called channels from each other. The release of relay 74 of the calling channel releases the associated relay 45, which in turn releases the relay 55 associated with balanced modulator BM-5 in the common outlet to the transmitting branches of the channels of line 1. The effect of this is to interrupt the flow of current from the A battery to balanced modulators BM-3 and BM-4 of the receiving branch of the calling channel, and to balanced modulator BM-5 in the common outlet to the transmitting branches of the line 1 channels, the latter, however, being subject to whether or not other channels of line 1 are in use at the time channel 1 is released. As long as any of the channels of the line continues in use, the relay 55 is held energized to maintain the supply of current from the A battery to balanced modulator BM-5. In like manner, the release of relay 72' of called channel 1 of line 4 releases associated relay 45', which in turn releases relay 58 associated with balanced modulator BM-8 thus causing the withdrawal of A battery current from balanced modulators BM-14 and BM-15 of the receiving branch of the called channel and from balanced modulator BM-8 in the common outlet to the transmitting branches of the line 4 channels, providing that the relay 58 is not continued energized by the use of some other one of the line 4 channels. The release of relay 55 associated with the outgoing channels of line 1 and relay 58 associated with the outgoing

channels of line 4 causes the release of relay 59, providing that relay 59 is not maintained energized by the operated condition of relays 56 and 57 associated with the channels of lines 2 and 3, and effects the withdrawal of A battery current from the balanced amplifier BA—2 in the common outlet 200 of all of the channels of all of the lines.

- 10 When release magnet 34 operates to restore switch S—1 it opens the circuit, by way of test brush 2 of switch S—1 and test conductor 134' of channel 1, line 4, in which the winding of relay 36' of the called channel is included, and an instant later the circuit is permanently interrupted by the return movement of brush 2 of switch S—1 off of the test terminal of called channel 1. When relay 36' of channel 1 releases, it re-
15 connects the A battery for the energization of the filaments of amplifier A—11, and rectifier R—3 of the receiving branch of channel 1, with the result that the receiving branch of the called channel is again made
20 responsive to a call initiated at station 4 with which it is associated.

- If it should happen that the switching apparatus at the switching station is released by the withdrawal of the toll plug from the channel springjack at the calling station before the operator at station 4 withdraws the toll plug from the springjack of channel 1 in which it has been inserted, relay 25' of channel 1 is energized and in turn energizes the slow release relay
35 26'. The resultant operation of relay 26' breaks the potential path over which relay 361 may be energized and at the same time applies ground to conductor 134' extending
40 to the test terminals of channel 1 of line 4 throughout the switches. This has the effect of guarding channel 1 against seizure by a calling switch as long as the operator at the distant station to which channel 1
45 extends has connection with it. When the operator at called station 4 removes the toll plug from the channel springjack this busy condition of the channel at the switching point is removed and the channel is
50 again made available for connection. Inasmuch as the release of relay 26' is delayed at the moment of disconnection until after the armature of relay 25' has fallen back, relay 27' is momentarily operated, and this
55 has the effect of momentarily closing the energizing circuit of stepping control relay 28' by way of brush 1 of switch S—10 and the stationary terminal upon which it rests in the normal position of the switch
60 brushes. As a result switch S—10 is advanced one step. But as relay 25' is not again energized at this time, the immediately following retraction of the armatures of relay 26' energizes release magnet 34' by

way of the off-normal contact 39', closed 65 when the switch brushes were moved one step from normal, and switch S—10 is immediately restored to its normal position.

Reference will now be made to the actions which occur when the calling operator attempts to establish connection with a station all of the channels of which are in use. Assuming that this is the condition that exists at the time of the call for connection with station 4 is initiated, the test terminals of all three channels have connection with ground, and consequently as test brush 2 of switch S—1 passes over them in the hunting operation of the switch there is no interruption of the circuit that extends from battery to ground at these test contacts by way of the winding of stepping control relay 28, inner left hand armature and front contact of relay 29, right hand winding and front contact and armature of relay 32, right hand armature and back contact of release magnet 34, conductor 132 and test brush 2. Therefore, relay 28 is held energized to cause the continued operation of the stepping magnet 33, and relay 32 is held energized to prevent the operation of relays 31 and 35 and the application of the channel matching frequencies. But as test brush 2 passes out of engagement with the test terminal of channel 3 of station 4 and into engagement with the next succeeding test terminal of the series the energizing circuit of relays 28 and 32 is broken, for the reason that the connection of the fourth test terminal of the group, just engaged, is by way of conductor 130 and winding of relay 37 with battery instead of with ground. Relay 28 in releasing stops the stepping action and brings the switch brushes to rest, and relay 32 in releasing closes a circuit that extends from battery through the winding of relay 37 (Fig. 4), conductor 130, fourth test terminal of the station 4 group, test brush 2, conductor 132, lower back contact and armature of release magnet 34, armature and back contact of relay 32, winding of relay 31 and outer front contact and armature of relay 29 to ground. Relay 31 in operating closes the energizing circuit of relay 35 to connect brushes 3, 4, 5 and 6 of switch S—1 to ground. But as the brushes are not in engagement with corresponding contact terminals at this time, their extension to ground is without effect. Relay 37 in operating interrupts the transmitting branch conductors of the calling channel and connects the outgoing portions of these conductors with the distributing conductor; 135 that convey the busy tone modulated carriers. Relay 37 in operating also closes a circuit that extends from battery through the left hand armature and front contact of relay 37, conductor 136, and winding of

relay 40 (Fig. 3) to ground. Relay 40 in operating applies current from the A battery for the heating of the filaments of the thermionic tubes of the modulator BM-9 and amplifier A-10 of the busy tone modulating apparatus. The 10,000, 13,333 and 16,666 cycle carrier waves supplied to the modulator BM-9 by way of band filter BF-39 are thus modulated by the busy tone, and the modulated carriers are supplied by way of the band filter BF-40 to the distributing circuit 135 from which the busy tone modulations flow to the outgoing branch of the channel whose relay 37 is operated. At calling station 1 the busy tone modulation passes into channel 1, and after demodulation and selection, in the manner hereinbefore described, is carried into the low frequency line with which the operator's connecting circuit is connected. Consequently the calling operator, upon bringing her telephone set into circuit by operating the listening key LK, hears the busy tone and knows that all of the channels extending to the called station 4 are in use. She thereupon withdraws the toll plug TP from the channel springjack, and a restoration of the apparatus at the switching station to normal occurs in the manner which has already been described. It will be observed that there is a busy tone applying terminal lying beyond each series of sets of channel terminals of the various stations, so that the busy tone is automatically sent back to the calling station whenever the switch brushes fail to establish connection with any of the channels of the station that is being called.

What is claimed is:

1. In a carrier wave communicating system, a plurality of carrier multiplex lines employing modulated waves of different frequencies, a switching station in which said lines converge, and means for selectively interconnecting said lines by shifting the frequency level of the transmitted modulated waves.

2. In a carrier wave communicating system, a plurality of carrier multiplex lines employing modulated waves of different frequencies, a switching station in which said lines converge, and means at said switching station for selectively interconnecting said lines by shifting the frequency level of the transmitted modulated waves.

3. In a carrier wave communicating system, a plurality of carrier multiplex lines employing modulated waves of different frequencies, a switching station in which said lines converge, and automatic switching mechanism at said switching station for selectively interconnecting said lines by shifting the frequency level of the transmitted modulated waves.

4. In a carrier wave communicating sys-

tem, a plurality of carrier multiplex lines, a switching station in which said lines converge, and switching mechanism at said switching station controlled from a distant point for selectively interconnecting said lines by shifting the frequency level of the transmitted carrier side bands thereof.

5. In a carrier wave communicating system, a plurality of carrier multiplex lines, modulated waves of different frequencies, a switching station in which said lines converge, and switching mechanism at said switching station controlled over said carrier multiplex lines for selectively interconnecting said lines by shifting the frequency level of the transmitted modulated waves.

6. In a carrier wave communicating system, a plurality of carrier multiplex lines each having a plurality of channels employing modulated waves of different frequencies, a switching station to which said lines extend, and means at said switching station for selectively interconnecting said lines and matching the wave frequency of each interconnected line with the wave frequency of the other interconnected line by shifting the frequency level of the transmitted modulated waves.

7. In a carrier wave communicating system, a plurality of carrier multiplex lines each having a plurality of channels including an incoming branch and an outgoing branch, said branches employing modulated waves of different frequencies, a common outlet to the outgoing branches of the channels of each line, said outlet operating at a frequency level differing from the frequency levels at which the outlets to the outgoing branches of channels of the other lines operate, and means associated with the receiving branch of each channel for shifting the frequency level of the modulated waves thereof to the operating level of the outlet to the line with which connection is being established.

8. In a carrier wave communicating system, a plurality of carrier multiplex lines each having a plurality of channels employing modulated waves of different frequencies, a switching station to which said lines extend, a common outlet to the channels of each line at said switching station, said outlets operating at different frequency levels for the various lines, and means at said switching station for shifting the frequency level of the modulated waves of the channel of one of said lines to the operating level of the common outlet to the channels of the line with which connection is desired.

9. In a carrier wave communicating system, a plurality of carrier multiplex lines each having a plurality of channels having an incoming branch and an outgoing branch for each channel, said branches employing modulated waves of different frequencies, a

common outlet upon which the incoming branches of all of the channels converge and from which the outgoing branches of all of the channels diverge, and frequency changing means associated with each incoming branch for shifting the frequency level of the modulated waves of that branch to cause it to pass through said common outlet and into a particular desired one of said outgoing branches diverging therefrom.

10. In a carrier wave communicating system, a plurality of carrier multiplex lines, each having channels with an incoming and outgoing branch for each channel and each channel employing modulated waves of different frequencies, a switching station in which said lines converge, a frequency selective network of local circuits at said switching station connecting the incoming channel branches of all of the lines with the outgoing channel branches of all of the lines, and frequency modulating means in each incoming branch for selectively shifting the frequency of the modulated waves of said incoming branch to predetermine the subsequent path of flow of the modulated waves through said frequency selective network.

11. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a plurality of channels each of which comprises an incoming branch and an outgoing branch said branches employing modulated waves of different frequencies, a frequency selective system of conductors and devices permanently connecting the incoming channel branches of all of the lines with the outgoing channel branches of all of the lines, and frequency changing means for changing the frequency of the modulated waves of any incoming branch to predetermine its path of flow through said frequency selective system to any desired outgoing channel branch.

12. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a carrier channel having an incoming branch and an outgoing branch said branches employing modulated waves of different frequencies, a common permanent connection between all of the incoming channel branches and all of the outgoing channel branches, and means for selectively shifting the frequency of the modulated waves of the incoming channel branch of any of said lines to direct the modulated waves to the outgoing channel branch of any desired one of said other lines.

13. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a carrier channel comprising an incoming branch and an outgoing branch said branches employing modulated waves of different fre-

quencies, a frequency selective system of conductors and devices connecting the incoming channel branches of all of said lines with the outgoing channel branches of all of said lines, and frequency changing means associated with said incoming channel branch of one of said lines for shifting the frequency level of the incoming modulated waves of the associated branch to predetermine its path of flow through said frequency selective system to the outgoing branch of the channel of a particular other line.

14. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a plurality of channels each comprising an incoming branch and an outgoing branch said branches employing modulated waves of different frequencies, a separate grouping filter common to all of the outgoing channel branches of each of said lines, the grouping filter of each line operating at a different frequency range from the grouping filters of the other lines, a common connection between all of said grouping filters and the incoming channel branches of all of said lines, and frequency changing means associated with the various incoming channel branches of each line for shifting the frequency elevation of the modulated waves of the incoming channel branches to bring it within the frequency range of the grouping filter of any of the other lines to select the corresponding line.

15. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a plurality of channels each comprising an incoming branch and an outgoing branch said branches employing modulated waves of different frequencies, a certain set of carrier frequencies being used for corresponding incoming channel branches of all the lines and another different set of carrier frequencies being used for corresponding outgoing channel branches of all the lines, a separate grouping filter common to all of the outgoing branches of each of said lines, the grouping filter of each line operating at a different frequency range from the grouping filters of the other lines, a common connection between all of said grouping filters and the incoming channel branches of all of said lines, frequency changing means associated with the various incoming channel branches of each line for matching the frequency of the modulated waves of the incoming channel branch with the frequency of the modulated waves of an available outgoing channel branch of a desired other line and for further shifting the frequency elevation of the matched modulated waves to bring it within the frequency range of the grouping

filter of the desired line, and frequency changing means beyond the grouping filter of the desired line for shifting the frequency elevation of the modulated waves back to the frequency of the available channel.

16. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a plurality of channels each comprising an incoming branch and an outgoing branch said branches employing modulated waves, the frequency levels of the waves at which the incoming and outgoing branches operate being different for each channel, a separate grouping filter common to all of the outgoing channel branches of each of said lines, the grouping filters of each line operating at a different frequency range from the grouping filters of the other lines, a common connection between all of said grouping filters and the incoming channel branches of all of said lines, and frequency changing means associated with the various incoming channel branches of each line for matching the frequency of the modulated waves of incoming channel branches with the frequency of the modulated waves of an available outgoing channel branch of a desired line and additionally shifting the frequency elevation of the matched modulated waves to bring it within the frequency range of the grouping filter of the desired other line.

17. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a plurality of channels each having an incoming branch and an outgoing branch said branches employing modulated waves of different frequencies, a common connecting system permanently connecting the incoming channel branches of all of the lines with the outgoing channel branches of all of the lines, means for remodulating the modulated waves of any incoming branch with frequencies having a channel matching component and a line selecting component, means included in the common connecting system for directing the remodulated waves to a particular line in accordance with the line selecting frequency component with which the modulated waves have been remodulated, and means for withdrawing the line selecting frequency component after the modulated waves have been directed to a particular line, the frequency selective characteristics of the outgoing channel branches acting to direct said modulated waves to the outgoing branch of a particular channel of said selected line in accordance with the channel matching frequency component with which the modulated waves have been remodulated.

18. In a carrier wave communicating system, a plurality of carrier multiplex lines

each having superposed thereon a channel having an incoming branch and an outgoing branch said branches employing modulated waves of different frequencies, a common connecting system permanently connecting the incoming channel branches of all of the lines with the outgoing channel branches of all of the lines, means for remodulating the modulated waves of an incoming branch with a channel matching frequency and a line selecting frequency, means included in the common connecting system for directing the remodulated waves to a particular line in accordance with the line selecting frequency with which the modulated waves have been remodulated, means for withdrawing the line selecting frequency from the remodulated waves after the remodulated waves have been directed to a particular line, and means forming part of the outgoing channel branch of the selected line adjusted to permit the passage of the remodulated waves.

19. In a carrier wave communicating system, a plurality of carrier multiplex lines each having superposed thereon a plurality of channels each having an incoming branch and an outgoing branch said branches employing modulated waves of different frequencies, a common connecting system permanently connecting the incoming channel branches of all of the lines with the outgoing channel branches of all of the lines, means for remodulating the modulated waves of any incoming channel branch with two frequencies chosen with respect to the particular line and the particular channel of the line to which the modulated waves are to be accommodated, and means included in the common connecting system for selectively directing the remodulated waves to the corresponding line and the corresponding outgoing channel branch of the line.

20. In a carrier wave communicating system, a plurality of carrier multiplex lines each having a plurality of channels employing modulated waves of different frequencies, a switching station to which said lines extend, means at said switching station for remodulating the incoming modulated waves of each of two lines that are to be interconnected by a frequency such as to cause the modulated waves of each line to be directed to the channels of the other line, and means for further modulating the remodulated waves of each line with a frequency such as to cause said waves to be directed to a particular channel of the other line.

21. In a carrier wave communicating system, a plurality of carrier multiplex lines each having a plurality of channels employing modulated waves of different frequencies, a common connecting system permanently connecting all of the channels of all

the lines, and means for modulating the incoming modulated waves of a calling channel of one line and a called channel of another line with frequencies such that the incoming modulated waves of each line is accommodated to the frequency level at which the other line and the particular interconnected channel of the other line are adjusted to operate.

22. In a carrier wave communicating system, a carrier multiplex line having a carrier channel superposed thereon employing modulated waves, a switching station to which said line extends, means at said switching station for remodulating the modulated waves of said channel to change their position in the frequency scale, and frequency selective paths into one or another of which the remodulated waves are directed in accordance with the frequency with which they are remodulated.

23. In a carrier wave communicating system, a carrier multiplex line having a carrier channel superposed thereon employing modulated waves, a switching station to which said line extends, remodulating means at said switching station for modulating the incoming modulated waves of said line to change their position in the frequency scale, means controlled from the distant end of said line through the medium of said modulated waves for selectively controlling said modulating means, and frequency selective branches into one or another of which said remodulated waves are directed in accordance with the frequency with which they are modulated at the switching station.

24. In a carrier wave communicating system, a plurality of carrier multiplex lines each having a plurality of channels employing modulated waves of different frequencies, a switching station to which said lines extend, means at said switching station for remodulating the incoming waves of each of two lines that are to be interconnected by a frequency such as to cause the waves of each line to be directed to the other line, means for further modulating the waves of each line with a frequency such as to cause the waves to be directed to a particular channel of the other line, and a switch controllable over one of the two lines that are to be interconnected for controlling the operation of said line selecting and channel selecting modulating means of the two lines.

25. In a carrier wave communicating system, a carrier multiplex line extending from a toll station to a switching station and having a carrier channel superposed thereon employing high frequency current waves, means at the toll station for modulating said waves with a voice frequency component and a controlling frequency component and transmitting the modulated waves through the channel of said line to the switching

station, means at the switching station for remodulating said waves to reproduce the controlling frequency component and selectively change the position in the frequency scale of said voice frequency component, means under the control of said reproduced controlling frequency component for selectively controlling said second mentioned modulating means to determine the position in the frequency scale of said modulated voice frequency component, and frequency selective paths into one or another of which said modulated voice frequency component is directed at the switching station in accordance with its modulated position in the frequency scale.

26. In a carrier wave communicating system, a carrier multiplex line having a carrier channel superposed thereon employing modulated waves, a switching station to which said switching line extends, modulating means at the switching station for effecting a shift in the frequency scale of the incoming waves of said line, other modulating means at said switching station for effecting a further change in the position of said shifted waves in the frequency scale, frequency selective branches into one or another of which said shifted and changed waves are directed in accordance with the extent of their modulation in the second mentioned modulating means, and frequency selective sub-branches of the selected branch into one or another of which said modulated waves are directed in accordance with the frequency shift they have received in the first mentioned modulating means.

27. In a carrier wave communicating system, a carrier multiplex line having a carrier channel superposed thereon employing modulated waves, a switching station to which said carrier multiplex line extends, a plurality of frequency selective branches at said station, a plurality of frequency selective sub-branches of each of said branches, and means at said switching station for remodulating incoming modulated waves of said line with two frequency components one of which operates to direct the modulated waves into a particular frequency selective branch and the other of which operates to direct the modulated waves into a particular frequency selective sub-branch of the selected branch.

28. In a carrier wave communicating system, a carrier multiplex line having a carrier channel superposed thereon employing modulated waves, a switching station to which said carrier multiplex line extends, a plurality of frequency selective branches at said station, a plurality of frequency selective sub-branches, means at said switching station for remodulating incoming modulated waves of said line with two frequency components one of which operates to direct the

modulated wave into a particular frequency selective branch and the other of which operates to direct the modulated wave into a particular frequency selective sub-branch of the selected branch, and means controlled from a distant point through the medium of said wave for determining the particular pair of frequency components with which said waves are to be remodulated at said switching station.

29. In a carrier wave communicating system, a carrier multiplex line having a carrier channel superposed thereon employing modulated waves, a switching station to which said line extends, a plurality of frequency selective branches at said switching station, a plurality of frequency selective sub-branches of each of said branches, each of said sub-branches being adjusted to pass a certain modulated wave frequency and each of said main branches being adjusted to pass the modulated wave frequencies of the associated sub-branches elevated to a higher frequency level, the frequency level at which each main branch operates being different from the frequency at which each other main branch operates, modulating means at the switching station for shifting the frequency of incoming modulated waves of said line to accommodate it to the modulated wave frequency of a particular sub-branch and further to elevate the shifted modulated wave frequency to a higher frequency to accommodate it to the frequency level at which a particular one of said main branches operates, and modulating means associated with each of said main branches for withdrawing from the modulated waves the frequency modulation employed to raise them to the frequency level of that particular main branch.

30. In a carrier wave communicating system, a carrier multiplex line having a carrier channel superposed thereon employing modulated waves, a switching station to which said line extends, modulating means at said switching station for shifting the frequency of incoming modulated waves and stepping up the shifted waves to a higher frequency level, a plurality of frequency selective main branches into a particular one of which said waves are directed in accordance with the frequency level to which they have been stepped up, means associated with each branch for stepping down the frequency of the waves by an amount equal to that by which they have been stepped up in order to enter the corresponding branch, and frequency selective sub-branches of each of said main branches to a particular one of which said waves are directed in accordance with the extent of their shift by said modulating means.

31. In a carrier wave communicating system, a carrier multiplex line having a superposed carrier channel employing modulated waves, means for remodulating incoming modulated waves of said line to shift their frequency and to step up the shifted waves to a higher frequency level, a plurality of frequency selective main branches into a particular one of which said waves are directed in accordance with the frequency level to which they have been stepped up, means associated with said main branch for stepping down the frequency of said modulated waves to an extent equal to that by which they have been stepped up in order to enter said main branch, frequency selective sub-branches of said main branch into a particular one of which said waves are directed in accordance with the extent of their frequency shift, and carrier channels of another carrier multiplex line connected with said frequency selective sub-branches.

32. In a carrier wave communicating system, a carrier multiplex line having a superposed carrier channel employing modulated waves, modulating means operating to shift the frequency of incoming modulated waves of said line, then to step up the shifted wave to a high frequency and then to step down the shifted wave to an intermediate frequency, and a system of frequency selective main branches and sub-branches into one of which main branches the waves are directed in accordance with the intermediate frequency that they occupy and into a particular sub-branch of which main branch the waves are directed in accordance with the extent of shift in their frequency.

33. The method of effecting a relatively small change in the frequency of a carrier side band which consists in modulating the side band with two high frequencies the frequency difference between which is equal to the amount by which the carrier side band is to be shifted in the frequency scale.

34. The method of effecting a relatively slight elevation in the frequency of a carrier side band which consists in successively modulating the side band first with a high frequency and then with a frequency lower than the said high frequency by an amount equal to the extent of the desired amount of elevation of the carrier in the frequency scale.

35. The method of effecting a relatively slight change in the position of a carrier side band in the frequency scale and at the same time eliminating undesired modulation products, which consists in modulating the carrier side band by a high frequency to scatter the undesired modulation products well above and below the position occupied in the frequency scale by the desired modulation product, filtering the desired modulation product to suppress the higher and

lower modulation products, modulating the desired modulation product by a second high frequency differing from the first mentioned high frequency by an amount equal to the desired shift of the carrier side band in the frequency scale so as to throw all of the undesired modulation products well above the position on the frequency scale occupied by the desired product of the second modulation, and filtering the desired product of the second modulation to suppress the higher undesired modulation products.

36. The method of elevating any one of a number of carrier waves collectively extending over a certain frequency band width in the frequency scale to a point in a frequency band width occupying a slightly higher position in the frequency scale, which consists in modulating the desired carrier waves in the lower frequency band with a high frequency so as to scatter undesired modulation products separably above and below a band width equal to the carrier frequency band width based upon the high
25 modulating frequency, filtering the desired modulation products within this elevated band width to suppress the higher and lower modulation products, modulating the filtered frequencies with another high frequency
30 differing from the first high frequency by an amount equal to the extent of the desired elevation of the carrier band in the frequency scale, so as to lower all of the desired modulation products to the desired
35 new position on the frequency scale and throw all the undesired modulation products well above this position or band width, and filtering the desired modulation products at their new slightly elevated position to suppress the undesired modulation products.

37. The method of operatively associating any two of a plurality of carrier multiplex lines normally connected together which consists in selectively modulating the incoming carrier frequency of a channel of each
45 line by a frequency such as to shift the carrier frequency of each line by an amount sufficient to accommodate it to the frequency at which the channel of the other line of the
50 pair desired to be associated is adapted to operate.

38. The method of operatively interconnecting any two of a plurality of carrier multiplex lines the channels of which are
55 permanently connected together, which consists in modulating the incoming carrier of each line in such a way as to shift its frequency to accommodate it to the frequency at which the outgoing channel branch of the
60 other line is adapted to operate.

39. The method of operatively interconnecting any two channels of two different ones of a plurality of carrier multiplex lines each of which is provided with a plurality
65 of channels employing modulated waves and

all of which channels are permanently connected together at a switching station, which consists in modulating the incoming waves of the two channels of the two lines that are to be interconnected by means of modulating frequencies having components so
70 chosen that one component shifts the frequency of the waves of each channel to accommodate it to the channel frequency of the other line, and the other component
75 changes the shifted waves frequency of each line to accommodate it to the characteristic operating frequency of the other line.

40. In a carrier wave communicating system, a plurality of channels, each having an
80 incoming branch, a modulating device in the incoming branch of each channel, a common outlet into which the output circuits of all of said modulating devices feed, and a network connecting all of said output circuits
85 in balanced relation with respect to each other and in unbalanced relation with respect to said common outlet.

41. In a carrier wave communicating system, a plurality of channels, each having an
90 incoming branch, a common outlet, and a system of conductors and impedance devices connecting all of said incoming channel branches in balanced electromotive force relation with respect to each other and in unbalanced electromotive force relation with
95 respect to said common outlet.

42. In a carrier wave communicating system, a plurality of channels each having an
100 incoming branch, a common outlet, and a conjugate network connecting said incoming branches with said common outlet in such a way that each incoming branch feeds into said common outlet and is prevented from
105 feeding back into any other incoming branch.

43. In a carrier wave communicating system, a plurality of channels each having an
incoming branch, a modulating device in each incoming branch, said modulating devices of the various incoming branches being adapted to produce by modulation carrier
110 side bands lying at any desired position within a frequency range which is substantially the same for all of said incoming channel branches, a common outlet into which
115 the output circuits of all of said modulating devices feed, and a system of conductors and impedance devices connecting all of said output circuits with said common outlet in such a way that each modulator feeds into said
120 common outlet and is prevented from feeding back into the output of any other of said modulators.

44. In a carrier wave communicating system, a plurality of channels employing modulated waves and having modulators, one for
125 each channel, operating to shift their associated waves over substantially the same frequency range, a common outlet circuit, and an anti-feedback circuit connecting the
130

modulators of all of said channels with said common outlet in such a way that the output of each modulator feeds into said common outlet and is prevented from feeding back into the modulator of any other of said channels.

45. In a carrier wave communicating system, a plurality of channels employing modulated waves and each including an incoming and an outgoing branch, modulators, one in the incoming branch of each channel, operating to shift their associated waves over substantially the same frequency range, a common outlet circuit, an anti-feedback circuit connecting the modulators of all of said channels with said common outlet, and a plurality of frequency selective paths selectively connecting said common outlet with the outgoing branches of said channels.

46. In a carrier wave communicating system, a plurality of channels employing modulated waves each including an incoming branch and an outgoing branch, modulators, one included in the incoming branch of each channel, for shifting their associated waves over substantially the same frequency range, a common outlet, means for connecting the modulators of all of said channel receiving branches with said common outlet in such a way that said modulators feed in substantially equal amounts into said common outlet and are prevented from feeding back into each other, and frequency selective paths selectively connecting said common outlet with the outgoing branches of said channels.

47. The method of shifting the frequency of a carrier side band which consists in impressing said side band and two local modulating waves upon the input circuit of a modulator, selecting from the output circuit a product of modulation of said side band with one of said local waves and reimpresing the same upon the modulator input circuit, and selecting from the output circuit a modulation product of said first mentioned product with the second of said local waves.

48. The method of effecting two stages of modulation in a single modulator, which consists in impressing an incoming signal modulated carrier together with two local modulating waves upon the input circuit of the modulator, selectively deriving from the output circuit of the modulator a modulation product of said carrier with one of said local waves and reimpresing the same upon the input circuit, and selectively deriving from

the output circuit of the modulator a modulation product of said reimpresed product and the other of said local waves.

49. The method of effecting two stages of modulation in a balanced modulator, which consists in impressing an incoming signal modulated carrier together with two local modulating waves upon the parallel input circuit of said modulator, selectively deriving from the parallel output circuit of said modulator a modulation product of said carrier with one of said local waves and reimpresing the same upon the series input circuit of said modulator, and selectively deriving from the series output circuit of said modulator a modulation product of said reimpresed modulation and the other of said local waves.

50. A balanced modulator having series and parallel input and output circuits, means for impressing a signal modulated carrier wave and two local modulating waves upon said parallel input circuit, frequency selective means connected between the parallel output circuit and the series input circuit of said modulator and adapted to pass a frequency band produced by the modulation of said signal modulated carrier wave with one of said local modulating waves and frequency selective means connected with said series output circuit and adapted to pass a frequency band produced by the modulation of the band passed by said first mentioned frequency selective means with the other of said local modulating waves.

51. The method of double modulation in a single balanced modulator, which consists in impressing a signal carrying component and two modulating waves upon the input circuit of said modulator, selectively deriving from the output circuit of the modulator a frequency band produced by the modulation of said signal carrying component with one of said modulating waves, reimpresing said modulation product upon the modulator input circuit in such a way as to prevent its amplification and repassage from the output circuit back into the input circuit, and selectively deriving from the modulator output circuit a frequency band produced by the modulation of said reimpresed modulation product with the other of said modulating waves.

In witness whereof, I hereunto subscribe my name this 5th day of November A. D., 1923.

EDWIN H. SMYTHE.