

July 24, 1928.

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E. H. SMYTHE

COMMUNICATING AND SWITCHING SYSTEM

Filed Feb. 27, 1923

7 Sheets-Sheet 1

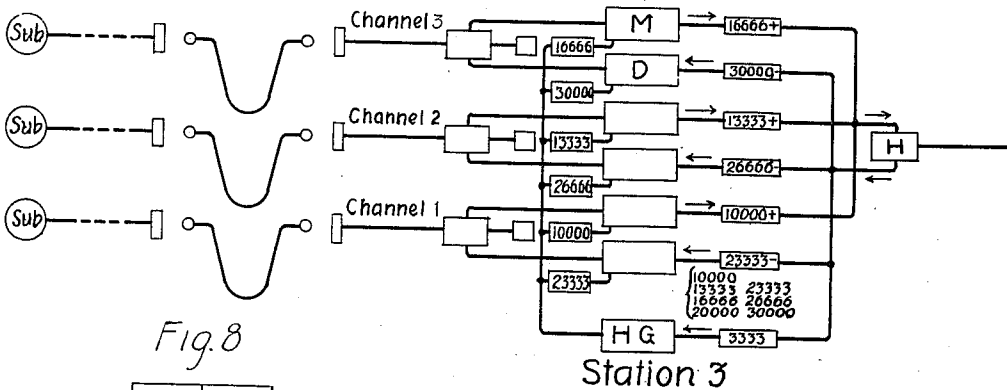
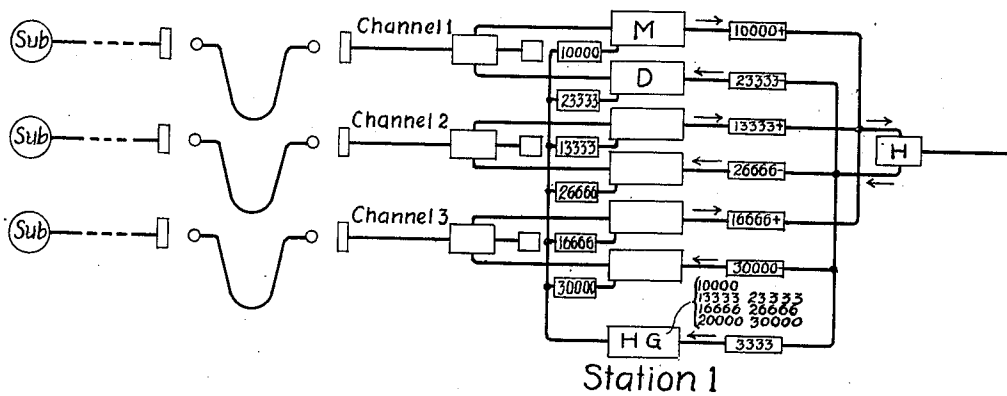
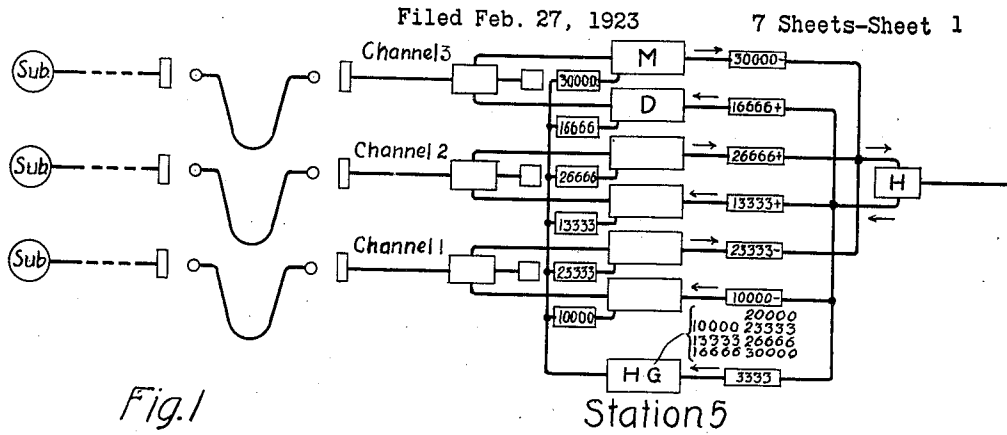


Fig. 1 Fig. 2

Fig. 3 Fig. 4 Fig. 5 Fig. 6 Fig. 7

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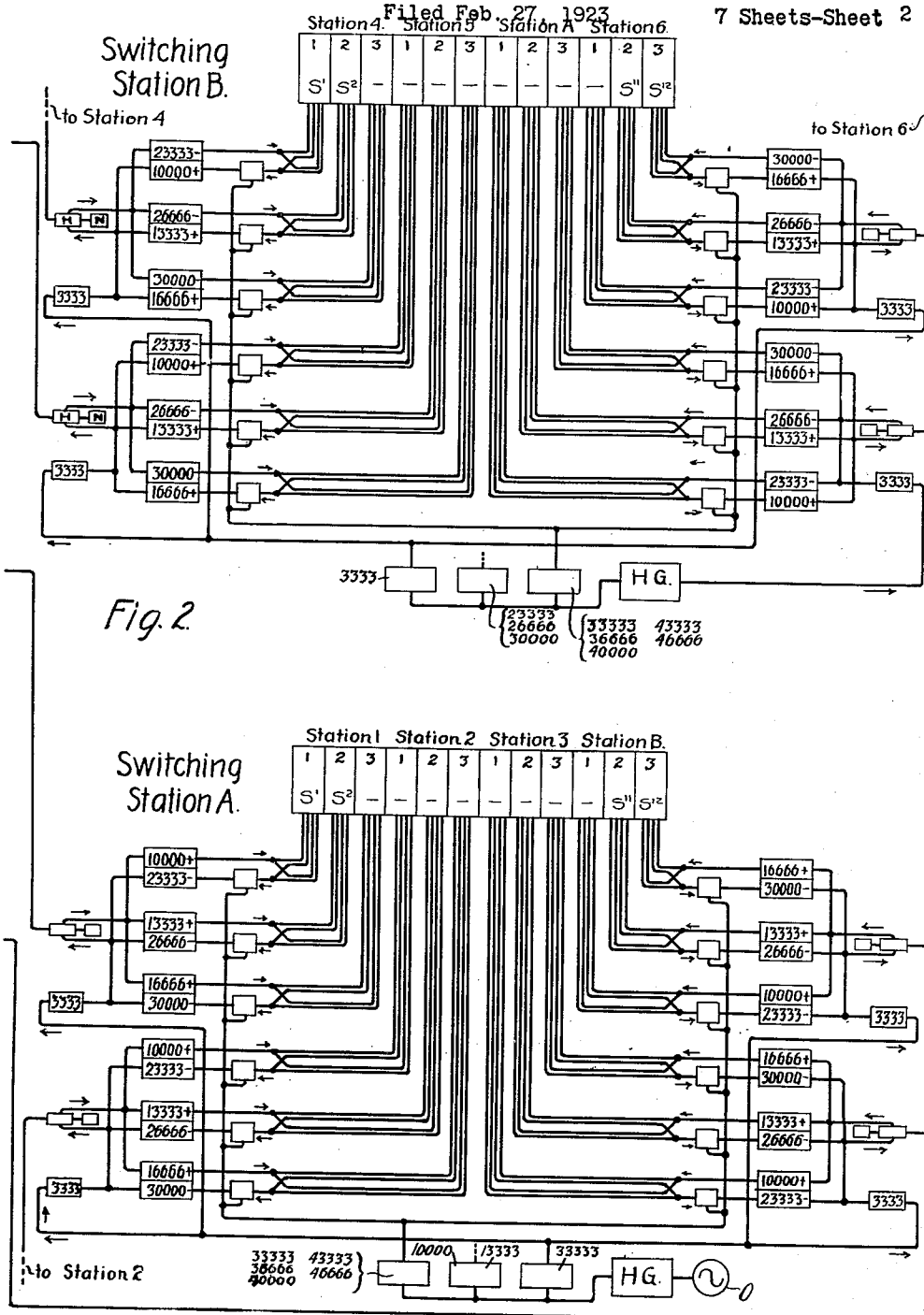
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7 Sheets-Sheet 2



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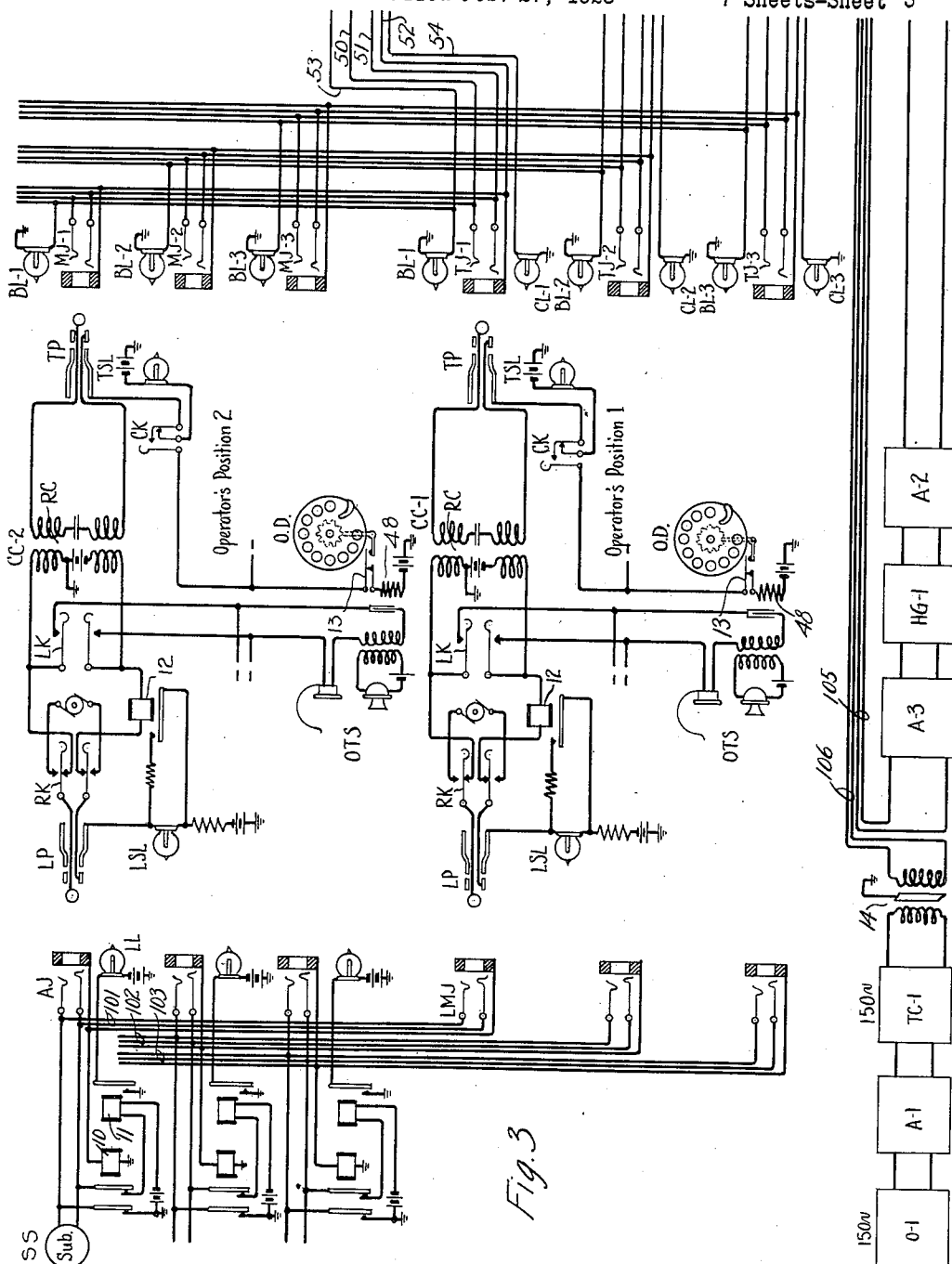
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7 Sheets-Sheet 3



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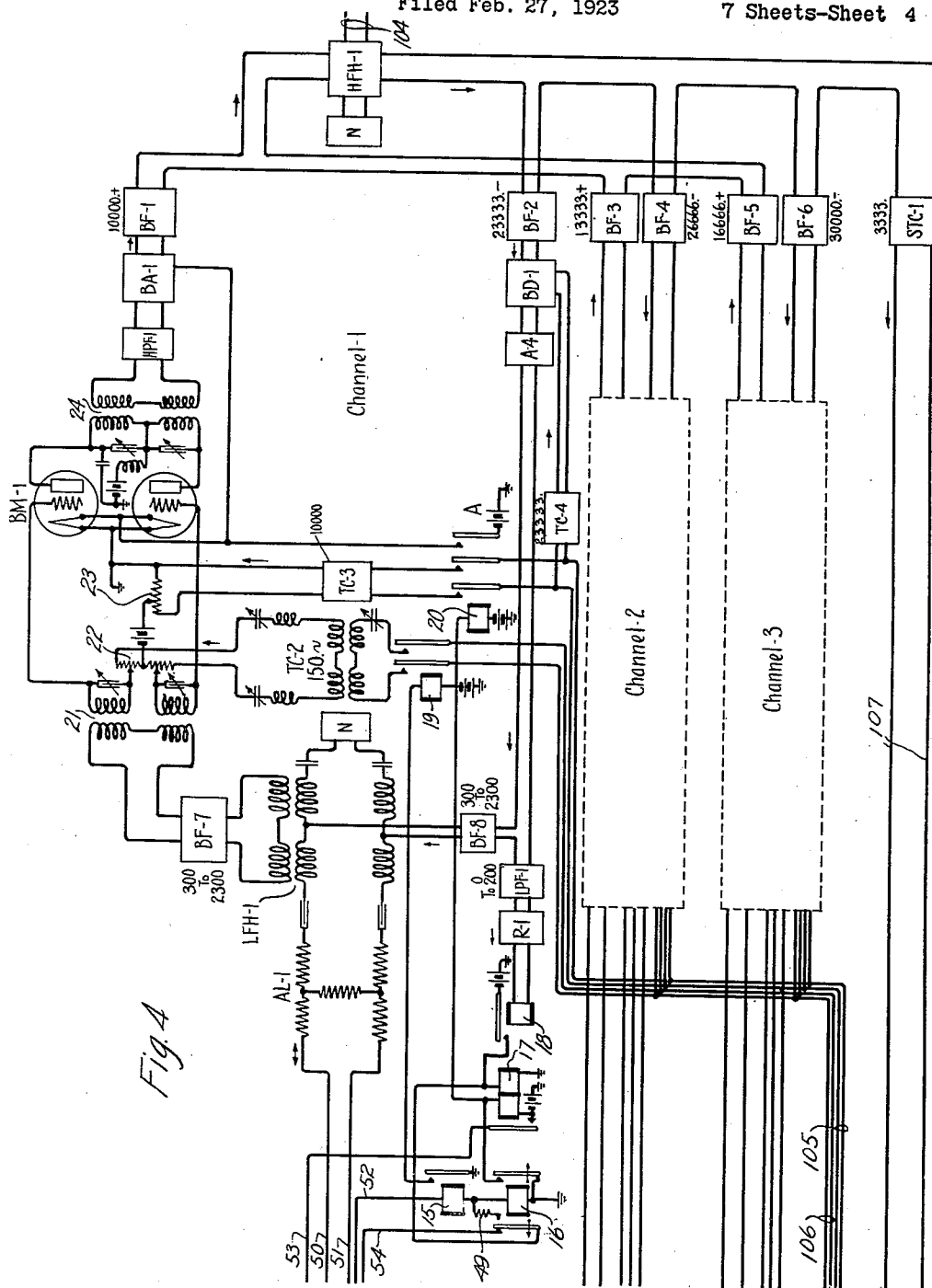
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7 Sheets-Sheet 4



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7 Sheets-Sheet 5

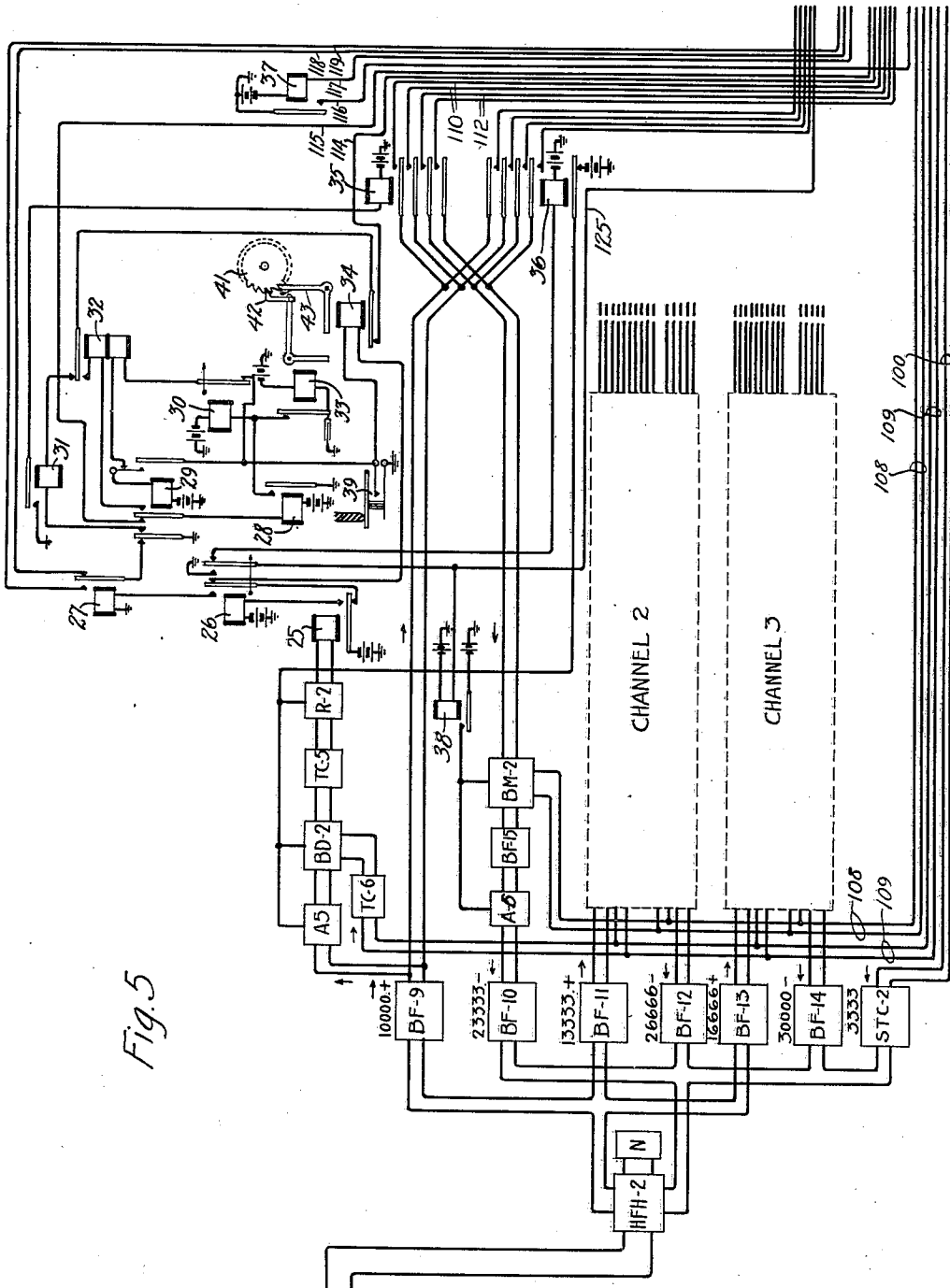


Fig. 5

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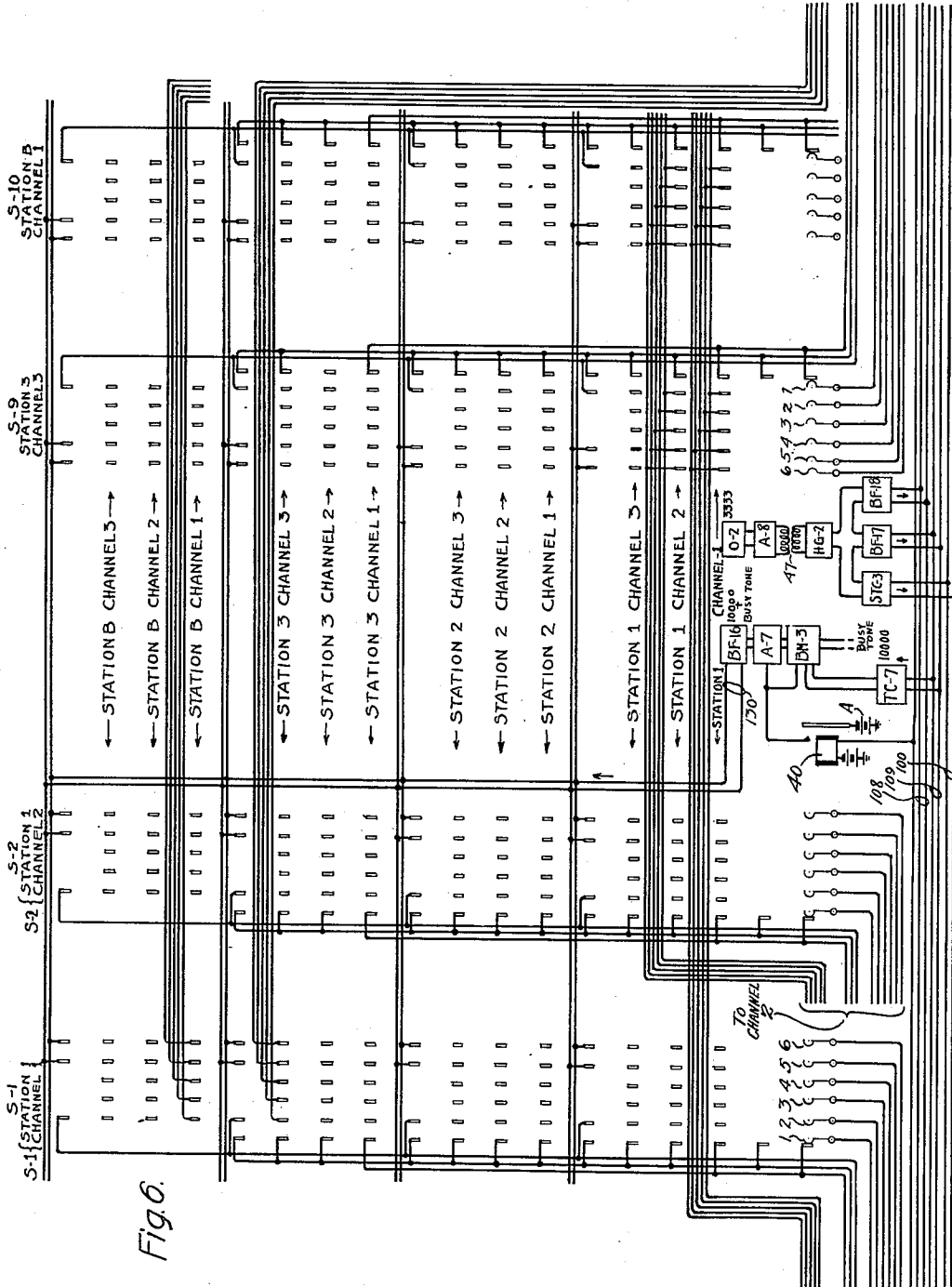
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7 Sheets-Sheet 6



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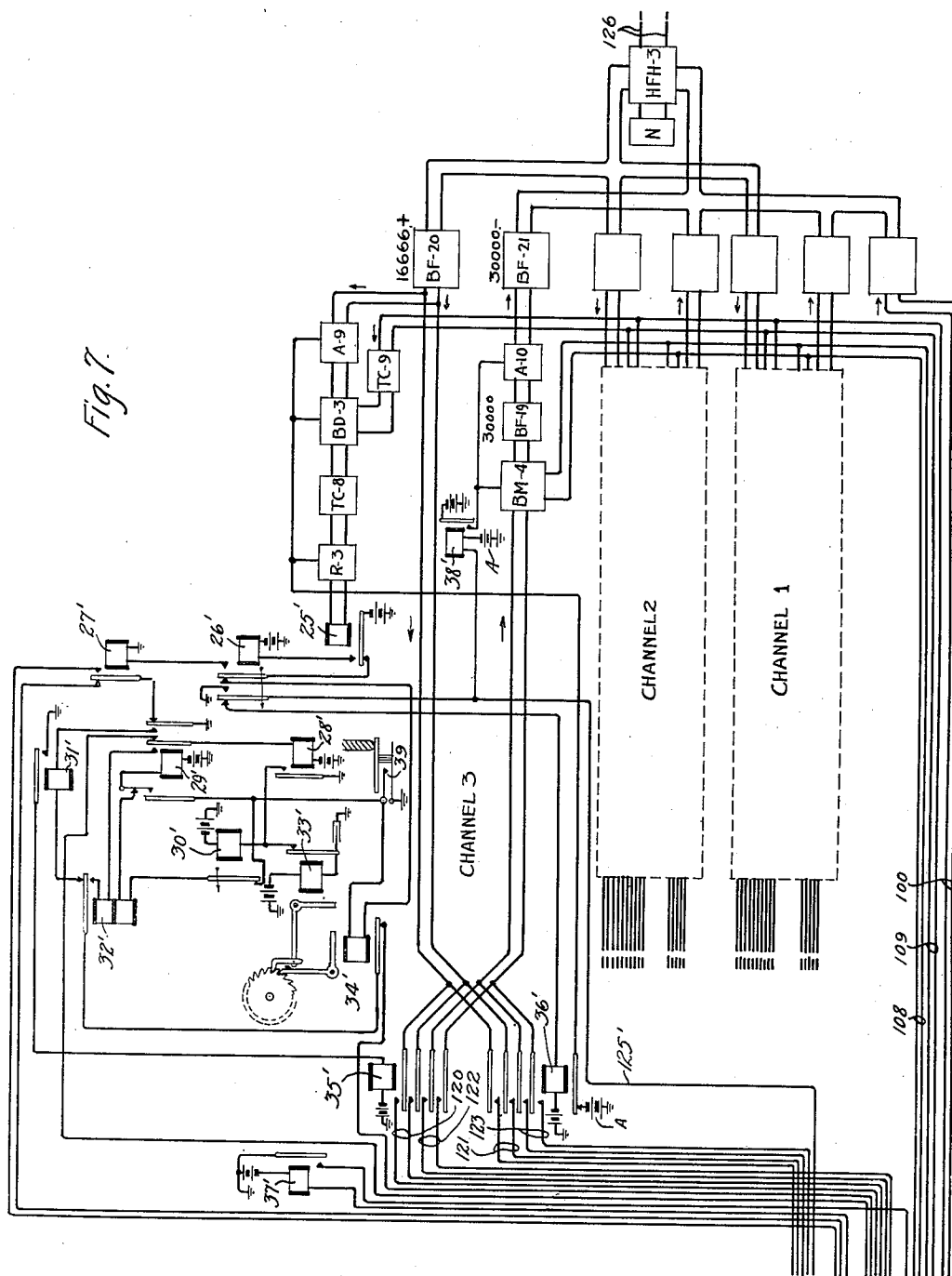
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COMMUNICATING AND SWITCHING SYSTEM

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7 Sheets-Sheet 7



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UNITED STATES PATENT OFFICE.

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COMMUNICATING AND SWITCHING SYSTEM.

Application filed February 27, 1923. Serial No. 621,635.

This invention relates to an improved communicating and switching 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 electric signaling switching 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 receiving arrangements each of which is selective of one carrier frequency to the exclusion of the others, and each of which serves to reproduce from the modulated carrier the voice, signal or controlling currents with which the carrier was modulated at the distant station.

The apparatus 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 built up, link by link, between two toll or long distance stations through intervening stations or toll centers and the lines extending between them without the necessity of employing human agencies at the intermediate stations or centers; also toward providing a system in which a connection thus built up between two toll stations through intervening intermediate stations may include a series of carrier channels each of which may be characterized

by the employment of a different frequency from the frequency employed by one or more of the other channels that are linked together to form the completed connection. As a consequence, in the system of this invention the operator at any of the toll stations of the system is able to control mechanisms that act at the intermediate stations or toll centers to build up the completed connection and automatically to select at each successive center an idle or available channel to the next station or center in the series, and automatically to cause connected channels of diverse frequencies to operate together as though they were of corresponding frequencies.

The present invention has for its principal objects to provide an organization in which the extending of a toll connection through one or more intermediate toll centers is accomplished by machine switching methods; in which machine switching methods are employed for effecting the interconnection of carrier channels with each other; in which the automatic interconnection of the carrier channels with each other takes place at carrier frequency levels; in which any station of the system is enabled to complete connection with any other station of the system through the agency of a series of carrier channel links automatically built up through one or more intervening carrier switching stations or toll centers and utilizing any of the carrier channels that happens at the time to be available in each of the series of links; in which where succeeding carrier channels in the series operate at diverse frequencies, these diverse frequencies are automatically transformed at each succeeding point of interconnection to the frequency at which the next succeeding channel of the series is adapted to operate the channel frequencies thus being automatically matched with each other; in which a plurality of matching frequencies is applied at the point of interconnection of two diverse channels of the series, and modulating means employing the matching frequencies, so that whatever the frequency level of the incoming frequency band may be, one of the products of modulation will be at the frequency level at which the outgoing channels is adapted to operate, means being provided to suppress the other modulation products; in which the matching frequencies applied

at the point of interconnection of two diverse frequency channels are higher than the frequency level at which the outgoing channel is adapted to operate in order to invert the relative positions of the side bands and prevent the passage of unmodulated matching frequencies into the outgoing channel; in which the control of the building up and holding of the connection between the stations and the control of the display of the calling and supervisory signals is effected by means of a continuously applied audible frequency modulation of the carrier, which, however, is barred from the talking circuits at the terminal stations; in which the switching circuits and apparatus at the intermediate stations or toll centers are designed and adapted to minimize interference effects and facilitate the shielding of the high frequency circuit paths; and in which the control of the building up, calling, supervising and connection holding operations at the terminal stations is effected over a path entirely separate and apart from the talking circuit of the terminal station.

The foregoing are some of the principal objects that the system of the present invention attains. The foregoing 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 and 2 taken together show in skeleton form a portion of a comprehensive carrier multiplex toll switching system having a plurality of terminal stations and a plurality of intermediate switching stations or toll centers; and in which Figs. 3, 4, 5, 6 and 7 taken together and arranged in the manner indicated in Fig. 8 show diagrammatically as much of the apparatus and circuits of one of the terminal stations and of one of the intermediate switching stations as is necessary to disclose the manner in which the apparatus and circuits of the entire system may be organized.

Reference will first be made to the portion of a comprehensive carrier multiplex interconnecting system illustrated in skeleton form in Figs. 1 and 2. The portion of the entire system shown in Figs. 1 and 2 includes station 1, station 3 and station 5, which may be terminal toll or long distance stations, each of which operates in conjunc-

tion with a telephone exchange in which local subscribers' lines are served; and switching station A and switching station B, which may be intermediate switching stations or toll centers into which the toll or long distance lines from the various terminal stations or other intermediate switching stations converge, and in which the various entering lines are adapted for interconnection by mechanisms under the control of the operators at the remote terminal stations. Toll or long distance lines extending to station 2, station 4 and station 6 are also indicated as having connection with the intermediate switching stations A and B.

As diagrammatically indicated in the portion of the comprehensive system illustrated in Figs. 1 and 2 there may be local lines at each of the terminal stations extending from their respective subscribers' stations to springjacks where the toll operator may have access to them by means of pairs of connecting cords and plugs. From each terminal station a toll line extends to the associated 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. Likewise switching station A and switching station B are connected by means of a toll line provided with apparatus to constitute three non-interfering frequency selective channels, which channels are also designated channel 1, channel 2 and channel 3. In the case of all of the toll lines entering switching station A from station 1, station 2 and station 3, and switching station B respectively, channel 1 in each case is arranged to receive upon the upper side band of the 10,000 cycle modulated carrier wave and to transmit upon the lower side band of the 23,333 cycle modulated carrier wave; channel 2 is arranged to receive upon the upper side band of the 13,333 cycle carrier and to transmit upon the lower side band of the 26,666 carrier, and channel 3 is arranged to receive upon the upper side band of the 16,666 cycle carrier and to transmit upon the lower side band of the 30,000 cycle carrier. At the distant end of each of the toll lines centering in switching station A, the frequency selective construction and adjustment of the channel apparatus is such that the transmission is effected upon the same frequency band which is used for reception at switching station A, while reception at the distant station is effected over the same frequency band that is employed for transmission at switching station A. That is, at the distant or terminal station channel 1 transmits over the upper side band of the 10,000 cycle modulated carrier and receives over the lower side band of the 23,333 cycle carrier,

channel 2 transmits over the upper side band of the 13,333 carrier and receives over the lower side band of the 26,666 carrier, and channel 3 transmits over the upper side band of the 16,666 carrier and receives over the lower side band of the 30,000 carrier.

In the case of the toll lines centering in switching station B, and connecting that station with station 4, station 5, station 6 and switching station A, the carriers and side bands employed for transmitting and receiving over the various channels are the same at switching station B as are employed at the terminal stations 1, 2 and 3 associated with switching station A; and the carriers and side bands employed for the various channels at the distant ends of the toll lines centering in switching station B are the same as those that are employed for transmitting and receiving over the corresponding channels in the case of switching station A. The reason for using the frequencies indicated above in connection with the channels at the various terminal and intermediate switching stations, and the manner in which these frequencies are adapted to each other in the building up of a communicating and controlling connection between different terminal stations by way of one or more intermediate switching stations will be explained in the detailed description of the system that will follow.

In the present embodiment of the invention, as shown diagrammatically in Figs. 1 and 2, four toll or long distance lines center in each of the intermediate or switching stations; and as each of these four toll or long distance lines is provided with three frequency selective channels, means are provided at each switching station for interconnecting any channel of any one of the toll lines with any channel of any of the other three toll lines entering the switching station. This is accomplished by terminating each channel of each of the four toll lines upon the movable terminals of an interconnecting switch, which movable terminals have access to stationary terminals representing the various channels of each of the other toll lines. These interconnecting switches are designated S^1 to S^{12} , inclusive, at each of the two switching stations A and B. At switching station A channels 1, 2 and 3 of the toll line extending to station 1 terminate upon interconnecting switches S^1 , S^2 and S^3 , respectively; channels 1, 2 and 3 of the toll line extending to station 2 terminate on switches S^4 , S^5 and S^6 ; channels 1, 2 and 3 of the toll line extending to station 3 terminate on switches S^7 , S^8 and S^9 ; channels 1, 2 and 3 of the toll line extending to intermediate or switching station B terminate on switches S^{10} , S^{11} and S^{12} . At switching station B interconnecting switches S^1 , S^2 and S^3 are similarly identified with

channels 1, 2 and 3 of toll line extending to station 4; interconnecting switches S^4 , S^5 and S^6 are identified with channels 1, 2 and 3 extending to switching station 5; interconnecting switches S^7 , S^8 and S^9 are identified with channels 1, 2 and 3 of the toll line extending to station A; and interconnecting switches S^{10} , S^{11} and S^{12} are identified with channels 1, 2 and 3 of the toll line extending to station 6.

No attempt has been made in the skeleton diagram of Figs. 1 and 2 to show the electrically actuated mechanisms at the switching stations and the controlling devices at the terminal stations by means of which the operations of the switching station mechanisms are governed, these elements being fully disclosed in the detailed circuit diagram of Figs. 3 to 7, inclusive. The skeleton diagram of Figs. 1 and 2 merely attempt to indicate the general scheme of interconnection employed between certain typical terminal stations and intermediate or switching stations of the system. The significance of what is shown merely in outline in Figs. 1 and 2 of the drawings will be clearly apparent after the detailed circuits as shown in the other figures of the drawing are explained. It is sufficient at this time to say, with regard to the arrangement shown in Figs. 1 and 2, that the operator at any one of the terminal stations indicated, by making connection with an available channel of that terminal station, obtains control over the interconnecting switch identified with that channel at the associated switching station; and that thereupon this interconnecting switch is caused to operate, under the control of the operator at the distant calling station, to extend the channel selected by the operator at the calling station to any available or non-busy channel of the toll line extending to the called terminal station, or in the direction of the called terminal station through the medium of a toll line extending to the next intermediate or switching station through which the completed connection must pass.

At switching station A, as shown in Figs. 1 and 2, there is an oscillator O, which produces a base frequency of 3,333 cycles, and this base frequency is supplied over the toll lines to the various other switching and terminal stations of the system. At each at the terminal stations this base frequency, acting through the medium of a harmonic generator, produces the various harmonic frequencies of the base, including 10,000, 13,333, 16,666, 23,333, 26,666 and 30,000 cycles, and these harmonic frequencies are supplied to the transmitting branches of the various channels to be modulated by the voice currents and to the receiving branches of the various channels to demodulate the corresponding incoming carrier side bands

and reproduce the voice currents with which the carriers are modulated at the distant stations. At each of the intermediate or switching stations the base frequency of 3,333 acts through the medium of a harmonic generator to produce two groups of harmonic frequencies. One of these groups, consisting of the frequencies 10,000, 13,333 and 16,666 at switching station A and the frequencies 23,333, 26,666 and 30,000 at switching station B, is employed for demodulating corresponding carrier side bands incoming to the switching station over the receiving branches of the channels of the various toll lines that center at the switching station for the purpose of separating out a relatively low controlling frequency that is employed to control the operation of the interconnecting switches at the switching station. The remaining harmonic frequencies produced at the intermediate or switching stations from the base frequency are the frequencies 33,333, 36,666, 40,000, 43,333 and 46,666; and these frequencies are all applied to modulators included one in each of the various channel transmitting branches to change the frequency level of the carrier side band received over the channel from the calling station to a level such as to permit it to pass out over the transmitting branch of the channel that the interconnecting switch identified with the calling station has selected for use in establishing the next link in the completed connection. Thus as the connection is built up from one station to the next in the series, the interconnecting switch of the calling toll line acts under the control of the calling station operator to select the line extending from the switching station to the terminal toll station wanted, or in the direction of such terminal toll station, the interconnecting switch automatically selects an idle channel of the toll line that is to constitute the next link in the connection, and the harmonic frequencies applied to the modulating apparatus in the transmitting branches of the two channels thus interconnected operate to change the carrier wave frequency level of the incoming branch of each channel to match it with the frequency level of the outgoing branch of whichever channel has been automatically selected to extend the connection to the next toll point.

As will subsequently appear from the detailed explanation of the organization and operation of the system, the system is capable of substantially indefinite extension so far as the inclusion of terminal stations and switching or intermediate stations is concerned, successive switching stations and their associated terminal stations employing modulating, demodulating and matching frequencies either of the value of those indicated in connection with switching sta-

tion A and its associated terminal stations, or of the value of those indicated in connection with switching station B and its associated terminal stations. Of course it will be understood, and will be evident from the detailed explanation of the system that follows, that the particular frequencies that have been indicated are merely typical, and that if desired for any reason other sets of frequencies may be substituted for them. Reference will now be had to the detailed representation of certain of the circuits of two of the terminal stations and one of the intermediate or switching stations that are shown in Figs. 3 to 7, inclusive, of the drawing. In order to present a concrete example it has been assumed that these circuits are the circuits of terminal stations 1 and 3 and certain of the circuits of switching station A indicated in Figs. 1 and 2 of the drawing. Inasmuch as stations 1 and 3 are identical in the matter of the arrangement of their circuits and the carrier frequencies employed, Fig. 3 and Fig. 4 will be assumed in the following description to represent the circuits of both of these stations, between which stations a connection will be assumed to be completed by way of the intermediate switching station or toll center station A. Referring now to Figs. 3 and 4, the terminal toll station illustrated 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 metallic 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 springjack AJ and one or more multiple springjacks LMJ. The circuit arrangements of such lines are well known in the art and need not be specifically described. Obviously any other desired 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 a supervisory relay 12, and a toll supervisory lamp TSL that is under the 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 for the purpose of signaling the local subscribers' stations and bring 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, which 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. 4 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 HFH¹ provided with the usual network N for balancing the toll line and producing a conjugate relation between the windings of the high frequency hybrid 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 TJ¹, TJ² and TJ³ at operator's position 1 and MJ¹, MJ² and MJ³ at operator's position 2. All of the channel springjacks at the two positions have associated with them busy lamps, designated BL¹, BL² and BL³, 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 CL¹, CL² and CL³, respectively, for the three channels. The busy lamps, as will be explained, are lighted whenever the corresponding channel

is in use either for 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 springjacks 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 lower calling and controlling frequency. The high frequency hybrid coil HFH¹ 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, BF¹, BF², BF³, BF⁴, BF⁵, and BF⁶, respectively, so constructed and adjusted as to pass the frequency bands comprising in each case the appropriate side-band of the modulated carrier wave of the frequency respectively indicated by the numerals placed above 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 description of Figs. 1 and 2 of the drawing. These and the 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 article that has been referred to. The organization of only one of the three channels, channel 1, is illustrated in Fig. 4. 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 BF² included in the receiving branch is carried into the balanced detector BD¹ where it is joined by the corresponding carrier frequency selected from the common distributing circuit 105 by the tuned circuit TC¹. Demodulation takes place in the balanced detector BD¹, and the products of demodulation are amplified in the amplifier A¹ and are carried to the low pass

filter LPF¹ and the band filter BF⁸. The low pass filter LPF¹, in the present instance, is constructed and adjusted to have an upper cut-off limit of 200 cycles per second and the band filter BF⁸ 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 LPF¹, is rectified and amplified in the rectifier R¹ and energizes the relay 18. The essential voice frequencies pass through the band filter BF⁸ and are carried to the mid-points of the line windings of the low frequency hybrid LFH¹. 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 AL¹ of the well known H type by way of conductors 50 and 51 to the tip and ring or talking springs of spring jack TJ¹, and also to the corresponding springjacks of such other multiple spring jacks MJ¹ as may be associated with this particular channel.

The series winding of the low frequency hybrid LFH¹ is connected by way of the band filter BF⁷ with the primary winding of the transformers 21. The band filter BF⁷ 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 BM¹, 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" battery and the potentiometer 23 with ground and the positive terminal of the filaments of the two thermionic tubes of the balanced modulator BM¹. 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 the frequency of 10,000 cycles per second. The organization of the modulator BM¹ 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 BF⁷ 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 TC², the connection with the primary side of the tuned circuit being by way of 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 BM¹ 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 TC³ which is constructed and adjusted to be selective of the particular carrier frequency that the channel employs. The connection with the primary side of the tuned circuit TC³ is by way of alternate contacts of the relay 20, and the secondary side of the tuned circuit has connection with the extremities of the potentiometer 23.

The output side of the balanced modulator BM¹ is connected by way of the windings of the transformer 24 and a high pass filter HPF¹ with the input side of the balanced amplifier BA¹. The high pass filter HPF¹ acts to prevent the passage of the amplified and unmodulated low controlling and voice frequencies through the balanced amplifier BA¹ in order to prevent these frequencies from overloading the amplifier. The balanced amplifier BA¹ is of the so-called

"push-pull" type as illustrated and described in connection with Fig. 49 of the Colpitts and Blackwell paper hereinbefore referred to, and the high pass filter HPF¹ is of the sort also illustrated and described in the Colpitts and Blackwell paper. The output of the balanced amplifier BA¹ is connected by way of the band filter BF¹ with the main transmitting branch that joins the various channel transmitting branches with the high frequency hybrid coil HFH¹.

As the tubes of the balanced modulator BM¹ and the balanced amplifier BA¹ 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 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 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 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 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 filaments normally energized, and therefore the A battery circuit for these tubes and means for controlling it are not shown.

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. 3 of the drawing. The receiving branch that extends from the high frequency hybrid coil HFH¹ to the receiving branches of the various channels also has another branch that has interposed in it a tuned circuit STC¹ which is tuned 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 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 tuned circuit STC¹ is connected by way of conductors 107 with the input circuit of the amplifier A² (Fig. 3) and the output circuit of the amplifier is connected with the input circuit of harmonic generator HG¹. The output circuit of the harmonic

generator is connected with the input circuit of the amplifier A³ and the output circuit of amplifier A³ 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 Blackwell paper previously referred to, the nature and arrangement of the apparatus being in accordance with the disclosure contained in Patent No. 1,446,752 of February 27, 1923 to Burton W. Kendall.

The low control frequency, 150 cycles per second in the present embodiment of the invention, is produced in the oscillator O¹ (Fig. 3), which oscillator may be of any usual and well known thermionic type with a feed back connection from its output into its input circuit. The sinusoidal oscillations produced in the oscillator O¹ are amplified in the amplifier A¹ and thence pass through the tuned circuit TC¹, 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 applied 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. 5, 6 and 7 of the drawing. Fig. 6 illustrates diagrammatically a part of the switches at the switching station through the medium of which interconnection is made between the various channels, and Figs. 5 and 7 show the channels identified with two of the four carrier multiplex lines that are assumed to terminate at the switching station, the circuits of one of the channels of each of the two carrier multiplex lines being illustrated diagrammatically in detail and the other two channels of each of these two lines being merely indicated by broken line rectangles. The organizations of the circuits of the different channels of each carrier multiplex line are identical excepting in the matter of the different carrier frequencies upon which the channels are adapted to operate. Therefore, a description of the organization of the carrier multiplex line illustrated in Fig. 5 and of channel 1 of this line will suffice for all of them. The conductors 104 of the toll line are connected with the high frequency hybrid coil HFH² and the opposite sides of the line

windings of the hybrid coil are connected with the network N which exercises the usual balancing function. From the high frequency hybrid coil HFH² the main receiving branch has connection by way of the band filters BF⁹, BF¹¹ and BF¹³ with the separate receiving branches of channel 1, channel 2 and channel 3, and the main transmitting branch entering the high frequency hybrid coil has connection by way of the band filters BF¹⁰, BF¹² and BF¹⁴ with the transmitting branches of the three channels. The main transmitting branch also is connected by the anti-resonantly shunted tuned circuit STC² with the apparatus illustrated in Fig. 6 that generates the base frequency of 3,333 cycles per second and the various desired harmonics of this frequency. The band filters BF⁹ to BF¹⁴, inclusive, are of the type disclosed in the Campbell patent previously referred to. The filters BF⁹, BF¹¹ and BF¹³ are constructed and adjusted to pass the upper speech and control frequency side bands of the 10,000 cycle, 13,333 cycle and 16,666 cycle carrier waves, respectively, and the filters BF¹⁰, BF¹² and BF¹⁴ are constructed and adjusted to pass the lower speech and control frequency side bands of the 23,333, 26,666 and 30,000 carrier waves respectively.

Referring now to the typical channel circuit arrangement illustrated in connection with channel 1 of Fig. 5, the receiving branch extends directly from the band filter BF⁹ to normally open contact points of two controlling relays 35 and 36, the functions of which controlling relays will be described hereinafter. The transmitting branch of the channel extends from other normally open contact points of these relays to the input circuit of the balanced modulator BM². The output side of modulator BM² extends by way of a Campbell type band filter BF¹⁵, adapted to pass the 23,333 cycle carrier wave and its lower speech and control frequency side band, to the input circuit of the amplifier A⁶, and the output circuit of this amplifier is connected with the band filter BF¹⁰, previously referred to, which is interposed between the channel transmitting branch and the common transmitting branch of the high frequency hybrid coil HFH².

The balanced modulator BM² 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 the balanced modulator BM² the currents to be modulated are supplied by way of the pair of conductors that extend to the modulator

from the normally open contact points of the controlling relays 35 and 36, and the modulating frequencies are supplied to the divided input circuit by way of the common distributing circuit 108 that extends from the harmonic frequency generating apparatus illustrated in Fig. 6. As will subsequently be described, there are present in the common distributing circuit the harmonic frequencies having the values of 33,333, 36,666, 40,000, 43,000 and 46,666 cycles per second. Consequently the frequencies that are supplied to the balanced modulator BM² by way of the serially connected portion of the modulator input circuit simultaneously modulate all of the frequencies supplied by way of the common distributing circuit 108 to the common portion of the divided input circuit of the modulator. The thermionic tubes of the balanced modulator BM² are chosen of sufficiently great capacity to carry the peak voltages of the combined modulating harmonic frequencies and the frequencies to be modulated without causing the grids of the tubes to go positive. If this occurred it would have a tendency to produce improper intermodulations between the various frequencies and to cause distortion in the modulator. But by exercising care to choose thermionic tubes of a type having ample capacity from among those which are available and well known in the art, the modulation which occurs between the frequencies which enter by way of the series portion of the input circuit and each of the multiplicity of harmonic frequencies which enter by way of the parallel portion of the input circuit may be made to be the same as through the other harmonic modulating frequencies were not present.

It may be well at this point to explain the manner in which this modulating organization operates in conjunction with the channel switching apparatus to establish operative relation between incoming and outgoing channels and change the incoming frequency to the frequency at which the apparatus of the outgoing channel is adapted to operate. It is apparent that in a general scheme of interconnection such as is contemplated in the present invention any incoming channel receiving branch must be capable of being extended to any outgoing channel transmitting branch regardless of the diverse frequencies of the different channels that may be brought into connection. Referring specifically for example to channel 1 as illustrated in Fig. 5 of the drawing, in order to pass through the band filters BF¹⁵ and BF¹⁰ in the transmitting branch of the channel the transmitted frequencies must lie within the range of the 23,333 cycle carrier wave and its lower speech frequency side band. Assuming that the speech frequency side band to

be transmitted has a breadth of 2,200 cycles, this means that in order to pass out of the transmitting branch of channel 1 the modulated current must lie within the range comprised between 23,333 cycles and 23,333—2,200 cycles per second. But the frequencies which enter the switching station by way of the receiving branches of the various channels of the carrier multiplex toll lines that center in the station are the upper side band of the 10,000 cycle carrier wave for channel 1, the upper side band of the 13,333 cycle carrier wave for channel 2, and the upper side band of the 16,666 carrier wave for channel 3 of each of the carrier multiplex toll lines. None of these frequencies, therefore, as they enter the switching station, are at the proper level to pass out by way of the transmitting branch of channel 1, or by way of the transmitting branches of channels 2 and 3. In order to pass out by way of the transmitting branch of any of the channels the level of the incoming frequencies must be changed; and moreover the extent of the change necessary depends upon the difference in frequency level between the incoming frequencies and the frequency at which the outgoing transmitting branch is adapted to operate. Furthermore, as the received modulations of the carrier of each channel are in the upper speech frequency side band of that carrier, and as the transmitted modulations outgoing from the switching station must lie in the lower speech frequency side band of the carrier, in the embodiment of the invention herein disclosed, the interconnection of one channel with another at the switching station must be effected in such a way as to invert the relative position of the side band with its carrier.

All of the above mentioned transformations necessary to the operative indiscriminate interconnection of the channels are effected by providing for the modulation, in each channel transmitting branch, of the frequencies received from the interconnected channel by a group or multiplicity of frequencies lying above the received frequencies by a definite, predetermined amount in the frequency scale.

To illustrate the action we may assume that the switch mechanism at the intermediate station has operated to connect channel 1 of one of the carrier multiplex lines with channel 1 of the line illustrated in Fig. 5. Under these circumstances the receiving channel of the first mentioned line is connected with the transmitting branch of channel 1 of Fig. 5, and consequently the 10,000 cycle carrier wave with its upper speech frequency side band is being applied to the series input circuits of the balanced modulator BM^2 of channel 1. At the same time there is applied to the parallel input circuit of the modulator BM^2 the harmonic fre-

quencies 33,333, 36,666, 40,000, 43,333 and 46,666. The result in the modulator BM^2 is to modulate each of these last mentioned harmonic carrier frequencies with the 10,000 receiving branch frequency of the interconnected channel,—that is, with the 10,000 carrier frequency and its upper speech frequency side band. As a result there appear the sum and difference modulation products of the received voice modulated carrier with each of the five harmonic waves as follows:

$$\begin{aligned} 33,333 + 10,000 + &= 43,333 + \\ 33,333 - 10,000 + &= 23,333 - \\ 36,666 + 10,000 + &= 46,666 + \\ 36,666 - 10,000 + &= 26,666 - \\ 40,000 + 10,000 + &= 50,000 + \\ 40,000 - 10,000 + &= 30,000 - \\ 43,333 + 10,000 + &= 53,333 + \\ 43,333 - 10,000 + &= 33,333 - \\ 46,666 + 10,000 + &= 56,666 + \\ 46,666 - 10,000 + &= 36,666 - \end{aligned}$$

As may be seen from the foregoing the result is a plurality of modulation products of which the second in the series, namely that represented by 23,333—, represents the 23,333 cycle carrier with its lower speech side band which is adapted to be transmitted through the band filters BF^{15} and BF^{10} interposed in the output circle of the modulator BM^2 . All of the other modulation products in the series lie outside of the limits of the band filter BF^{15} , and consequently are suppressed and do not pass to the amplifier A^6 which is interposed between the two band filters BF^{15} and BF^{10} . It may be remarked that the amplifier A^6 is employed for the purpose of relieving the balanced modulator BM^2 as far as possible of the work of amplification which would tend to overload it and therefore prevent it from properly performing its primary function of separately combining without distortion the multiplicity of frequencies present in its input circuit. It may also be remarked that there will be present in the output circuit of the modulator a number of frequencies other than those noted in the table given above, these frequencies including the amplified 10,000 cycle carrier with its upper side band of the interconnected receiving channel as well as the group of harmonic modulating frequencies 33,333 to 46,666, inclusive, which are not entirely suppressed in the balanced modulator. But it may be seen that these frequencies also are outside of the frequency range of the band filters BF^{15} and BF^{10} interposed in the output circuit of the modulator BM^2 , so that these undesired frequencies are also suppressed and do not pass into the common transmitting branch of the carrier multiplex line.

If it is assumed that it is channel 2 of

one of the other carrier multiplex lines that has been brought into connection with channel 1 of Fig. 5, then it will be the 13,333 cycle carrier with its upper side band that will separately modulate each of the five harmonic frequencies that in the present instance are applied to the parallel portion of the balanced modulator input circuit. Under these circumstances the sum and difference modulation products which appear in the output circuit of the modulator BM^2 will be 46,666+, 20,000-, 50,000+, 23,333-, 53,333+, 26,666-, 56,666+, 30,000-, 60,000+ and 33,333-. Of these modulation products it may be seen that the fourth in the series represents the 23,333 cycle carrier with its lower speech side band which is adapted to pass through the band filters BF^{15} and BF^{10} in the output circuit of the modulator BM^2 , and that the other products of modulation will be suppressed in these filters and barred from entering the carrier multiplex line. Furthermore, as stated in connection with the case first considered, the other undesired frequencies which are present in the output circuit of modulator BM^2 are outside of the range of the filters BF^{15} and BF^{10} and are also suppressed.

If it is assumed that it is channel 3 of one of the other carrier multiplex lines that is connected with channel 1 of Fig. 5, it is the 16,666 carrier wave with its upper speech frequency side band which is imposed upon the series circuit of the input side of the balanced modulator BM^2 . The sum and difference modulation products which then appear in the output side of the balanced modulator are 50,000+, 16,666-, 53,333+, 20,000-, 56,666+, 23,333-, 60,000+, 26,666-, 63,333+ and 30,000-. It will be noted that the sixth in this series represents the frequency bearing the speech modulation that is adapted to pass through the filters BF^{15} and BF^{10} interposed in the output circuit of the modulator, and that the frequencies of the other modulation products are such that they are suppressed in these filters.

A further fact which appears from an inspection of the groups of modulation products recited in connection with the three assumptions that have been made as to the particular channel that has been connected with the outgoing or transmitting branch of channel 1 of Fig. 5, is that each of the three groups noted contains the modulation products represented by the numbers 26,666-, and 30,000- as well as that represented by the number 23,333-. That is to say, whenever the receiving branch frequency 10,000+, 13,333+ or 16,666+ modulates the plurality of harmonic modulating frequencies 33,333 to 46,666, inclusive, among the modulation products there is a speech modulated carrier frequency so located in the frequency scale as to be capable of pass-

ing through the band filters, as BF^{15} and BF^{10} , of whichever one of the three channels is included in the connection; and such other amplification or modulation products as are present in the output circuit of the modulator are so positioned in the frequency scale as to be barred out of the main transmitting branch of the carrier multiplex line by the interposed band filters.

It seems well at this point to digress long enough from the description of the organization of switching station A illustrated in Figs. 5, 6 and 7 to explain the way in which the above described manner of matching the diverse frequencies of the different interconnected channels is applied at switching station B. As illustrated in Figs. 1 and 2, the channels of the lines that center at switching station B employ the same carrier frequencies as the frequencies employed by the channels of the lines that center at switching station A excepting that the carrier and side band frequencies associated with the transmitting branches of the channels at switching station A are associated with the receiving branches of the channels at switching station B, and vice versa. Consequently the modulation that occurs in the transmitting branches of the channels at switching station B must be of a character that will transform the incoming lower side bands of the carriers 23,333, 26,666 and 30,000 into the upper side bands of the outgoing carriers 10,000, 13,333 and 16,666. This is effected by applying to the common portion of the divided or parallel input paths of the balanced modulators in the transmitting branches the same harmonic modulating frequencies that have been described as being employed to perform the frequency transformation in the balanced modulators of switching station A,—that is, the frequencies 33,333, 36,666, 40,000, 43,333 and 46,666. The intermodulation of these five frequencies with the carriers 23,333, 26,666 and 30,000 with their lower side bands, one or another of which is applied to the series input circuit of the balanced modulator by way of the receiving branch of the interconnected channel, gives rise to sum and difference modulation products in the output circuit of the balanced modulator, just as described in the explanation of the modulating action at switching station A. All of the sum or additive products of modulation are far above the frequency range of the band filters for passing the 10,000+, 13,333+ and 16,666+ frequencies to the transmitting branches of the high frequency hybrid coils of the respective carrier multiplex lines. The difference or subtractive products of modulation of the five harmonic modulating frequencies with the three incoming or receiving branch carrier frequencies and their lower side bands include the

frequencies 10,000+, 13,333+, 16,666+, 20,000+ and 23,333+ in the case of the 23,333- receiving branch frequency of an interconnected channel 1; the frequencies 6,666+, 10,000+, 13,333+, 16,666+ and 20,000+ in the case of the 26,666- incoming or receiving branch frequency of an interconnected channel 2; and the frequencies 3,333+, 6,666+, 10,000+, 13,333+ and 16,666+ in the case of the 30,000- incoming or receiving branch frequency of an interconnected channel 3. It will be noted that in the case of each of the interconnected channels, channel 1, channel 2 and channel 3, there appear in the difference modulation products in the output circuit of the modulator the frequencies 10,000+, 13,333+ and 16,666+. In other words, no matter which channel at switching station B is connected to any one of the other channels, the modulation of its receiving branch frequency by the five harmonic modulating frequencies applied to the balanced modulator in the transmitting branch gives rise among the different modulation products to a carrier wave and upper side band that is so positioned in the frequency scale as to be capable of passing out through the band filters interposed in the output circuit of the modulator; and furthermore that the cut-off limits of the band filters interposed beyond the balanced modulator in the transmitting branch of each of the three channels is such as to bar the passage of all modulation product frequencies other than the particular speech modulated carrier which the transmitting branch of that channel is designed and adapted to transmit.

It may be seen from the foregoing discussion that the modulating frequency required to match the carrier side bands in an interconnection between channel 1 and channel 1 is 33,333, between channel 1 and channel 2 is 36,666, between channel 1 and channel 3 is 40,000, between channel 2 and channel 2 is 40,000, between channel 2 and channel 3 is 43,333, and between channel 3 and channel 3 is 46,666. This is under the assumptions hereinbefore set forth with respect to the carrier frequencies employed for the different channels and the relation of the speech frequency side bands to their respective carriers. Of course, a change in these factors will necessitate corresponding changes in the values of the modulating frequencies for matching the channel frequencies with each other. It is obvious that in the case of the interconnection of any one of the channels with any one of the other channels only one of the multiplicity of matching frequencies, that is the frequencies from 33,333 to 46,666, inclusive, is usefully employed. The particular one which is needed is automatically selected and made effective by virtue of the frequency selective

characteristics of the apparatus in the output side of the balanced modulator BM^2 , the other frequencies and their modulation products being automatically suppressed and eliminated in this apparatus. It is to be understood that it is deemed to be within the scope of the present invention to effect the selection of the particular matching frequency desired by means of a selection automatically effected before the matching frequency is applied to the modulator, as, for instance, by selective circuits operating to make effective one or another of the matching frequencies in the movement of the channel selecting switch upon which each channel terminates. But it has been found that the normal application of all of the matching frequencies to all of the modulators, and the suppression and elimination of the undesired modulation products in the output circuit of the modulator, permits of a very substantial simplification of the switching apparatus; and therefore this form of the invention is disclosed as the preferred embodiment.

It may further be noted that the modulation which effects the matching of the carrier frequency of one channel with another may be effected in modulators of well known types other than the particular balanced or carrier suppression type indicated at BM^2 , the filters in the output circuit of the modulator being relied upon to suppress the undesired products of modulation. But the balanced modulator of the type that has been described is preferred for the reason that it is adapted in itself to suppress or materially reduce in quantity a portion of the undesired modulation products, and is furthermore well adapted to handle without distortion the relatively large amounts of energy that are present in the multiple modulation that the preferred form of the invention renders desirable.

Further reference may now be made to the organization of the receiving branches of the channels, as typified in connection with the receiving branch of channel 1 shown in Fig. 5. As has hereinbefore been stated, the receiving branch extends in two conductors from the band filter, as BF^3 , interposed at the head of the channel to normally open contact points of the two controlling relays, as 35 and 36. It is over this path that the voice modulated frequency bands pass between the two interconnected stations. For switching control purposes a branch extends from this path by way of the amplifier A^5 to the balanced detector BD^2 . This detector is of the type disclosed in Patent 1,343,306 to Carson issued June 15, 1920, and is supplied from the common distributing circuit 109 by way of the tuned circuit TC^6 with the harmonic demodulating frequency of 10,000 cycles corre-

sponding with the carrier frequency of the associated channel branch. The output circuit of the balanced detector BD^2 is connected with the input circuit of the rectifier R^2 by way of the tuned circuit TC^5 which is so constructed and adjusted as to pass the control frequency of 150 cycles per second which is separated out by the demodulating action which takes place in the detector BD^2 . After amplification and rectification in the rectifier R^2 the 150 cycle control frequency is effective to energize the relay 25 connected in the output circuit of the rectifier, and the relay 25 acts as the medium through which the distant station controls the selective operation of the intermediate station switching mechanism and its restoration to normal when disconnection occurs. This switching mechanism and its associated controlling circuits will now be described.

Under the conditions that have been assumed there are at switching station A twelve switches, each one serving as the active terminal of a different one of the twelve channels of the four carrier multiplex lines centering at the station. In Fig. 6 only four of these switches are diagrammatically illustrated, the switches shown being designated S^1 , S^2 , S^9 and S^{10} . As the titles on Fig. 6 indicate, switches S^1 and S^2 are the incoming terminals of channels 1 and 2 respectively of station 1, switch S^9 is the incoming terminal of channel 3 of station 3, and switch S^{10} is the incoming terminal of channel 1 of switching station B. Each of the switches may conveniently be of the single motion rotary type in which brushes or wipers, 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. 5, in which the stepping magnet 33 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 one ordinarily skilled in the art may readily and without the exercise of invention substitute other of the well known types of switches for the single motion step by step rotary switch that is indicated. It may be remarked, however, that a type of switch like that indicated, in which the groups of contact terminals associated with all of the channels of the carrier multiplex lines may be reached, as will be described,

by a single unidirectional movement of the brushes or wipers, is particularly well adapted for the realization of that feature of the invention which secures a simple, compact and also readily shielded wiring arrangement for the channel conductors that operate at the diverse carrier frequencies required.

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 serving as terminals of channels 1, 2 and 3 respectively of station 1. In the 6th position brushes 1, 2, 5 and 6, engage terminals concerned with the transmission of a busy tone signal to the calling operator in case all of the channels of station 1 are in use. The 7th, 8th, 9th and 10th groups of stationary contact terminals serve similar purposes in connection with the channels of station 2. The 11th, 12th, 13th and 14th groups of stationary terminals serve like purposes in connection with the channels of station 3, and the 15th, 16th, 17th and 18th groups of terminals engaged by the set of brushes serve like purposes in connection with the channels of switching station B. Corresponding groups of contact terminals in all the switches of the series are multiplied together, and the multiple wires of each group are connected with conductors extending to the channel apparatus of the associated channel. As it is never necessary for any of the channels to complete connection with another channel of the same carrier multiplex line, the multiple wiring between corresponding groups of stationary terminals in the various switches does not have connection with the groups of terminal contacts in the switches serving as the active terminals of the channels of the corresponding carrier multiplex lines. Thus as shown in Fig. 6, the multiple conductors representing the incoming paths to channel 1 and channel 2, respectively, of station 1 are not extended to connect with the stationary contact group engaged in the 3rd and 4th positions of the brushes of switches S^1 and S^2 , and corresponding omissions are made at switches S^9 and S^{10} in the connections of the multiple

conductors that serve as the incoming paths to channel 3 of station 3 and channel 1 of station B respectively.

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 station or group of channels to which it is desired to extend connection; 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 the stationary contacts engaged by the brushes 3, 4, 5 and 6 have to do with the transmission of the speech modulated carrier frequencies between the connected terminal stations. This will appear clearly in connection with the description of the operation of the system hereinafter. It will be observed that the order of the switch brushes and their respective rows of contact terminals shown at one side of Fig. 6 is inverted relatively to the arrangement shown at the other side of Fig. 6. This involves no change in the relative circuit arrangements of the different switches, but is merely for the purpose of symmetry in the two halves of the drawing shown in Figs. 5, 6 and 7.

There still remains to be made a brief reference to the apparatus illustrated at the bottom of Fig. 6 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 demodulations to which reference has hereinbefore been made; also the apparatus for impressing a busy tone upon one of the carriers to be employed in case all of the channels of a selected group are found to be in use. The 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 feed back connection from its output into its input circuit. The sinusoidal oscillations produced in the oscillator O^2 are amplified in the amplifier A^8 , have the magnitude of their voltages greatly increased in the transformer 47 and are then impressed upon 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 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 said Kendall Patent No. 1,446,752. The harmonics thus produced consist of an extended series having relatively uniform

energy values. The base frequency of 3,333 cycles is separated out by means of the anti-resonantly shunted tuned circuit STC^3 and is applied to the distributing circuit 100 from which it is supplied by way of shunted tuned circuits, as STC^2 of Fig. 5, to the main transmitting branches of the different carrier multiplex lines centering in switching station A. The group of harmonic frequencies 10,000, 13,333 and 16,666 is separated out by means of the band filter BF^{17} and is applied to the distributing circuit 109 from which the different frequencies of the group are supplied for the demodulation of the carriers of the channels of the various carrier multiplex lines by means of tuned circuits as TC^6 of Fig. 5. It will be understood of course that the harmonic frequency taken off by the tuned circuit TC^6 of each of the various channels centering in the switching station is such as in each case to correspond with the carrier frequency of the receiving branch of that channel. The harmonic frequencies 33,333, 36,666, 40,000, 43,333, and 46,666 are separated out by means of the band filter BF^{18} and are applied to the distributing circuit 108 from which they are supplied to the balanced modulators, as BM^2 , of the transmitting branches of all of the channels centering in the switching station for the purpose of matching the channel frequencies, as hereinbefore described.

Any one of the three frequencies 10,000, 13,333 or 16,666, the 10,000 cycle frequency being used in the particular embodiment disclosed, is selected by means of the tuned circuit TC^7 (Fig. 6) and is applied to the parallel input circuit connection of the balanced modulator BM^3 for the purpose of being modulated by a characteristic frequency or tone which is derived from any suitable source and is applied to the series input circuit of the balanced modulator BM^3 . The modulation products are amplified by means of the amplifier A^7 connected in the output circuit of the modulator BM^3 ; and the 10,000 cycle carrier frequency with its upper side band carrying the busy tone modulation is selected by the band filter BF^{16} and is applied to the distributing circuit 130 which has a branch connection with the pairs of stationary contact terminals adapted to be engaged by brushes 5 and 6 of the various switches in the 6th, 10th, 14th and 18th positions that the switch brushes are adapted to occupy in the successive stages of their movement.

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 3 by way of switching station A, as shown generally in the skeleton diagram of Figs. 1 and 2 and as shown more specifically in

the detail drawings of Figs. 3 to 7 inclusive. Assuming that it is the local subscriber at station SS (Fig. 3) that initiates the call for a subscriber at the 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 CC² 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.

It is assumed that the route to the distant toll station is by way of the carrier multiplex line illustrated in Fig. 4 and extending to the intermediate or switching station shown in Figs. 5, 6 and 7. 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 BL¹, BL² and BL³ corresponding with the different channels of the carrier multiplex line, and then inserts the toll plug TP of the connecting circuit CC² into the multiple spring jack of one of the channels that is not at the time in use. It may be assumed that this is the springjack MJ¹ associated with the busy lamp BL¹. 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 MJ¹, 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 BM¹ and the balanced amplifier BA¹ of the transmitting branch of channel 1, and also connects the harmonic distributing circuit 105 with the tuned circuit TC³ so that the 10,000 cycle carrier frequency appropriate to channel 1 is applied to the balanced modulator BM¹ 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 BL¹ 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 CL¹ of the associated channel and gives it control over the toll supervisory lamp TSL of the cord circuit CC² 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 MJ¹. Relay 15 in operating energizes relay 19; and relay 19 in operating connects the control frequency distributing circuit 106 with the tuned circuit TC² to cause the application of the 150 cycle control frequency to the balanced modulator BM¹ 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 MJ¹ the transmitting branch of channel 1 is energized, and that the 10,000 cycle carrier frequency of this channel and the 150 cycle control frequency are both applied to the balanced modulator BM¹. The modulation of the carrier frequency by the control frequency takes place in the balanced modulator, and after amplification in the balanced amplifier BA¹ the modulated upper side band of the 10,000 cycle carrier passes by way of the band filter BF¹ into the common transmitting branch and thence by way of the high frequency hybrid coil HFH¹ to the carrier multiplex line 104.

At the switching station the upper side band of the 10,000 cycle carrier wave passes through the high frequency hybrid coil HFH² (Fig. 5) into the receiving branch common to the various channels of the line, and thence by way of the band filter BF⁹ into the receiving branch of channel 1. After passing through the band filter BF⁹ the modulated upper side band of the 10,000 cycle carrier is amplified in the amplifier A⁵ and passes to the input circuit of the balanced detector BD² where it is joined by the corresponding 10,000 cycle frequency derived from the common distributing circuit 109 by way of the tuned circuit TC⁶. Demodulation takes place in the balanced detector BD² and the 150 cycle control frequency is separated out of the other demodulation products by the tuned circuit TC⁵, is rectified and amplified in the rectifier R² and causes the energization of relay 25. Re-

lay 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 MJ¹ 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 125 and the multiple test terminals of this channel that appear upon the interconnecting switches representing 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 125 to ground that creates a busy test condition upon the busy test terminals of this channel in the other interconnecting switches, and in addition energizes relay 38. Relay 38 in operating connects the A battery with the filaments of the thermionic tubes of the balanced modulator BM² and the amplifier A⁶ of channel 1 and thus places the modulator and amplifier in operative condition.

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. 3, the operator at position 2 now operates the calling key CK of the connecting cord circuit CC². 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, or the first of the series of digits, corresponding to the arbitrarily assigned call number of the distant terminal station to which the connection is to be extended. In the present instance it is assumed that the distant terminal station is station 3, and the calling number for his station is the number "3". 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 associated contacts 13 to break and make the circuit in which they

are included three 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 longer interval, the circuit remaining closed after the last break until the dial is again operated.

At the first interruption of the circuit at the dial contacts 13 the relay 15 included in the circuit of sleeve conductor 52 (Fig. 4) 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 10,000 cycle carrier wave applied. But relay 15 in releasing releases relay 19 and disconnects the 150 cycle control frequency from the balanced modulator BM¹. 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 three times.

Referring now to the effects that are produced at the distant end of the carrier multiplex line as illustrated in Fig. 5, each withdrawal of the 150 cycle control frequency from the transmitting branch of channel 1 causes a corresponding deenergization of relay 25 which is 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 3 that is being called and that the dial contacts 13 are interrupted and then closed three times. At the first interruption of the dial contacts, and consequent energization of relay 27 (Fig. 5), 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 115, brush 1 of switch S¹ and the stationary contact terminal upon which it normally rests, conductor 119, 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 windings of the slow release relay 30 and the stepping magnet 33 in parallel and is com-

pleted 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 right 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 position to the second of the positions that they are 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 115, switch brush 1 and the second contact terminal of the series upon which it is now resting, conductor 118, 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 three 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, and 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 118 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 con-
 10 tacts 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
 15 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 suc-
 20 ceeding 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. In
 25 this position they are in engagement with the set of stationary terminals representing the multiple connection to channel 1 of station 3, to the station that is being called.

No further interruptions of the dial con-
 30 tacts 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 en-
 35 gagement with a contact terminal that is connected by way of conductor 119 with the front contact of relay 27, the energizing circuit of relay 28 remains interrupted; and when the contacts of relay 28 have remained
 40 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
 45 associated contacts. When this occurs a circuit is closed that extends from battery through the winding and right hand switch
 50 spring and resting contact of relay 29, lower winding of relay 32, back contact and armature of relay 30 and off-normal con-
 55 tacts 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
 60 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
 65 left hand armature shifts the energizing circuit of the stepping control relay 28 from the path that extends by way of conductor 115 to switch brush 1 to the path that extends by way of the upper winding and up-
 per front contact and armature of relay 32, lower armature and resting contact of re-
 lease magnet 34 and conductor 114 to test brush 2 of the switch. Relay 29 also dis-
 connects the ground controlled at its outer
 left hand armature from the circuits con-

trolled 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
 70 about the energization of relay 31 upon the release of relay 32, as will presently be de-
 75 scribed. 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
 80 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
 85 terminals that brush 2 is adapted to engage.

For the purpose of this description it will be assumed that channel 1 of station 3 is in use as a calling channel, that channel 2 of station 3 is in use as a called channel, and that channel 3 of station 3 is idle and avail-
 90 able for connection. The multiple connections from the stationary terminals of channel 1 and channel 2 of station 3 have not been illustrated, with the object of simplifying the drawing. The connection of the
 95 test terminals of these channels engaged by brush 2 may however be understood by reference to the similarly wired channel 1 of Fig. 5. Referring to Fig. 5, therefore, it may be seen that the test terminal of the
 100 channel is connected by way of conductor 125 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
 105 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 125, and therefore to the multiplied test terminals to which this conductor extends.

Again referring to the channel circuit as illustrated in detail in Fig. 5, 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 cor-
 110 responding 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 114, back contact and armature of release magnet 34, armature
 115 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
 120 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 rela-
 125

tively low so that the potential impressed upon the test terminals under these circumstances is substantially the ground potential.

5 Returning now to a description of the manner in which the two channels of station 3 assumed to be busy are passed over and the third channel assumed to be idle is seized at the moment relays 29 and 32 are
10 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, upper locking winding and front contact and
15 armature of relay 32, lower armature and back contact of release magnet 34 and conductor 114 to the switch test brush 2. As test brush 2 is resting upon the test terminal of channel 1 of station 3, which channel has
20 been assumed to be busy as a calling channel, the circuit is completed from the test terminal to ground by way of the path corresponding to conductor 125 and the outer right hand armature and front contact of relay 26 as
25 shown in Fig. 5. As a result relay 28 of the calling channel is energized and relay 32 remains energized. Relay 28 in operating energizes slow release relay 30 and stepping magnet 33 as hereinbefore described. The
30 operation of relay 30 does 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
35 the control of its self-interrupting contacts, advances the switch brushes one step into engagement with the group of terminals representing channel 2 of station 3. As has heretofore been pointed out, the relationship
40 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
45 is shifted from the test terminal of channel 1 to the test terminal of channel 2 without interrupting the continuity of the energizing path of relays 28 and 32; and as channel 2 of station 3 has been assumed to be busy as a called channel, the above mentioned energizing
50 path may now be traced from test terminal of channel 2 to ground by way of the multiple connection that extends from the test terminal of switch S^1 to the corresponding test terminal upon which the
55 brush 2 of the other switch is resting, and thence by way of the path through the other switch circuit corresponding to conductor 114, lower back contact and armature of the
60 release magnet 34, armature and back contact of the relay 32, winding of the relay 31 and outer left hand front contact and armature of the relay 29 of that other switch. Therefore the energizing path by way of the
65 energizing winding of relay 28 and the up-

per winding of relay 32 of the calling channel switch S^1 remains closed and the stepping magnet 33 associated with relay 28 is caused to take another step, as a result of
70 which the brushes of switches S^1 are brought into engagement with the set of stationary terminals representing channel 3 of station 3. When this occurs there is no longer a path for the energization of relays 28 and
75 32 of the calling channel switch, as there is no path to ground by way of the conductor 125 extending from the multiplied test terminals of the channel as long as the channel is in its normal condition. Therefore relays
80 28 and 32 are both immediately deenergized and release their armatures. The release of the armature of relay 28 puts a stop to the stepping operation of the switch, and the
85 release of the armature of relay 32 opens the holding circuit by way of the upper or locking winding of relay 32 and completes the previously traced path from brush 2 to
90 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
95 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
100 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
105 is engaged, and to which a conductor corresponding to 125 is connected, closes a circuit that extends from battery through the winding of relay 35 and the armature and front
110 contact of relay 31 to ground. Relay 35 in operating extends the receiving branch of calling channel 1 to the brushes 3 and 4 of switch S^1 by way of conductors 110, and extends the transmitting branch of channel
115 1 to brushes 5 and 6 of switch S^1 by way of conductors 112. It may be noted that the extension of the channel conductors to the brushes 3, 4, 5 and 6 does not occur until the switch S^1 has been moved to the desired station group of channels and has
120 come to rest upon the terminals of an idle channel of this group. Therefore interference effects are avoided by keeping the channel conductor extensions normally disconnected, and the passage of the brushes 3, 4, 5
125 and 6 over the terminals of the other channels on their way to the selected channel is without effect upon the circuits of the channels traversed.

When the brushes of switch S^1 of the calling channel become connected with the set of
130 stationary terminals of channel 3 of station 3, as described, a circuit is completed that extends from battery by way of the winding of relay 36' of channel 3 (Fig. 7). outer left

hand back contact and armature of relay 26', conductor 125, the multiple wire that joins the test terminals of channel 3 of station 3, the test terminal of this channel in switch S¹, test brush 2 which now rests upon this test terminal, conductor 114, 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 supplied to the amplifier A⁹, balanced detector BD³ and rectifier R³ of channel 3 to maintain them in their normal 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 channel 3 for the control of the signaling apparatus of channel 1 at the calling station from effecting the operation of the switching apparatus associated with channel 3 at the intermediate station. Relay 36' of the seized channel 3 in operating also connects the receiving branch of channel 3 with the stationary terminals of the receiving branch of this channel throughout the switches by way of conductors 121 and the associated multiple wiring, and also connects the transmitting branch of channel 3 with the corresponding stationary terminals of this channel throughout the switches by way of the conductors 123 and the associated multiple wiring. The receiving branch of calling channel 1 (Fig. 5) may now be traced by way of the two inner armatures and front contacts of relay 35, conductors 110, brushes 3 and 4 of switch S¹, the stationary contact terminals of station 3, channel 3 upon which these brushes have come to rest, multiple conductors of these terminals throughout the switches, conductors 123 and the two inner front contacts and armatures of relay 36' (Fig. 7) to the transmitting branch of channel 3. Likewise the transmitting branch of channel 1 (Fig. 5) may be traced by way of the two outer armatures and front contacts of relay 35, conductors 112, brushes 5 and 6 of switch S¹, the stationary terminals of station 3, channel 3 upon which brushes 5 and 6 are now resting, the multiple wiring connecting the corresponding terminals throughout the switches, conductors 121, and the two outer front contacts and armatures of relay 41 (Fig. 7) to the receiving branch of the seized channel 3.

At the same time that relay 36' was operated upon the seizure of channel 3 by the

calling channel 1 relay 38' of channel 3 was also energized over a circuit extending from battery through the winding of relay 38' and thence by way of conductor 135 over the path previously traced for the energization of the relay 36'. The resultant operation of relay 38' connects the A battery for lighting the filaments of the thermionic tubes of modulator BM⁴ and amplifier A¹⁰ of the transmitting branch of the seized channel 3. Therefore the seizure of channel 3 of station 3 by switch S¹ of calling channel 1 of station 1 makes operative the transmitting branch of channel 3.

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 CC² 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. 4) is now steadily energized, the 150 cycle control frequency is steadily applied to modulate the 10,000 cycle carrier wave of channel 1. The upper side band of this modulated wave passes through the band filter BF¹, the high frequency hybrid coil HFH¹, the carrier multiplex toll line 104 extending from calling station 1 to switching station A, the high frequency hybrid coil HFH² at the switching station, the band filter BF⁹ of the receiving branch of channel 1 of this line at the station, the two inner armatures and front contacts of relay 35, conductors 110, brushes 3 and 4 of switch S¹ and the stationary terminals of the seized channel 3 upon which these brushes rest, the multiple wiring of these terminals extending through the switches, conductors 123, the two inner front contacts and armatures of relay 36' of channel 3 and thence to the series input circuit of the balanced modulator BM⁴ in the transmitting branch of channel 3. Here the 10,000 cycle carrier path with its 150 cycle control modulation transmitted from the calling station is met by the group of modulating frequencies 33,333 to 46,666, inclusive, supplied by way of the common distributing circuit 108 to the parallel portion of the input circuit of balanced modulator BM⁴, and among the products of modulation, as hereinbefore fully explained, there appears the lower side band of the 30,000 cycle frequency bearing the 150 cycle control frequency modulation. This modulation product of the output circuit of modulator BM⁴ is selected by

the band filter BF^{10} , is amplified in the amplifier A^{10} and passes through the band filter BF^{21} into the common transmitting branch extending to the high frequency hybrid coil HFH^3 of the carrier multiplex toll line extending between switching station A and station 3 which is being called.

As the organization of the carrier multiplex circuit at called station 3 may be exactly the same as the organization of the circuits at calling station 1 shown in Figs. 3 and 4, the circuits illustrated in these two figures may now be assumed to represent the circuits of the station to which the connection is being extended. In temporarily referring to the circuits of Figs. 3 and 4 as representing the circuits at the called station, however, the further assumption will have to be made that the channel the circuit of which is shown in detail in Fig. 4 is channel 3 of the called station, for the reason that that is the channel over which the call has been assumed to be extended, and that consequently the band filter BF^1 is adapted to pass the upper side band of the 16,666 cycle carrier wave and that the band filter BF^2 is adapted to pass the lower side band of the 30,000 cycle carrier wave; also that corresponding changes in the frequency values are made in the associated tuned circuits TC^3 and TC^4 .

The passage of the 10,000 cycle carrier wave with its 150 cycle control modulation has been traced from the calling station through the switching station, where it is transformed into the 30,000 cycle frequency with the 150 cycle control modulation, and into the carrier multiplex line 126 extending to called station 3. Proceeding now upon the assumptions that have been made with regard to the representation of the called station by Figs. 3 and 4, the lower side band of the 30,000 cycle carrier 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 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 branch extending through the band filter BF^3 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 .

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 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. 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 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 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 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 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 both relays 16 and 15. Relay 16 in operating operates relay 20, and that relay energizes the transmitting branch of the corresponding channel and applies the appropriate carrier wave, in the present instance assumed to be the 16,666 cycle wave, to balanced modulator BM^1 by way of tuned 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 16,666 cycle 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 spring-jack 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 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 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 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 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 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 circuit CC² and multiple jack MJ¹ of the channel, the 10,000 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 3 of station 3 is established at the intermediate or switching station, the 10,000 cycle carrier with its 150 cycle control frequency modulation is holding the intermediate station switch S¹ in its operated position and is also being transformed to the 30,000 cycle carrier with an accompanying 150 cycle control frequency modulation in the transmitting branch of channel 3 at the switching station, this modulated carrier is being received in channel 3 of station 3 and is holding the relay 18 associated with the receiving branch of that channel operated, the operator at operators' position 1 at the called station 3 has made connection by means of connecting circuit CC¹ with the channel over which the call is being received, calling lamp CL¹ and toll supervisory lamp TSL at the called station 3 are extinguished and the 16,666 cycle carrier wave with the 150 cycle frequency modulation is being applied to the transmitting branch of channel 3 at station 3 over which the call from station 1 has come in. The 16,666 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 3, and passes into the receiving branch of channel 3 (Fig. 7) by way of band filter BF²⁰. The modulated 16,666 carrier is applied to the input circuit of the amplifier A⁹. But as the seizure of channel 3 and the accompanying operation of relay 36' (Fig. 7) has disconnected the normally connected A battery from the filaments of the thermionic tubes of amplifier A⁹, balanced detector BD³ and rectifier R³, these devices are inert and the modulated 16,666 cycle carrier has no effect upon relay 25', and the switching apparatus associated with channel 3 remains therefore in its normal condition. The modulated 16,666 cycle carrier, however, passes by way of the two outer armatures and front contacts of relay 36', conductors 121, multiple wiring of channel 3 throughout the switches, stationary contact terminals upon which brushes 5 and 6 of switch S¹ are resting, outer front contacts and armatures of relay 35 (Fig. 5), and transmitting branch of channel 1 to the series input circuit of balanced modulator BM². Here the modulated 16,666 cycle carrier is joined by

the matching frequencies supplied to the parallel portion of the input circuit of balanced modulator BM² by way of the distributing circuit 108, and the products of the plural modulation that occurs include the lower side band modulation of the 23,333 cycle frequency. This is passed selectively through the band filter BF¹⁵ to the input circuit of the amplifier A⁶, and after amplification is selectively passed through the band filter BF¹⁰ and the high frequency hybrid coil HFH² to the carrier multiplex line 104 extending from the switching station to calling station 1. It will have been noted that the balanced modulator BM² and the amplifier A⁶ are energized at this time as a result of the energization of relay 38 due to the energized condition of slow release relay 26 in the receiving branch of calling channel 1.

The modulated 23,333 cycle carrier produced by the transformation of the 16,666 cycle modulated carrier in balanced modulator BM², as described, passes over the carrier multiplex line 104, through high frequency hybrid coil HFH¹ (Fig. 4), band filter BF² of the receiving branch of channel 1 of the calling station and thence to balanced detector BD¹ where demodulation occurs. The 150 control frequency product of demodulation is amplified in amplifier A⁴ and passes selectively through low pass filter LPF¹ to rectifier R¹, 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 CC² in the channel spring-jack MJ¹. 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 station 3 to the call received over channel 3 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 CC². The carrier circuit between calling station 1 and called station 3 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 3. Assuming that the connection is to be extended to local station SS at called station 3, this is effected by the insertion of plug LP of connecting circuit CC¹ 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. 4) through the artificial line AL¹ to the line windings of the low frequency hybrid coil LFH¹ and thence by way of the series winding of the hybrid coil, the band filter BF⁷ and the transformer 21 to the series input circuit of the two thermionic tubes of balanced modulator BM¹. The band filter BF⁷, 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 BF⁷ 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 BM¹ the carrier wave, 10,000 cycles in the case of calling station 1 and 16,666 cycles in the case of called station 3, 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 upper modulation side band is transmitted. The upper side band of the 10,000 cycle carrier transmitted from calling station 1 is converted at the switching station by the action of balanced modulator BM⁴ (Fig. 7) into the lower side band of the 30,000 cycle frequency; and the upper side band of the 16,666 cycle carrier transmitted from called station 3 is converted at the switching station by the action of balanced modulator BM² (Fig. 5) into the lower side band of the 23,333 cycle frequency. 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 BD¹. The 150 cycle control frequency product of demodulation is then selected by low pass filter LPF¹ to effect the energization of relay 18 in the manner hereinbefore described and the voice frequency product of demodulation lying between 300 cycles and 2300 cycles per second are selected by band filter BF⁸ and applied to the mid-points of the line windings of the low frequency hybrid coil LFH¹. 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. 5), 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 S¹, 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 side band into which the balanced modulator BM⁴ (Fig. 7) converts the side band transmitted from calling station 1, or from the side band into which the balanced modulator BM² (Fig. 5) converts the side band transmitted from called station 3 if that is the station which is operating its dial to cause the signaling intermissions of the 150 cycle control frequency. 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 con-

cluded 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 spring-jacks into which they have been inserted. When the operator withdraws toll plug TP from the channel spring-jack 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 BM¹. 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 BM¹ and balanced amplifier BA¹ to render the channel transmitting branch inert, and also withdraws the carrier wave from the input circuit of the balanced modulator BM¹.

The withdrawal of the toll plug TP from the channel spring-jack 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 A², balanced detector BD² and rectifier R². 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 spring-jack, relay 25 of the receiving branch of the channel at the switching station (Fig. 5) 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 which has been holding energized relay 38, and that relay in releasing interrupts the flow of current from the A battery to the filaments of balanced modulator BM² and amplifier A² and thus deenergizes the transmitting branch of channel 1 at the switching station. As it is this ground connection at the outer front contact of relay 26 that has been maintaining the test potential on conductor 125 con-

nected with the test terminals of this channel throughout the switches, the release of relay 26 removes the busy test condition from the channel, and also at the back contact of the outer armature of relay 26 reconnects to the test conductor 125 the branch from battery including the relay 36, so that relays 36 and 38 are again under the control of conductor 125 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 S¹ and to ground by way of the closed off-normal contacts 39 of switch S¹. 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 S¹, the holding pawl 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, and lower armature and back contact of release magnet 34 to test brush 2 of the switch. This has the effect of opening the circuit 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 maintained disconnected from their channel circuits during the return movement of the brushes. Brush 1 of the switch is kept disconnected during the return movement by the energized condition of relay 29 which continues until the brushes have completed their return and have opened the off-normal contacts 39.

The operator at the calling station in withdrawing the toll plug from the channel spring-jack not only brings about the restoration to normal of the calling channel switch S¹ and the associated channel appa-

ratus at the switching station, but also brings about the restoration to normal of the apparatus associated with the called channel 3 of station 3. This is effected through the medium of relays 36' and 38' (Fig. 7) of channel 3 which relays are included in parallel branches of the conductor 125' the circuit of which during the continuance of the connection has been completed by way of the test terminal and brush 2 of calling channel switch S^1 , contacts of release magnet 34 and relays 32 and 29, and winding of relay 31 (Fig. 5). When release magnet 34 operates to restore switch S^1 it opens this circuit in which the windings of relays 36' and 38' of channel 3 are 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 3. When relay 36' of channel 3 releases it opens the circuit of the associated channel conductors that was extended by way of the four conductors 121 and 123 to the multiple wiring of channel 3 throughout the switches. At the same time relay 36' in releasing reconnects the A battery for the energization of the filaments of amplifier A^9 , balanced detector BD^3 and rectifier R^3 of the receiving branch of channel 3, with the result that the receiving branch of channel 3 is again made responsive to a call initiated at station 3 with which it is associated. Relay 38' in releasing interrupts the connection of the A battery with the filaments of the thermionic tubes of balanced modulator BM^4 and amplifier A^{10} of channel 3, thus rendering the transmitting branch of channel 3 inert until it is again energized by the taking of channel 3 for use.

If it should happen that the switching apparatus at the switching station is released by the withdrawal of the toll plug from the channel spring-jack at the calling station before the operator at station 3 withdraws the toll plug from the spring-jack of channel 3 in which it has been inserted, relay 25' of channel 3 is energized and in turn energizes the slow release relay 26'. The resultant operation of relay 26' breaks the path from battery through the winding of relay 36' and at the same time applies ground to conductor 125' extending to the test terminals of channel 3 throughout the switches. This has the effect of guarding channel 3 against seizure by a calling switch as long as the operator at the distant station to which channel 3 extends has connection with it. When the operator at station 3 removes the toll plug from the channel spring-jack this busy condition of the channel at the switching point is removed and the channel is 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 has the

effect of momentarily closing the energizing circuit of stepping control relay 28' by way of brush 1 of switch S^9 and the stationary terminal upon which it rests in the normal position of the switch brushes. As a result switch S^9 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 when the switch brushes were moved one step from normal, and switch S^9 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. It will be remembered that in the foregoing description of the completion of a connection between calling channel 1 of station 1 and channel 3 of the called station 3 it was assumed that channels 1 and 2 of calling station 3 were in use and that channel 3 of station 3 was idle and available for connection. It will now be assumed that all three channels of station 3 are in use at the time the call for connection with that station is initiated. Under these circumstances 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, upper winding and front contact and armature of relay 32, lower armature and back contact of release magnet 34, conductor 114 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 relay 31 and the cutting through of the channel connection. But as test brush 2 passes out of engagement with the test terminal of channel 3 of station 3 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 117 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. 5), conductor 117, fourth test terminal of the station 3 group, test brush 2, conductor 114, 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 and brings about the extension of the conductors of channel 1 by way of pairs
 5 of conductors 110 and 112 to the brushes 3, 4, 5 and 6 of switch S^1 . Relay 37 in operating closes a circuit that extends from battery through the winding of relay 40 (Fig. 6), conductor 116 and armature and
 10 front contact of relay 37 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^3 and amplifier A^7 of the busy tone modulating
 15 apparatus. The 10,000 cycle carrier wave supplied to the modulator BM^3 by way of tuned circuit TC^7 is thus modulated by the busy tone, and the upper side band of the 10,000 cycle carrier wave thus modulated
 20 and amplified is supplied by way of the band filter BF^{10} to the distributing circuit 130. A branch of this distributing circuit extends to the stationary terminals upon which switch brushes 5 and 6 are now resting; and
 25 as a result the upper side band of the busy tone modulated 10,000 cycle carrier is applied by way of conductors 112 and the two lower front contacts and armatures of relay 35 to the series input circuit of the balanced
 30 modulator BM^2 of the transmitting branch of channel 1. Here the busy tone modulated carrier is met by the group of matching frequencies 33,333 cycles to 46,666 cycles, inclusive, applied to the parallel input circuit
 35 of balanced modulator BM^2 by way of distributing conductors 108, and among the products of modulation appearing in the output circuit of the modulator is the lower side band of the 23,333 cycle frequency.
 40 This, after selection in the band filter BF^{15} , amplification in the amplifier A^6 and further selection in the band filter BF^{10} , is applied by way of the high frequency hybrid coil HFH^2 to the carrier multiplex line 104 extending
 45 to calling station 1. 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
 50 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
 55 all of the channels extending to the called station 3 are in use. She thereupon withdraws the toll plug TP from the channel spring-jack, and a restoration of the apparatus at the switching station to normal occurs
 60 in the manner which has already been described. It will be observed that there is a set of busy tone applying terminals lying beyond each series of sets of channel terminals of the various stations, so that the busy
 65 tone is automatically sent back to the calling

station whenever the switch brushes fail to make connection with any of the channels of the station that is being called.

A brief reference will now be made of the manner in which any of the stations of the
 70 system, for instance station 1, obtains connection with another of the stations, as station 5, which must be reached by the extension of the connection through a plurality of the intermediate or switching stations. Referring to the schematic diagram
 75 of the system illustrated in Figs. 1 and 2, it may be seen that in order for station 1 to reach station 5 the connection is made by way of the carrier multiplex toll line extending from station 1 to switching station
 80 A, one of the switches S^1 , S^2 or S^3 of station 1 at switching station A depending upon which of the channels is taken for use at station 1, the carrier multiplex toll line
 85 extending from switching station A to switching station B, one of the three switches S^4 , S^5 or S^6 at station B, depending upon which of the three channels has been seized by the switching apparatus at
 90 station A, and thence by way of the carrier multiplex toll line extending from switching station B to the called station, station 5. It will be assumed that channel 1 of each of
 95 these interconnecting links is the one which is taken for use. In establishing the connection therefore the operator at station 1 inserts the toll plug of the pair of connecting
 100 cords into a terminal spring-jack of channel 1, which act causes the energization of the channel and the application of the 150 cycle control frequency to the channel carrier wave, as hereinbefore described. In the present instance it is the fourth main
 105 group of stationary switch terminals at switching station A (Fig. 6), the group associated with the channels of the carrier multiplex line extending from station A to station B, in which the selection of an idle
 110 channel is to be effected. Consequently the operator at calling station 1 operates the calling dial OD so as to cause four interruptions of the dial contacts 13. As a result the 150 cycle control frequency is withdrawn
 115 from and reapplied to the channel 1 carrier of station 1 four times. This has the effect of bringing the switch brushes of switch S^1 at switching station A into engagement with the first set of terminals of the fourth
 120 or uppermost group before the slow release relay 30 (Fig. 5) releases to bring about the change-over and start the hunting operation of the brushes of switches S^1 . As it is assumed that channel 1 of the carrier multiplex
 125 line extending to station B is available for use, the brushes of switches S^1 remain in engagement with the first set of terminals of the fourth group, and consequently the conductors of channel 1 of station 1 at
 130 switching station A are extended to the con-

ductors of channel 1 of the carrier multiplex line extending to station B. This extension is accompanied, in the manner hereinbefore described in connection with the extension of channel 1 of station 1 to channel 3 of station 3, by the energization of the transmitting branch of the seized channel and the deenergization of the switch control and receiving branch of the seized channel. Consequently there occurs in the energized transmitting branch of the seized channel at switching station A a conversion of the carrier frequency transmitted from calling station 1 to the frequency adapted to pass out over the transmitting branch of channel 1 of the carrier multiplex line extending to switching station B. The calling operator at station 1 therefore now has control over the receiving apparatus connected with the receiving branch at switching station B of the carrier multiplex line that extends to station B from switching station A.

It may be assumed that the stationary channel terminals at switching station B associated with the channels of the carrier multiplex line extending from switching station B to station 5 are those of the third main group of the four groups traversed by the brushes of the switches at switching station B. Therefore, the calling operator at calling station 1 again operates the calling dial OD, this time in such a way as to cause the associated dial contacts 13 to interrupt the circuit three times. This causes the 150 cycle control frequency to be withdrawn from and reapplied to the carrier wave three times. As the carrier transmitted from calling station 1 is now being transformed in frequency in the transmitting branch of the interconnected channel at switching station A and is being received at that transformed frequency at switching station B by way of the receiving branch of the channel of the carrier multiplex line extending to switching station B from switching station A, these intermissions of the 150 cycle control frequency have exactly the same effect upon the operation of the associated switch S^4 at switching station B as has hereinbefore been explained at length in connection with the detailed description of the extension of a connection from calling station 1 to called station 3. The second operation of the operator's dial at the calling station therefore causes switch S^4 at switching station B to bring its brushes into engagement with the first set of channel terminals of the third group, that is the group associated with the channels of the carrier multiplex line extending to called station 5. It has been assumed that channel 1 of the line extending from switching station B to called station 5 is available for use. Therefore the brushes of switch S^4 at switching station B remain in engagement with the

first set of contacts of the third group, and a connection is consequently extended by way of channel 1 of that group to the called station 5. The subsequent operations at the calling and called stations thus interconnected are exactly as have hereinbefore been described, the carrier side band transmitted from each station being transformed by the matching frequencies at the successive intermediate stations and finally demodulated at the distant station. It may be noted that the second set of dial impulses transmitted by the calling operator at station 1 for the control of the switching apparatus at switching station B do not cause any change in the condition of the switching apparatus at switching station A, for the reason that the relay 29 (Fig. 5) at switching station A is being held in its operated position, and therefore that the energization and deenergization of relay 27 as a result of the corresponding movements of the armature of relay 25 are ineffective because the ground circuit controlled by the armature of relay 27 is held open at the outer left hand back contact and armature of relay 29. The intervals during which the armature of relay 25 is released as a result of the second series of interruptions produced by the operator's dial are too short, as has been described, to permit the release of the slow release relay 26. But when the conversation between the interconnected subscribers is completed, and the operator at the calling station disconnects, the relays 25 associated with the receiving channel branches at each intermediate or switching station are simultaneously and continually released and consequently the associated relays 26 at the series of intermediate stations retract their armatures and bring about the operation of the associated release magnets 34 to restore the switches at the intermediate stations to their normal positions.

What is claimed is:

1. In a carrier wave communicating system, two lines, means for transmitting signals over each of said lines in the form of variations of a carrier wave, automatic switch mechanism, and means operating in response to variations in the carrier wave transmitted over one line for actuating said switch mechanism to operatively associate said two lines so that the signals transmitted over one line are repeated into the other line and transmitted thereover in the form of variations of a carrier wave.

2. In a carrier wave communicating system, two lines each having a plurality of frequency selective channels superimposed thereon, an automatic switching mechanism associated with each channel, a controller adapted to be variably operated to govern the operation of any one of said automatic

switching mechanisms to extend and connect the corresponding channel of one line to any channel of the other line, and a control circuit including said controller, the automatic switching mechanism and the corresponding channel to the line to be extended.

3. In a carrier wave communicating system, a plurality of lines each having a plurality of superimposed frequency selective channels, automatic switching mechanism, a controller for governing the operation of the same to interconnect any two channels of different lines and a control circuit including said automatic switching mechanism and said controller.

4. In a carrier wave communicating system, two lines, a plurality of frequency selective channels superimposed upon each line, a switching station, automatic switching mechanism thereat, a controller adapted to be variably operated to govern the operation of said automatic switching mechanism to connect any two channels of different lines, and a circuit including said automatic switching mechanism and said controller.

5. In a carrier wave communicating system, a plurality of lines each having a plurality of frequency selective channels superimposed thereon, a switching station, automatic switching mechanism thereat for each channel of each line, a variably operable controller, means for associating the same with any of said switching mechanisms to govern the operation thereof in connecting the associated channel with a channel of another line, and a circuit including said switching mechanism and said controller.

6. In a carrier wave communicating system, two lines each having a plurality of frequency selective channels superimposed thereon, a switching station to which said lines extend, an automatic selector switch at said switching station for each channel of each line, an impulse controlling mechanism, means for associating the same with any of said selectors to govern the operation thereof in connecting the associated channel with a channel of the other line and a circuit including said selector and said impulse mechanism.

7. In a carrier wave communicating system, two lines each having a plurality of frequency selective channels superimposed thereon, an automatic switch for each channel of each of said lines, and means controlled over each channel for effecting the operation of the corresponding automatic switch to connect the associated channel with any of the channels of said other line.

8. In a carrier wave communicating system, a plurality of lines each having a plurality of frequency selective channels superimposed thereon, an automatic switch for each channel of each line, and means controlled over each channel for effecting the

operation of the corresponding automatic switch selectively to connect the associated channel with any of said other lines and with an idle channel of the selected line.

9. In a carrier wave communicating system, a plurality of lines, each having superimposed thereon a plurality of frequency selective channels, automatic switching mechanism associated with each line, and means controlled over each frequency selective channel for effecting the operation of said automatic switching mechanism of the corresponding line to connect the channel over which the control is exercised with an idle channel of any desired one of said other lines.

10. A plurality of lines each having a frequency selective channel superimposed thereon, a switching station to which said lines extend, automatic switching mechanism at said station, and means controlled over the frequency selective channel of any of said lines for establishing connection between said line and any other of said lines.

11. A plurality of lines each having a frequency selective channel superimposed thereon, a switching station to which said lines extend, an automatic switch at said switching station for each of said lines, and means controlled over the frequency selective channel of each of said lines for effecting the operation of the corresponding automatic switch to connect the associated line with any desired one of said other lines.

12. A plurality of lines each having a frequency selective channel superimposed thereon, a switching station to which said lines extend, an automatic switch for each of said lines at said station, means controlled over the frequency selective channel of each line for actuating the corresponding automatic switch to connect the associated line with any desired one of said other lines, and means controlled over the frequency selective channel of one of the connected lines for operating said automatic switch to effect disconnection.

13. In a carrier wave communicating system, two lines each having a plurality of frequency selective channels superimposed thereon, a switching station to which said lines extend, automatic switching mechanism for each line at said station, means controlled over any of said frequency selective channels for actuating said automatic switching mechanism to connect the corresponding channel with any channel of said other line, and means made operative in the establishment of said connection for preventing either of said channels from being connected with by any other channel.

14. In a carrier wave communicating system, two lines each having a plurality of frequency selective channels superimposed thereon, a switching station to which said

lines extend, automatic switching mechanism at said station for each channel, a controller adapted to be variously operated to govern operations of any one of said automatic switching mechanisms to extend and connect the corresponding channel of one line to any channel of the other line at a certain carrier frequency, and a control circuit including the controller and the automatic switching mechanism and corresponding channel of the line to be extended.

15 In a carrier wave communicating system, a switching station, two lines entering said station, means associated with each of said lines for transmitting signals thereover in the form of variations of a high frequency carrier wave, an automatic switch mechanism associated with each line, means controlled by variations in the carrier wave transmitted over one of said lines for effectively connecting said lines to repeat signals received over one line as variations of said carrier wave, into the other line as variations of the carrier wave utilized on that line, and means associated with said automatic switch mechanism adapted to pass only currents in the frequency level of said carrier waves and to prevent the passage of voice frequency currents.

20 16. In a carrier wave communicating system, two lines each having superimposed thereon a two-way frequency selective channel arranged to transmit upon one frequency band and receive upon another frequency band, means for interconnecting the two-way frequency selective channels of said lines, and means included in the interconnection of said channels for directly and immediately converting the frequency band that each of the channels is adapted to transmit into the frequency band that the other channel is adapted to receive.

25 17. In a carrier wave communicating system, a line arranged to transmit a speech modulated carrier of one frequency, another line arranged to receive a speech modulated carrier of another frequency, means for interconnecting said lines, and means automatically made operative in the interconnection of said lines for directly and immediately converting the frequency of the speech modulated carrier transmitted by the first line into the frequency of the speech modulated carrier that the second line is adapted to receive.

30 18. In a carrier wave communicating system, a line having superimposed thereon a channel adapted to transmit a side band of a carrier wave modulated with a low frequency, another line having superimposed thereon a channel adapted to receive the side band of another carrier modulated with said low frequency, means for interconnecting said lines, and means made active in

effecting said interconnection for converting the side band transmitted by the first line into the side band adapted to be received by the second line by a single modulation of the transmitted side band.

35 19. In a carrier wave communicating system, a transmitting station and a receiving station, a line extending from each of said stations to a switching station, means at said switching station for interconnecting said lines, means at the transmitting station for modulating a carrier wave with a low frequency, means at the receiving station for receiving and demodulating another carrier wave modulated with said low frequency, and a modulating device included in the interconnection of said lines at the switching station for directly converting the modulated carrier wave transmitted from the first station into the modulated carrier wave that the second station is adapted to receive and demodulate.

40 20. In a carrier wave communicating system, two lines each having superimposed thereon a two-way channel comprising a transmitting branch adapted to transmit the side band modulation of one carrier and a receiving branch adapted to receive the side band modulation of another carrier, a switching station to which said lines extend, and automatic switching mechanism at said station for operatively connecting the transmitting channel branch of each line with the receiving channel branch of the other line.

45 21. In a carrier wave communicating system, two lines each having superimposed thereon a two-way channel comprising a transmitting branch and a receiving branch, the receiving branch of each line being adapted to receive a different frequency from that which the other line is adapted to transmit, means for connecting the transmitting branch of each line with the receiving branch of the other line, and means made operative in establishing such interconnection for converting at the interconnecting point the frequency transmitted by each line into the frequency which the other line is adapted to receive.

50 22. In a carrier wave communicating system, a receiving channel adapted to be responsive to a band of frequencies occupying a certain position in the frequency scale, a plurality of transmitting channels each adapted to transmit a band of frequencies occupying a position in the frequency scale differing from the bands transmitted by the other channels and from the band adapted to be received by the receiving channel, means for connecting any of said transmitting channels with said receiving channel, and means made operative in effecting such interconnection for changing the position of

the transmitted band to a position corresponding to that of the band which the receiving channel is adapted to receive.

23. In a carrier wave communicating system, a transmitting station and a receiving station, a series of frequency selective channels constituting a connection between said stations, the frequencies at which said channels are adapted to operate being different one from another, means at the transmitting station for impressing speech frequencies upon a carrier wave to produce a speech modulated side band of the frequency at which the first channel of the series is adapted to operate, modulating apparatus at the point of connection of the first channel with the second channel for changing the frequency of this side band to the frequency at which the second channel is adapted to operate, similar modulating apparatus at subsequent points of diverse channel interconnection, and means at the receiving station for demodulating the band of frequencies received over the last channel of the series and reproducing therefrom the speech frequencies impressed upon the carrier at the transmitting station.

24. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, and automatic switch mechanism controlled from a distant point for connecting the incoming branch of each channel with the outgoing branch of the other channel.

25. In a carrier wave communicating system, a switching station, two lines entering said station and extending to their respective terminal stations, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, and automatic switch mechanism controlled from one of the distant stations for connecting the incoming branch of each channel with the outgoing branch of the other channel.

26. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, and automatic switch mechanism controlled over one of said channels for connecting the incoming branch of each channel with the outgoing branch of the other channel.

27. In a carrier wave communicating system, a switching station, a plurality of lines entering said station each of said lines having a superposed carrier channel provided with an incoming branch and outgoing branch at the switching station, and automatic switch mechanism controlled from a

distant point for connecting the incoming and outgoing branches of any one of said channels with the outgoing and incoming branches respectively of any other channel.

28. In a carrier wave communicating system, a switching station, a plurality of lines entering said station each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, and automatic switch mechanism controlled over the carrier channel of one of said lines in calling for effecting the connection of the incoming and outgoing branches of said calling line with the outgoing and incoming branches respectively of any other of said lines.

29. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, each of said incoming branches being adapted to operate at a different frequency from that of any of said outgoing branches, and interconnecting mechanism for uniting the incoming branch of each channel with the outgoing branch of the other channel and changing the frequency received over the incoming branch to the frequency at which the united outgoing branch is adapted to operate.

30. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, the incoming branch of each line being adapted to operate at a different frequency from that at which the outgoing branch of the other line is adapted to operate, means for uniting the incoming branch of each line with the outgoing branch of the other line, and a modulating device in the outgoing branch of each line for changing the incoming frequency received from the other line to the frequency at which the outgoing branch associated with said modulating device is adapted to operate.

31. In a carrier wave communicating system, a switching station, a plurality of lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, the frequency at which the incoming branch of each of said lines is adapted to operate differing from the frequency at which any of the outgoing branches of the other lines are adapted to operate, means for uniting the incoming and outgoing branches of any of said lines with the outgoing and incoming branches respectively of any of the other lines, and means included in the outgoing branches of two lines thus united for modulating the frequency received from the in-

coming branch of the united line with a frequency adapted to produce a modulation product of the received frequency corresponding to the frequency at which the outgoing branch associated with said modulating device is adapted to operate.

32. In a carrier wave communicating system, a switching station, a plurality of lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, the frequency at which the incoming branch of each of said channels is adapted to operate being different from the frequency at which the outgoing branch of any of the other of said channels is adapted to operate, means for uniting the incoming and outgoing branches of any of said channels with the outgoing and incoming branches, respectively, of any of the other channels, means in each outgoing branch for modulating the frequency received from the incoming branch of another channel united therewith to produce a modulation product of the frequency at which the associated outgoing branch is adapted to operate, and means for suppressing other undesired products of modulation.

33. In a carrier wave communicating system, a switching station, a plurality of lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, the outgoing branch of each channel being adapted to operate at a frequency differing from the frequency at which the incoming branch of each other channel is adapted to operate, means for interconnecting said channels, a modulator included in the outgoing branch of each channel, and means for supplying each modulator with a plurality of modulating frequencies, one of which is adapted to combine with the frequency received from the incoming branch of the interconnected channel to produce the frequency at which the outgoing branch associated with the modulator is adapted to operate.

34. A carrier channel interconnecting system including an outgoing channel branch adapted to operate at a certain frequency, a plurality of incoming channel branches each adapted to operate at a different frequency, means for connecting any one of said incoming branches with said outgoing branch, and modulating means included in the connection of said outgoing branch with any of said incoming branches for directly changing the frequency received by way of the connected incoming branch to the frequency at which the outgoing branch is adapted to operate.

35. A carrier channel interconnecting system including an outgoing channel

branch and a plurality of incoming channel branches adapted to operate at different carrier frequencies, automatic interconnecting means for connecting said outgoing branch with any of said incoming branches, and means actuated in the operation of said interconnecting means for changing the frequency received over the connected incoming branch to the frequency at which said outgoing branch is adapted to operate.

36. A carrier channel interconnecting system including an outgoing branch and a plurality of incoming branches each adapted to operate at a different carrier frequency, means for interconnecting said outgoing branch with any of said incoming branches, a modulating device in said outgoing branch, and a plurality of modulating frequencies supplied to said modulating device for the plural modulation of the frequency received from the connected incoming branch to create a plurality of modulation products one of which is at the frequency at which said outgoing branch is adapted to operate.

37. A carrier channel interconnecting system including an outgoing channel branch and a plurality of incoming channel branches each adapted to operate at a different carrier frequency, a modulating device in said outgoing branch, a plurality of frequency changing modulating frequencies, means for interconnecting any of said incoming branches with said outgoing branch, and means actuated in the operation of said interconnecting means for applying said plurality of frequency changing modulating frequencies to said modulating device, whereby the frequency of any interconnected incoming branch is matched with the frequency of said outgoing branch.

38. A carrier channel interconnecting system including an outgoing branch and a plurality of incoming branches each adapted to operate at a different carrier frequency, a modulating device in said outgoing branch, a plurality of frequency changing modulating frequencies simultaneously supplied to said modulating device, and means for connecting any of said incoming branches with said outgoing branch, whereby the frequency of any connected incoming branch is matched with the frequency at which said outgoing branch is adapted to operate.

39. A carrier channel interconnecting system including an outgoing branch and a plurality of incoming branches each adapted to operate at a different carrier frequency, means for interconnecting any of said incoming branches with said outgoing branch, a modulating device in said outgoing branch, and a plurality of matching frequencies applied to said modulating device, each of said matching frequencies being equal to the sum of the carrier frequency at which the

outgoing branch is adapted to operate and the carrier frequency at which a particular different one of said incoming branches is adapted to operate, whereby the positions of the side bands with respect to their carriers in the connected incoming and outgoing channel branches are inverted.

40. A carrier channel interconnecting system including an outgoing branch and an incoming branch adapted to operate at different carrier frequencies, means for connecting said branches, a modulating device included in the circuit of the connected branches, and a frequency matching modulating frequency applied to said modulating device, the frequency of said modulating frequency being equal to the sum of the carrier frequencies at which the outgoing branch and said incoming branch are adapted to operate, whereby the positions of the side bands in the outgoing and incoming branches are inverted with respect to the carriers of these branches.

41. A carrier channel interconnecting system including an outgoing branch and a plurality of incoming branches each adapted to operate at a different carrier frequency, means for connecting said outgoing branch with any of said incoming branches, a modulating device in said outgoing branch, a plurality of matching frequencies simultaneously applied to said modulating device, the frequency of each of said matching frequencies being equal to the sum of the carrier frequency at which said outgoing branch is adapted to operate and the carrier frequency at which a particular different one of said incoming branches is adapted to operate, and all of said matching frequencies lying above the carrier frequency rate of said outgoing branch in the frequency scale, whereby unmodulated matching frequency is prevented from passing out over said outgoing branch.

42. A carrier channel interconnecting system including an outgoing branch and an incoming branch each adapted to operate at a different carrier frequency, means for interconnecting said outgoing branch and said incoming branch, a modulating device included in the circuit of said interconnected branches, and a matching frequency applied to said modulating device, the frequency of said matching frequency being equal to the sum of the carrier frequencies at which said outgoing branch and said incoming branch are adapted to operate, whereby unmodulated matching frequency and its harmonics are prevented from passing out over said outgoing branch.

43. A carrier channel interconnecting system including an outgoing branch and a plurality of incoming branches each adapted to operate at a different carrier frequency, means for connecting any of said incoming

branches with said outgoing branch, a modulating device in said outgoing branch, a plurality of matching frequencies simultaneously applied to said modulating device and each adapted to match the carrier frequency at which a particular different one of said incoming branches is adapted to operate with the carrier frequency at which said outgoing branch is adapted to operate, and means for preventing unmodulated matching frequencies from passing out over said outgoing branch.

44. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel, an automatic switch at said switching station having active terminals and passive terminals, a normally open extension from one of said channels to the active terminals and from the other channel to the passive terminals of said switch, means for operating said switch to bring said active terminals into engagement with said passive terminals, and means actuated in said operation of the automatic switch for closing the normally open extension from each channel to the respective active and passive terminals of the automatic switch.

45. A carrier channel switching system including a line having a carrier channel superposed thereon, an automatic switch having a set of active terminals and a plurality of sets of passive terminals, other lines having carrier channels superposed thereon associated with said sets of passive terminals, a normally open extension from the channel of said first mentioned line to said active terminals, means for moving said set of active terminals, to cause them to connect with one of said sets of passive terminals, and a switch actuated as a result of the operation of said automatic switch for closing said channel extension to said set of active terminals.

46. A carrier channel interconnecting system including a plurality of lines each having a superposed high frequency channel, automatic switching mechanism for interconnecting said lines, normally open extensions from said channels to the terminals of said automatic switching mechanism to connect the channels of any two of said lines for closing the normally open extensions of said two last mentioned channels to automatic switch terminals.

47. A carrier channel interconnecting system including a plurality of lines each having a high frequency channel superposed thereon, automatic switching mechanism for interconnecting said channels comprising a set of active terminals and multiple sets of passive terminals for each channel, means controlled over each channel for moving the active set of terminals of that channel into

engagement with one of the passive sets of terminals of any of the other channels, and means for keeping said channels disconnected from their respective active and passive sets of terminals until such engagement has been effected by said automatic switching mechanism.

48. A carrier channel interconnecting system including a plurality of lines each having a carrier channel superposed thereon, automatic switching mechanism for interconnecting said channels, each channel having a set of active terminals and multiple sets of passive terminals on said switching mechanism, a normally open extension from each channel to its set of associated active terminals and another normally open extension from each channel to its associated multiple sets of passive terminals, and means made operative when said automatic switching mechanism operates to connect a calling channel with a called channel for closing the normally open extension of the calling channel to its associated set of active terminals and the normally open extension of the called channel to its associated multiple sets of passive terminals.

49. A carrier channel interconnecting system including a plurality of lines each having a carrier channel superposed thereon, each of said channels having two normally open extensions, one of said extensions being adapted to be employed when the channel is calling and the other extensions being adapted to be employed when the channel is called, and means made operative in the establishment of connection with any of said channels over either of said extensions for maintaining open the other of said extensions.

50. A carrier channel interconnecting system including a line having a carrier channel superposed thereon, two extensions of said carrier channel, means for establishing connections with said channel by way of one of said extensions when the channel is calling and by way of the other of said extensions when the channel is called, and means made operative in establishing connection by way of either of said extensions for maintaining the other extension disconnected from said channel.

51. A carrier channel interconnecting system including a line having a carrier channel superposed thereon, automatic switching mechanism for establishing connection between the channel of said line and the channels of other like lines, said automatic switching mechanism having active terminals and passive terminals, an extension of said channel for connecting the same with the active terminals of said switching mechanism, an extension for connecting said channel with the passive terminals of said switching mechanism, and

means for closing either of said extensions and at the same time preventing the closure of the other extension.

52. A carrier channel interconnecting system including a plurality of high frequency channels each having a plurality of interconnecting extensions, automatic switching mechanism for interconnecting any two of said channels by way of one of said interconnecting extensions of each, and means actuated in the establishment of such interconnection for maintaining disconnected the other extensions of each of the interconnected channels, whereby cross-talk between channels is minimized.

53. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and outgoing branch at the switching station, automatic switch mechanism for connecting the incoming branch of each channel with the outgoing branch of the other channel, and a responsive device operatively associated with the incoming branch of each channel and controlled from the distant end of said channel for governing the interconnecting operation of said automatic switch mechanism.

54. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, automatic switch mechanism for connecting the incoming branch of each channel with the outgoing branch of the other channel, a responsive device operatively associated with the incoming branch of each channel for governing the interconnecting operation of said automatic switch mechanism, and means actuated in the operation of said automatic switch mechanism under the control of the responsive device of one of said channels for rendering ineffective the responsive device of the other channel.

55. In a carrier wave communicating system, a switching station, two lines entering said station, each of said lines having a superposed carrier channel provided with an incoming branch and an outgoing branch at the switching station, automatic switch mechanism for connecting the incoming branch of each channel with the outgoing branch of the other channel, a responsive device operatively associated with the incoming branch of one of said channels for controlling the operation of said automatic switch mechanism, means for energizing the outgoing branch of each of said channels, and means under the control of said responsive device for making operative said outgoing branch energizing means of each of the connected channels.

56. In a carrier wave communicating system, a line having a carrier channel superposed thereon, means for impressing upon said channel a composite carrier frequency band including a communicating modulation component and a controlling modulation component, and means for switching said channel controlled by said controlling modulation component.

57. In a carrier wave communicating system, a line having a carrier channel superposed thereon, means for impressing upon said channel at one end thereof a composite carrier frequency band including a voice modulation component and a controlling modulation component, channel switching mechanism at the other end of said channel, and means responsive to said controlling modulation component for controlling the operation of said channel switching mechanism.

58. In a carrier wave communicating system, a line having a carrier channel superposed thereon, means for impressing upon said channel a composite carrier frequency band including a communicating modulation component and a controlling modulation component, an automatic switch at the distant end of said channel, other lines having superposed carrier channels terminating upon said switch, and means responsive to said controlling modulation component for controlling the operation of said switch to interconnect the channel of said first mentioned line with a channel of any desired one of said last mentioned lines.

59. In a carrier wave communicating system, a line having a carrier channel superposed thereon, means for impressing upon said channel a composite carrier frequency band including a communicating modulation component and a controlling modulation component, other carrier channels, an automatic switch, and means responsive to said controlling modulation component for operating said switch to interconnect said first mentioned channel with any desired one of said other channels and for thereafter operating said automatic switch to disconnect said channels.

60. In a carrier wave communicating system, two terminal stations and an intermediate station, a line extending from each terminal station to said intermediate station, each of said lines having a carrier channel superposed thereon, means for impressing upon the channel of one of said lines at the terminal station thereof a composite carrier frequency band including a voice modulation component and a controlling modulation component, a signal at the terminal station of the other line, switching mechanism at said intermediate station for interconnecting said channels and transferring said frequency band from one to the other, means

responsive to said controlling modulation component for controlling the operation of said switching mechanism, and other means responsive to said controlling modulation component for controlling said signal at the distant station.

61. In a carrier wave communicating system, two lines each extending from a terminal station to an intermediate station and each line having a carrier channel superposed thereon, switching mechanism at said intermediate station for interconnecting the channels of said lines, means at one of said stations for impressing upon the channel of the associated line a composite carrier frequency band including a voice modulation component and a controlling modulation component, means at said intermediate station responsive to said controlling modulation component for controlling the operation of said switching mechanism, and means at the station of said other line selectively responsive to said voice modulation and said controlling modulation components.

62. In a carrier wave communicating system, a carrier line extending from a terminal station to a switching station, means at said terminal station for impressing upon said line a plurality of different carrier waves each modulated with a frequency band including a voice frequency component and a controlling frequency component, other carrier lines centering at said switching station, and automatic switching mechanism at said switching station responsive to the controlling frequency modulation of any of said carrier waves for establishing connection to cause the speech frequency and controlling frequency modulations of the corresponding carrier wave to be impressed upon any desired one of said other lines as modulations of the carrier wave of that line.

63. In a carrier wave communicating system, a carrier line extending from a terminal station to a switching station, means at said terminal station for impressing upon said line a carrier wave modulated with a frequency band including a communicating frequency component and a controlling frequency component adjacent thereto in the frequency scale, another carrier line extending from said switching station to a terminal station, and automatic switching mechanism at said switching station responsive to the controlling frequency modulation of said carrier wave for impressing said communicating frequency and accompanying controlling frequency modulation components upon said other line as modulations of the carrier wave of that line.

64. In a carrier wave communicating system, a calling station, a called station and an intermediate station, a carrier line extending to said intermediate station from each of said other stations, means at said calling

station for impressing upon the line extending therefrom a carrier wave modulated with a frequency band including a voice frequency component and a controlling frequency component adjacent thereto in the frequency scale, automatic switching mechanism at said intermediate station for interconnecting said carrier lines and transferring said speech frequency and accompanying controlling frequency modulation components from said calling line to said called line as modulations of the carrier wave of the called line, and means at said intermediate station responsive to said controlling modulation component for controlling the operation of said switching mechanism.

65. In a carrier wave communicating system, a carrier line extending from a terminal station to a switching station, means at said terminal station for impressing upon said line a carrier wave modulated with a frequency band including a communicating frequency component and a controlling frequency component adjacent thereto in the frequency scale, a plurality of other carrier channels centering in said switching station, means for transferring to any desired one of said other carrier channels said communicating frequency and accompanying controlling frequency modulation components as modulations of the carrier wave of the connected channel, and mechanism at the distant end of each of said channels responsive to said transferred controlling frequency modulation component.

66. In a carrier wave communicating system, a plurality of high frequency channels, means for interconnecting said channels, means for impressing upon one of said channels a frequency band produced by the modulation of the carrier wave of said channel by a voice frequency component and a controlling frequency component adjacent thereto in the frequency scale, means made operative in the interconnection of said channel with any of said other channels for transferring said composite frequency band as a modulation of the carrier wave of said other channel, means at the distant end of said other channel for reproducing and separating said voice frequency component and said controlling frequency component, and mechanism at the distant end of said other channel responsive to said controlling frequency component.

67. In a carrier wave communicating system, a plurality of high frequency channels, means for producing and transmitting over said channels a plurality of carrier waves each modulated with a frequency band including a voice frequency component and a controlling frequency component adjacent thereto in the frequency scale, means for interconnecting any of said channels with any other of said channels and transferring

thereto the corresponding voice frequency and controlling frequency modulation components as modulations of the carrier wave of said other channel, and means at the distant end of said other channel for separating said voice frequency and communicating frequency components and utilizing said controlling frequency component to control responsive apparatus thereat.

68. In a carrier wave communicating system comprising a plurality of high frequency channels and means for interconnecting any two of said channels, means for producing and transmitting over said channels a plurality of communication modulated carrier waves each accompanied by a controlling frequency modulation of said carrier wave, and means made operative in the operation of said interconnecting means for transferring the communication frequency modulation and its accompanying controlling frequency modulation from any one of said channels to any other of said channels.

69. In a carrier wave communicating system having a plurality of stations and a plurality of carrier channels for interconnecting said stations, the method of channel control which consists in producing and associating at one station a communicating frequency component and a controlling frequency component as a single frequency band, transmitting said frequency band as a modulation of the carrier wave of a series of channels uniting said station with a distant station and separating and utilizing said controlling frequency component for controlling apparatus of the associated channel at the distant station and at an intermediate point.

70. In a carrier wave communicating system having a plurality of stations and a plurality of carrier channels for interconnecting said stations, the method of channel control which consists in producing and associating at one station a communicating frequency component and a controlling frequency component in the communicating frequency range as a single frequency band, transmitting said frequency band as a modulation of the carrier waves of a series of channels uniting said station with a distant station, separating said communicating and controlling frequency components at the distant station, utilizing said communicating frequency component for communication purposes, and utilizing said controlling frequency component for controlling apparatus of the associated channel at the distant station.

71. In a carrier wave communicating system having a plurality of terminal stations, a common switching station and a plurality of carrier channels for interconnecting said stations, the method of channel control

which consists in producing and associating at one station a communicating frequency component and a controlling frequency component as a single frequency band, transmitting said frequency band as a modulation of the carrier wave of a channel extending to said switching station, switching said single frequency band to any desired one of said channels extending to another station and transmitting said frequency band as a modulation of the carrier wave of that channel, separating the frequency components of said band at the distant station, and utilizing said controlling frequency component for controlling apparatus of the associated channel at said distant station.

72. In a carrier wave communicating system having a plurality of stations and a plurality of carrier channels for interconnecting said stations, the method of channel control which consists in producing and associating at one station a communicating frequency component and a controlling frequency component as a single frequency band, transmitting said frequency band as a modulation of the carrier wave of a channel extending from said station, utilizing said controlling frequency component for effecting the connection of the distant end of said channel with another channel, transmitting said single frequency band as a modulation of the carrier wave of said last mentioned channel, and separately utilizing said frequency components of the band at said other station.

73. In a carrier wave communicating system, a line having a carrier channel superposed thereon, means including a telephone extension circuit for impressing upon said channel a composite carrier frequency band including a voice modulation component and a controlling modulation component, means associated with said telephone extension circuit for controlling said controlling modulation component, and means for switching the other end of said channel controlled through the medium of said controlling modulation component.

74. In a carrier wave communicating system, a line having a carrier channel superposed thereon, means including a telephone extension circuit for impressing upon said channel a composite frequency band including a voice modulation component and a controlling modulation component, a switch associated with said telephone extension circuit for causing intermissions of said controlling modulation component, and a channel extending switch at the other end of said channel selectively responsive to said intermissions of said controlling modulation component.

75. In a carrier wave communicating system, a line having a carrier channel superposed thereon, means including a telephone

extension circuit for impressing upon one end of said channel a composite frequency band including a voice modulation component, and a controlling modulation component, means associated with said telephone extension circuit for causing intermissions of said controlling modulation component, a switch upon which the other end of said channel terminates other groups of channels terminating upon said switch, means responsive to said intermissions of the controlling modulation component for operating said switch to bring said channel into operative relation with one of said groups of channels, and means automatically operated to extend said channel to an idle channel of the selected group.

76. In a carrier wave communicating system, a line having a carrier channel superposed thereon, a connection terminal for said channel, said connection terminal having line contacts and a local contact, a telephone extension circuit adapted to be brought into operative relation with said channel at said connection terminal thereof, a local circuit adapted to be completed by way of the local contact of said channel terminal in establishing connection therewith, means for impressing a carrier wave upon said channel, means made operative by the closure of said local circuit for modulating said carrier wave with a controlling frequency, a supervisory signal associated with said telephone extension circuit, a relay responsive to a control frequency modulation impressed upon said channel at the distant end thereof, and means under the control of said relay and acting through the medium of said local conductor for controlling said signal.

77. In a carrier wave communicating system, a line having a carrier channel superposed thereon, said channel having a transmitting branch and a receiving branch, means including a telephone extension circuit and a channel connection switch for establishing connection with said channel, a local circuit closed in the establishment of such connection, means for impressing a controlling frequency modulation upon the transmitting branch of said channel, a relay associated with the receiving branch of said channel and responsive to a controlling frequency modulation impressed upon said channel at the distant end thereof, a signal associated with said telephone extension circuit, and means made operative through the medium of said local conductor in establishing connection with said channel at the connection switch thereof for operating said controlling frequency impressing means and for placing said supervisory signal under the control of said receiving branch relay.

78. In a carrier wave communicating system, two stations, a carrier channel connec-

tion between said stations, a telephone extension circuit at each station with means for establishing connection between said extension circuit and the corresponding end of said carrier channel, a supervisory signal associated with each of said extension circuits, a local circuit at each station closed in establishing connection with said channel, and means made operative over said local circuit for applying a controlling frequency modulation to said carrier channel at the associated station and for placing the supervisory signal of that station under the control of the controlling frequency modulation applied at the other station.

79. In a carrier wave communicating system, two stations, a carrier channel connection between said stations, a telephone extension circuit at each station with means for establishing connection between said extension circuit and the corresponding end of said carrier channel, a supervisory signal associated with each of said extension circuits, a local circuit at each station closed in establishing connection with said channel, means made operative over said local circuit for applying a controlling frequency modulation to said carrier channel at the associated station and for placing the supervisory signal of that station under the control of the controlling frequency modulation applied at the other station, a switch at each station operating over said local circuit for causing intermissions of said controlling frequency modulation applied at that station, and channel controlling means responsive to such intermissions of the control frequency modulation.

80. In a carrier wave communicating system, a switching station, a plurality of lines entering said station each of said lines having a plurality of carrier channels superposed thereon, an interconnecting switch having a set of brushes serving as the terminals of the carrier channel of one of said lines and a plurality of sets of stationary contacts serving as terminals of the carrier channels of said other lines, said sets of stationary contacts being arranged in a single series adapted to be traversed by a uni-directional movement of the associated switch brushes and being divided into groups corresponding with the several channels of each of said other lines, means controlled over the carrier channel corresponding to the movable brushes of said switch for advancing said brushes to a particular desired group of stationary contacts, and means controlled by the busy or idle condition of the channels terminating upon the stationary contacts of the selected group for controlling the movement of said movable brushes into engagement with the stationary contacts of an idle channel of said group.

81. In a carrier wave communicating sys-

tem, an automatic interconnecting switch comprising a single extended series of sets of stationary contacts divided into groups, a set of movable brushes adapted to be moved uni-directionally to traverse said stationary contacts, electrically controlled mechanism for moving said set of brushes, a carrier channel terminating on said movable brushes, groups of carrier channels terminating upon the sets of stationary contacts constituting the aforesaid groups, means controlled from the distant end of said first mentioned carrier channel for causing said moving means to advance said brushes to a particular desired group of sets of stationary contacts, and means controlled by the busy or idle condition of the channels terminating upon the stationary contacts of the selected group for causing said moving means further to advance said brushes into engagement with the stationary contacts of an idle channel of the selected group.

82. In a carrier wave communicating system, a switching station, a plurality of lines entering said station, each of said lines having a plurality of carrier channels superposed thereon, an interconnecting switch for each channel of each line, each of said switches having a set of brushes serving as the terminals of the corresponding carrier channel and a plurality of sets of stationary contacts serving as terminals of the carrier channels of said other lines, said sets of stationary contacts of each switch being arranged in a single series adapted to be traversed by a uni-directional movement of the associated switch brushes, and said interconnecting switches of the various channels being placed side by side with corresponding sets of stationary contacts directly opposite and in line with each other, and straight short bands of shielded conductors serving as multiple connections between corresponding sets of stationary contacts of the various switches.

83. In a carrier channel switching system for the interconnection of a plurality of carrier channels, an interconnecting switch for each channel, each switch having a set of brushes serving as the terminals of the corresponding channel and a plurality of sets of stationary contacts serving as terminals of the other channels, said sets of stationary contacts of each switch being arranged in a single series adapted to be traversed by a uni-directional movement of the associated switch brushes, and said interconnecting switches of the various channels being placed close together side by side and with the stationary sets of contacts representing corresponding channels in line and directly opposite each other, and groups of conductors shielded from each other extending across the series of sets of stationary contacts of the various switches and each group consti-

tuting the multiple wiring of corresponding sets of stationary contacts of a different one of said channels, whereby interference between the high frequency currents of said channels is minimized.

84. In a transmission network comprising a plurality of multiplex transmission lines each employing a plurality of carrier frequency channels, each channel on a line operating at a different frequency level from the other channels on the same line, means to interconnect any channel of one line selectively with any channel of another line, and to repeat between the connected channels at carrier frequency level, said interconnecting means including means to shift the frequency level in passing from an incoming channel to an outgoing channel of a different frequency level.

85. In combination, an incoming carrier transmission channel, a plurality of outgoing carrier transmission channels each employing a different carrier frequency, and means for operatively associating said incoming channel with any desired one of said outgoing channels and for directly repeating into the associated outgoing channel at carrier frequency level.

86. In combination, an incoming carrier transmission channel, a plurality of outgoing carrier transmission channels each employing a different carrier frequency, means for operatively associating said incoming channel with any desired one of said outgoing channels for through repeating

into the outgoing channel so associated, and means for shifting the incoming carrier frequency to the frequency employed for transmission over the associated outgoing channel.

87. In multiplex carrier transmission employing systems each having a plurality of separate channels utilizing different carrier frequencies, the method of connecting an incoming channel of one system with an outgoing channel of another system utilizing a different carrier frequency, comprising modulating the incoming carrier wave by a plurality of matching-frequency waves to convert the frequency of the incoming carrier wave to such values as are utilized by outgoing channels of the system to be connected with, and selecting from the resulting modulated waves the wave of the frequency utilized by the desired outgoing channel.

88. The method of connecting a carrier channel of a multiplex carrier system with a carrier channel of a desired other multiplex carrier system comprising directly selecting the desired other multiplex system, automatically selecting a channel of the selected system, and automatically shifting the frequency of the carrier wave received over one of two channels to be connected to the frequency employed by the other of the two channels.

In witness whereof, I hereunto subscribe my name this 26th day of February A. D., 1923.

EDWIN H. SMYTHE.