

April 16, 1929.

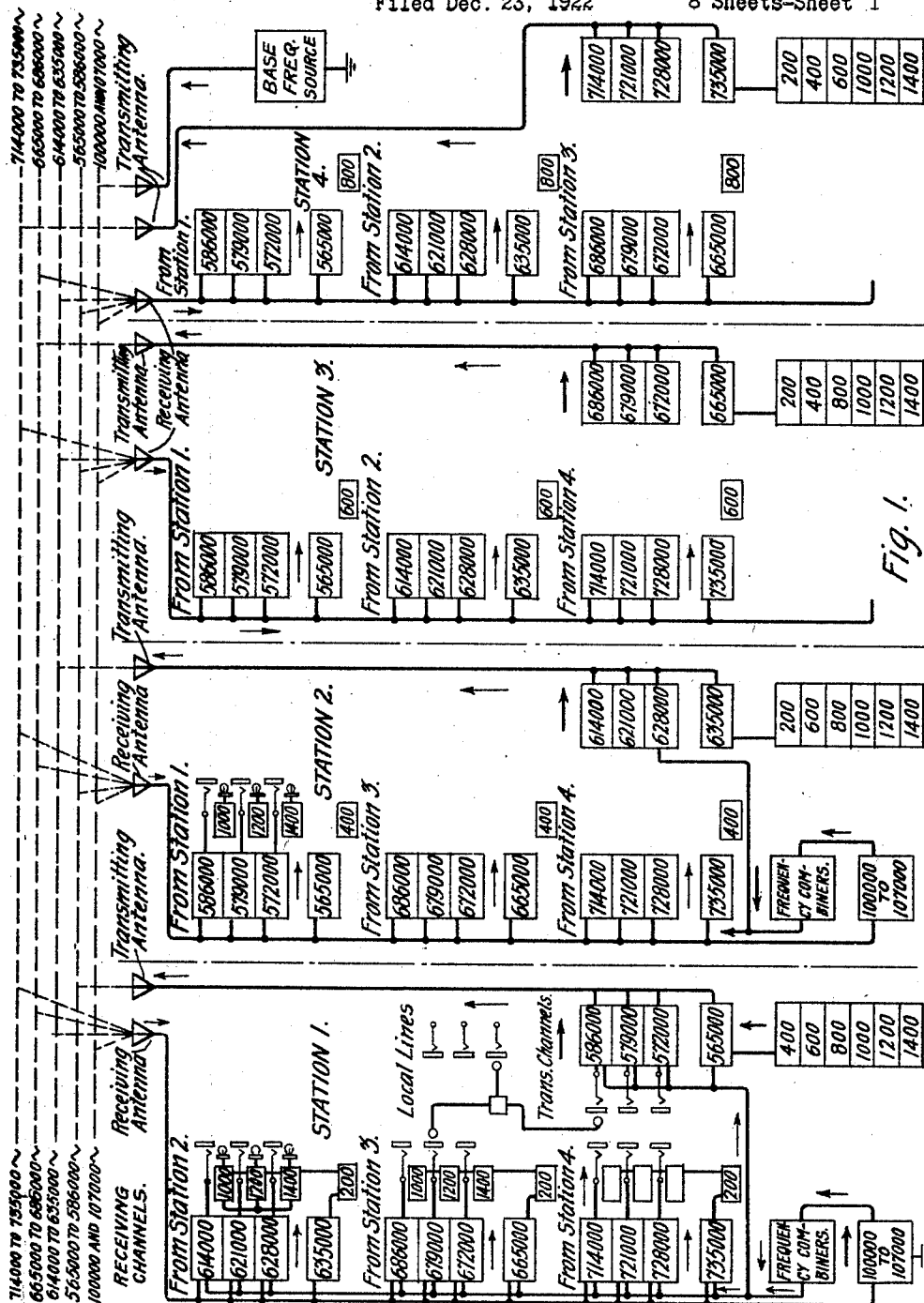
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1,709,044

MULTIPLEX CARRIER WAVE COMMUNICATION

Filed Dec. 23, 1922

8 Sheets-Sheet 1



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April 16, 1929.

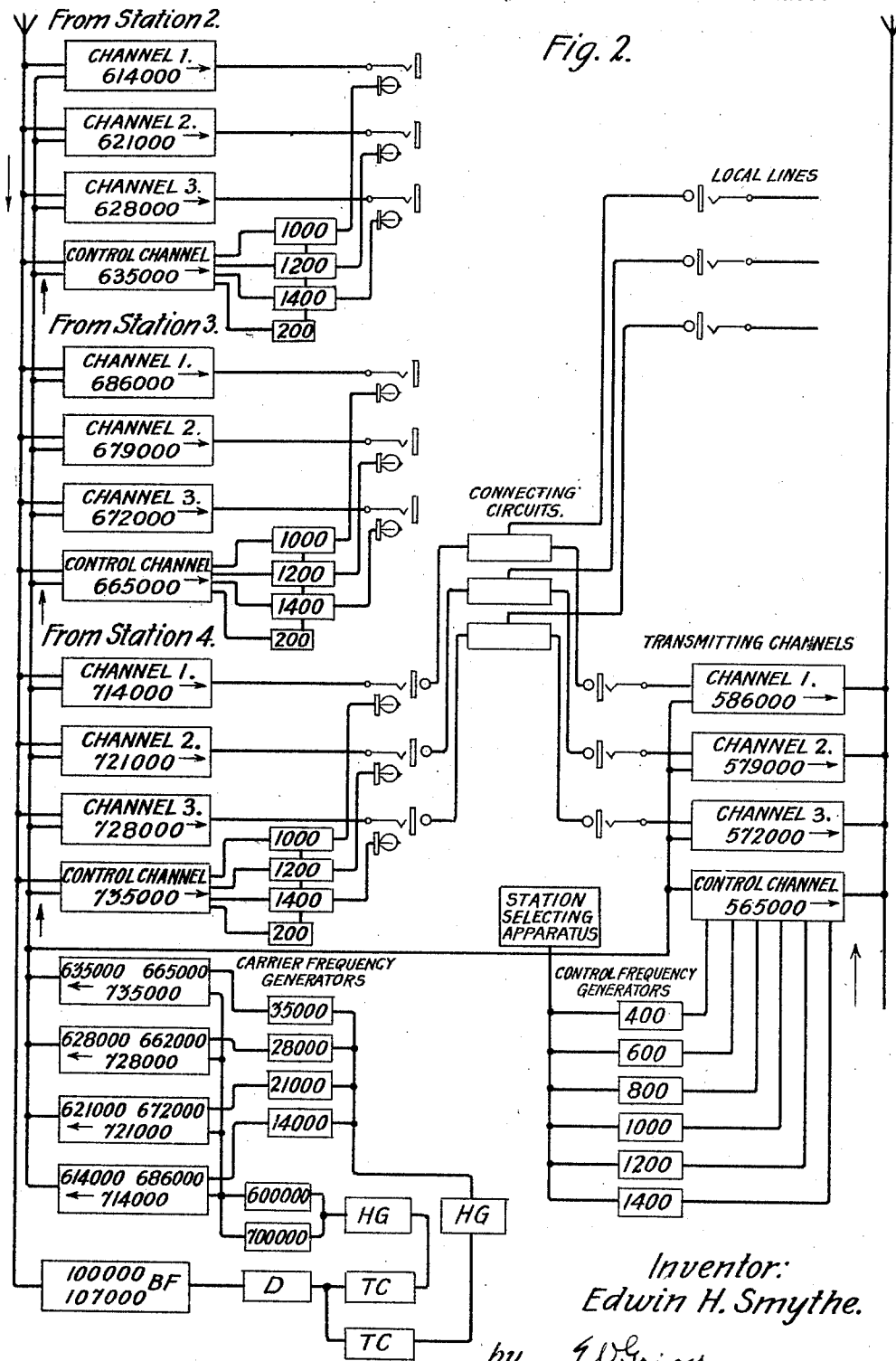
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1,709,044

MULTIPLEX CARRIER WAVE COMMUNICATION

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8 Sheets-Sheet 2



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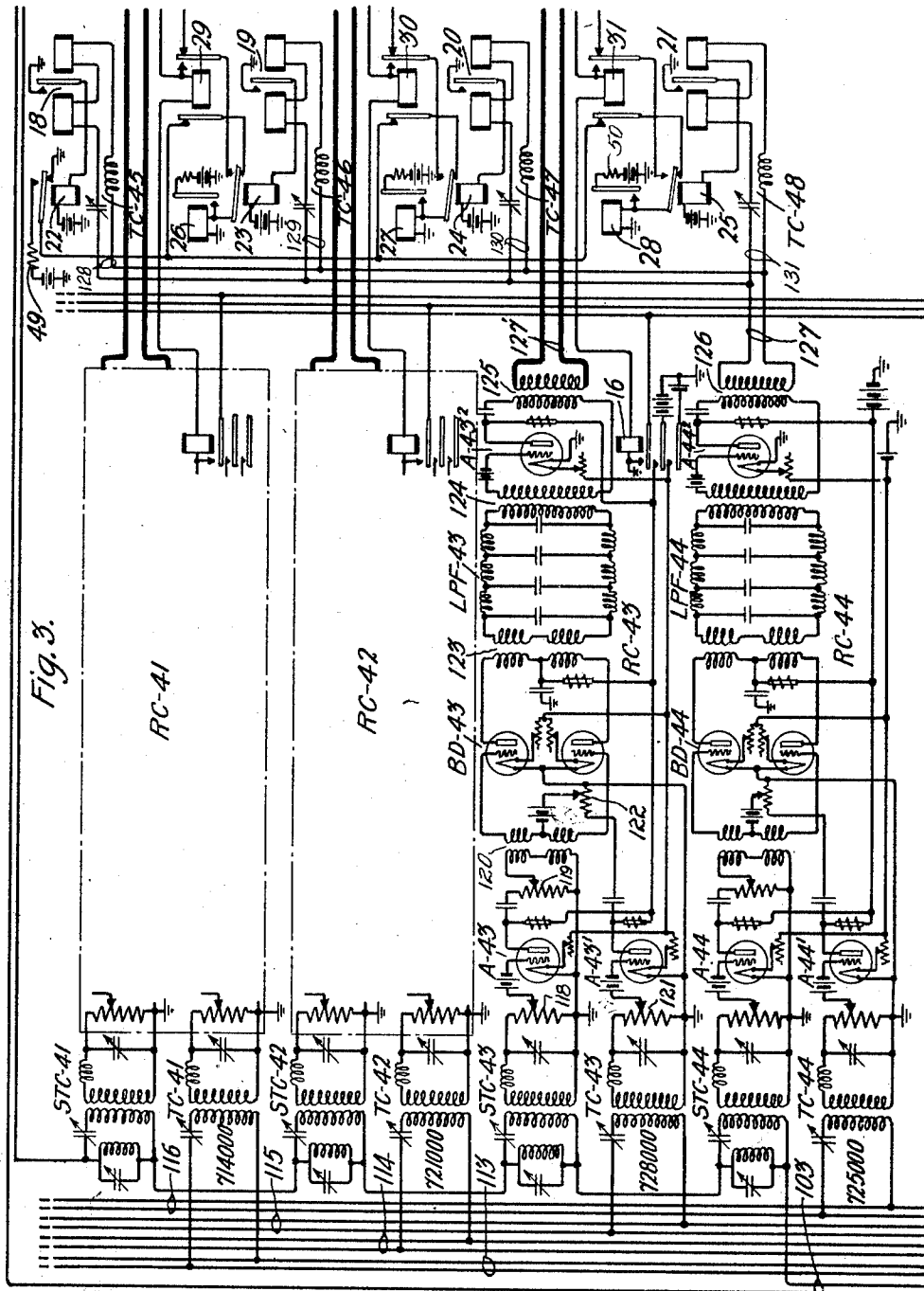
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MULTIPLEX CARRIER WAVE COMMUNICATION

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8 Sheets-Sheet 3



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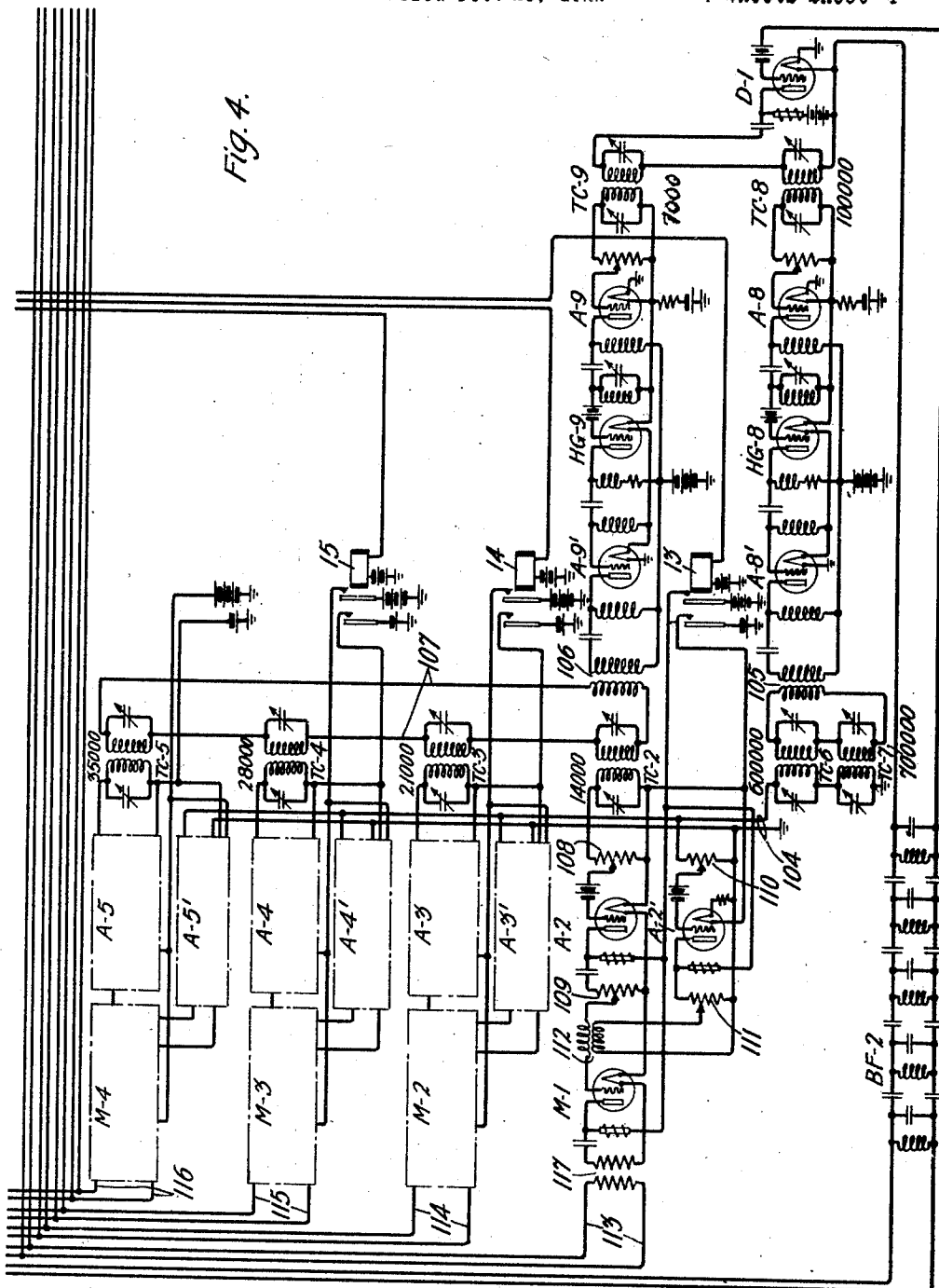
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MULTIPLEX CARRIER WAVE COMMUNICATION

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8 Sheets-Sheet 4



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MULTIPLEX CARRIER WAVE COMMUNICATION

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8 Sheets-Sheet 5

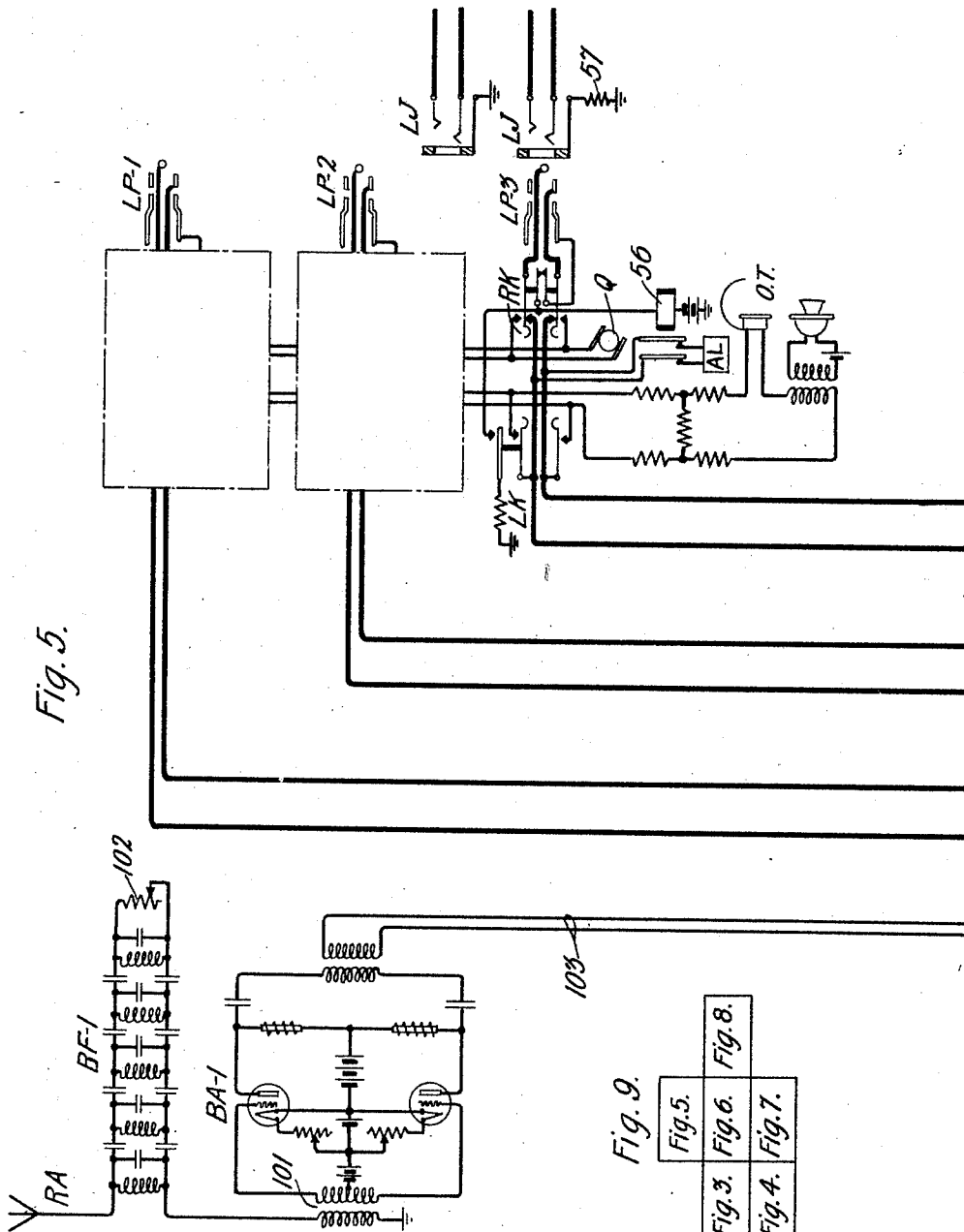


Fig. 5.

Fig. 5.	Fig. 8.
Fig. 3.	Fig. 6.
Fig. 4.	Fig. 7.

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MULTIPLEX CARRIER WAVE COMMUNICATION

Filed Dec. 23, 1922

8 Sheets-Sheet 6

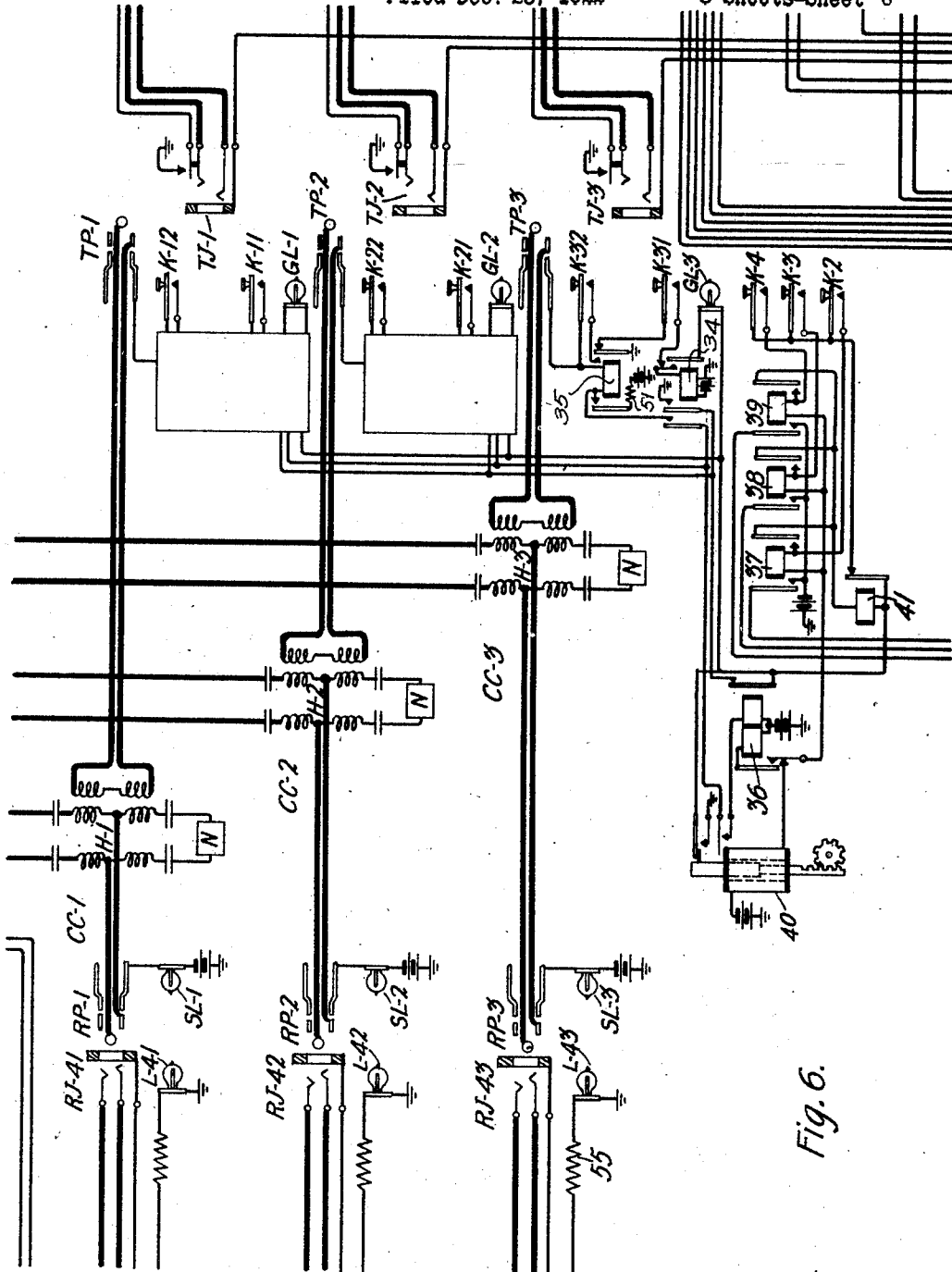


Fig. 6.

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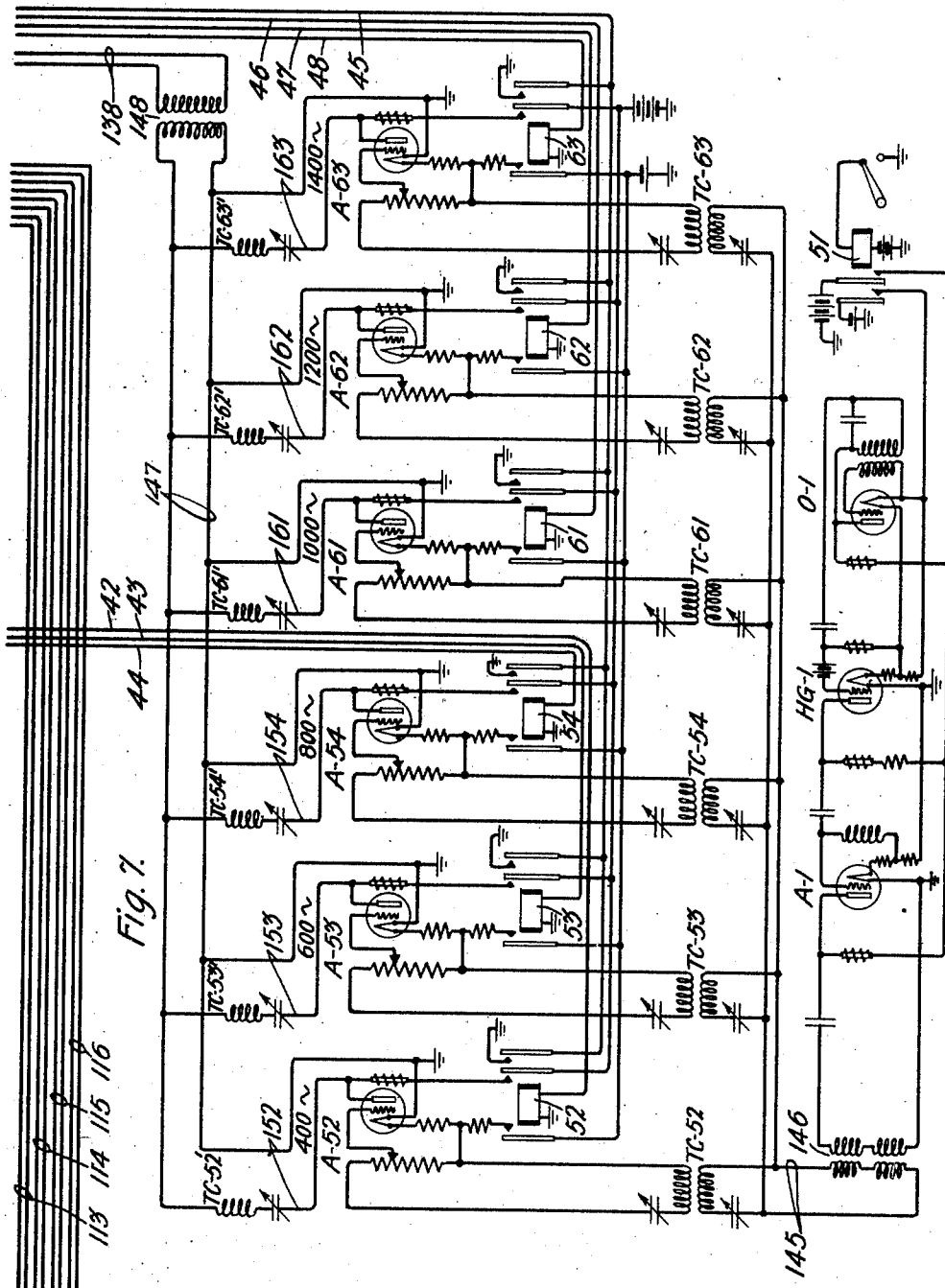
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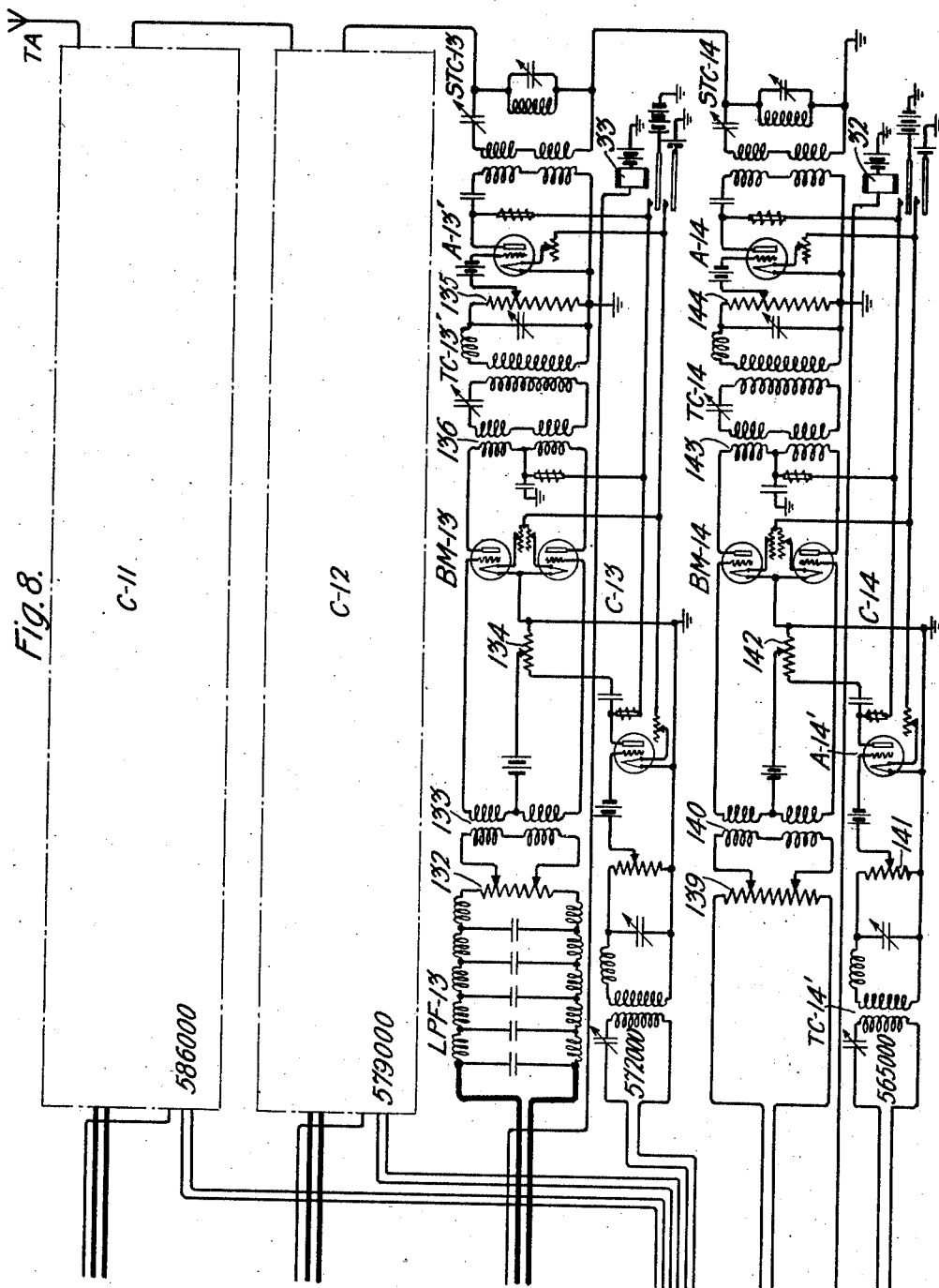
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MULTIPLEX CARRIER WAVE COMMUNICATION

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8 Sheets-Sheet 8



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UNITED STATES PATENT OFFICE.

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MULTIPLEX CARRIER-WAVE COMMUNICATION.

Application filed December 23, 1922. Serial No. 608,766.

This invention relates to multiplex carrier wave communication, and more particularly to radio toll links for connecting ordinary telephone and telegraph systems for two-way communication.

Carrier wave transmission is accomplished by means of high frequency oscillations termed "carrier waves" which are modified or modulated in accordance with the signals to be transmitted. Where two ordinary conductive communication circuits are to be connected by means of a carrier wave link for simultaneous two-way transmission, each of the conductive communication circuits is operatively associated with carrier transmitting and carrier receiving apparatus. The carrier transmitting apparatus serves to modulate a carrier wave in accordance with the speech or signal to be transmitted and to transmit the energy of the modulated wave over a carrier circuit or to radiate it into space. The carrier receiving apparatus selectively receives carrier waves modulated at a distant station and demodulates the received waves to produce low frequency currents corresponding to the low frequency speech or signal currents by which these carrier waves were modulated at the distant station. Where a plurality of communications are to be effected simultaneously, the carrier waves are assigned such frequencies as to be non-interfering one with another; or in other words each of a plurality of carrier wave transmitting apparatus is so organized as to produce, and each corresponding carrier wave receiving apparatus is so organized as to receive, a particular frequency of carrier wave to the exclusion of carrier waves produced and received by the other transmitting and receiving apparatus. In a system thus organized there may be as many simultaneously proceeding and non-interfering communications as there are non-interfering carrier waves with apparatus for producing and receiving them.

The apparatus which is used to transmit and receive by means of any one high frequency or carrier 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 channel, or a high frequency communication channel.

In the present invention the selective properties of high frequency or carrier wave pro-

ducing, transmitting and receiving devices are utilized to provide a system for operatively relating a plurality of toll centers or stations through the medium of carrier wave links in such a way that there may be established between these stations a plurality of simultaneous and non-interfering intercommunications without any restriction as to whether the connections which may simultaneously exist with each station are incoming or outgoing with respect to that station. In other words the system is so organized that each station may be the calling station with respect to certain of the connections and at the same time the called station with respect to others of the connections that simultaneously exist; and each station may employ its entire radio or high frequency trunking facilities simultaneously in either calling one or more of the other stations, or in being called by one or more of the other stations, or in calling some and being called by others, in whatever way traffic conditions may happen to require and without interference of one communication with another. This may be, and in the present embodiment of the invention is, accomplished by means of a single pair of antennae at each station.

In the particular embodiment of the invention to be specifically described hereinafter, four carrier wave stations will be assumed to comprise the system, but it is to be understood that the system may have any desired number of stations and that these stations may be provided by merely duplicating and extending the arrangements of the four stations described.

In the present embodiment of the invention each radio toll center or station is assigned a certain number of carrier waves or frequencies for transmitting purposes; and each station has available for use as many receiving channels, preferably permanently organized as there are carrier waves adapted to be transmitted by the other distant stations collectively. Each of these receiving channels at each station is so organized as to be selectively responsive to a different one of the carrier waves that the other distant stations are arranged to transmit. At none of the stations are there receiving channels responsive to the particular carrier waves transmitted from that station; and further to prevent the locally transmitted frequencies from interfer-

ing with the corresponding receiving system, the receiving antenna system at each station includes a device, which may be in the form of a band filter, that acts to divert the received energy of the locally transmitted frequencies from the receiving branches of the receiving antenna system and to dissipate this energy, if desired, in suitable resistance elements or an artificial line.

Of the carrier wave transmitting channels with which each station is provided, one serves, in the present embodiment of the invention, as a channel for transmitting a wave which is modulated to control the signals incident to the establishment and supervision of the connections, while the other transmitting channels are employed to transmit the waves that are modulated to convey the speech or communicating currents. At each station the group of communication transmitting channels and the several groups of communication receiving channels, one group for receiving the carriers from each of the distant stations, are conveniently terminated in springjacks with which a number of plug-terminated connecting cord circuits cooperate to associate, as desired, a transmitting channel with a receiving channel to constitute a radio link for two-way communication, and to connect the two-way radio trunk thus formed with any desired one of a number of springjack terminated local lines.

As each of the stations of the system has certain frequencies which it employs in transmitting, the receipt of the frequency assigned to a particular station definitely identifies that station as the calling station; and the modulation of the calling station's controlling or calling frequency by lower frequencies in various combinations serves to identify the particular one of the distant stations that is being called and the particular one of its communicating channels that the calling station has selected for establishing the connection. The combination of lower frequencies which the calling station employs to modulate its calling or controlling carrier wave causes the display at the particular station that is being called of a signal associated with the particular communication receiving channel corresponding to the transmitting communication channel which the calling station has selected for use. The signals associated with the corresponding receiving channels at the stations other than the one being called are not displayed. The establishment of the two-way radio link between the calling and called stations is completed by the called station selecting and connecting with one of its available communicating channels, and indicating the selected channel to the calling station by modulating its own calling or controlling carrier wave with the proper combination of

lower frequencies to cause the display of the corresponding signal at the calling station.

In the present embodiment of the invention two base frequencies generated in any convenient manner and transmitted from any convenient point are received at each of the stations; and harmonics generated from these base frequencies are combined to produce carrier waves for modulation by speech or controlling frequencies in the transmitting channels of each station, and for the demodulation of the modulated carrier waves in the receiving channels at each station. The combination of the base frequencies at each station is effected in such a manner that each of the combining units serves to produce a number of the desired carrier and demodulating waves as a plurality of readily separable side bands of the combined harmonics of the base frequencies.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention, both as to its organization and mode of operation, together with the particular objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, which constitute a disclosure of the preferred embodiment of the invention. In the accompanying drawings, Fig. 1 illustrates in schematic form a carrier wave communication system comprising four stations organized for general intercommunication through the medium of a plurality of non-interfering carrier waves; Fig. 2 illustrates schematically, but in greater detail, the organization of one of the stations, station 1, of Fig. 1; and Figs. 3 to 8, inclusive, when arranged as indicated in Fig. 9, show in detail as much of the circuits of one of the stations as is necessary to enable the wiring and organization of the entire system to be understood.

Referring first to Fig. 1, this schematic drawing is merely intended to show an outline or skeleton of the general arrangement and relationship of four stations adapted for interconnection through the medium of high frequency or carrier waves in accordance with the plan of the present invention. These stations are indicated in the present instance as radio stations, that is, stations between which interconnection and intercommunication are established through the medium of unguided high frequency waves transmitted through space. In the specification that follows, the high frequency stations will occasionally be referred to as radio stations; but it is to be understood that the use of this term is not intended to limit the invention to exclude a system the stations of which are operatively related through the medium of high frequency

waves guided upon conductors, as the stations of the organization disclosed may be of this character. Furthermore, in Fig. 1 as well as in the other figures of the drawing, definite frequency values are indicated as being assigned to the carrier waves, to the base frequencies and to the lower controlling frequencies with which the calling or controlling carrier wave of each station is adapted to be modulated. It should be understood, however, that these definite and specific frequency values are used merely for the purpose of clarity in the disclosure and that a wide diversity of frequency values may be substituted, as desired, for the purely typical and illustrative values that are herein employed without in any way departing from the spirit of the invention.

In the typical arrangement indicated in outline in Fig. 1 there are four stations, station 1, station 2, station 3 and station 4, respectively; and in addition thereto there is illustrated a transmitting station designated "Base frequency source" which may be assumed to be any convenient location,—at some separate point, at any one of the four stations indicated, or, if desired, may have its function served by the transmitting antenna of one of the four stations. Associated with the base transmitting antenna are oscillation generators of any suitable type which act to produce two base frequencies, in the present instance 100,000 and 107,000 cycles per second, and to transmit these base frequencies through the base transmitting antenna to the other stations of the system. The frequencies that are employed in the system and which the stations use for interconnection are indicated in Fig. 1 by a number of broken lines. The lowest of these broken lines is designated 100,000 and 107,000 cycles. The other four broken lines are designated respectively 565,000 to 586,000, 614,000 to 635,000, 665,000 to 686,000 and 714,000 to 735,000. The broken line connection of the transmitting antenna of each of the four stations to a particular one of the four last mentioned broken lines indicates that the corresponding transmitting antenna is adapted to utilize for transmitting purposes the particular band of frequencies of the broken line with which it has connection. Thus station 1 is represented as transmitting on the 565,000 to 586,000 band, station 2 on the 614,000 to 635,000 band, station 3 on the 665,000 to 686,000 band, and station 4 on the 714,000 to 735,000 band.

The broken line connections of the receiving antenna at each station with the horizontal broken lines indicate the particular frequency bands to which the receiving systems of the various stations are adapted to be responsive. As may be seen by reference to Fig. 1 the receiving system of each station is responsive to the base frequencies, and also to all of the other frequency bands excepting

that which is adapted to be propagated from the associated transmitting antenna.

The total frequency range assigned to each station for transmitting purposes is divided, in this particular embodiment of the invention, into four frequency bands, one of which is employed for calling or signal controlling purposes and the other three of which are used for communication or speech transmission. As indicated in Fig. 1, station 1 transmits modulated carrier waves of 586,000, 579,000 and 572,000 cycles respectively for communicating and a modulated wave of 565,000 cycles for signal controlling; station 2 transmits carrier waves of 614,000, 621,000 and 628,000 cycles respectively for communicating and a wave of 635,000 cycles for controlling; station 3 transmits waves of 686,000, 679,000 and 672,000 cycles respectively for communicating and a wave of 665,000 cycles for controlling; and station 4 transmits waves of 714,000, 721,000 and 728,000 cycles respectively for communicating and a wave of 735,000 for controlling. The receiving antenna system of each station in the embodiment of the invention illustrated, has a tuned branch responsive to each of the four carrier wave frequencies transmitted by each of the other three or distant stations, as well as a tuned branch responsive to the two base frequencies of 100,000 and 107,000 cycles. There is also included in the circuit of the receiving antenna of each station a tuned branch responsive to the frequencies of the associated transmitting antenna, which branch, as will be explained in connection with Fig. 5, acts as a trap to divert the energy received from the local transmitting antenna and largely prevent it passing through the portion of the circuit including the other tuned branches of the receiving antenna system.

The general scheme of organization of the various stations of the system will now be explained by reference to Fig. 2 of the drawing. The particular station that has been chosen for schematic illustration in this figure of the drawing is station 1. It will be understood that the plan of each of the other stations is the same excepting for such differences as have already been indicated in the matter of the particular frequencies assigned to the different transmitting and receiving channels. For the purpose of simplified and concise representation, most of the devices and groups of apparatus that constitute elements in the organization are indicated in Fig. 2 by means of appropriately lettered squares. For convenient reference a key to the lettered squares in this and the other figures is here given. The squares marked A are amplifiers. The squares marked BA are balanced amplifiers. Squares BF are band filters. Square AL is an artificial line or energy dissipating device. Squares BD are balanced detectors. Squares TC are tuned circuits. Squares STC are

tuned circuits with anti-resonant shunts. Squares LPF are low pass filters. Squares M are modulators. Squares D are detectors. Squares HG are harmonic generators. Squares O are oscillators. Squares BM are balanced modulators. Squares Hy are hybrid or conjugate coils. Squares N are balancing networks. In addition a number of unlettered squares are employed which merely represent groups of apparatus the detailed representation of which is unnecessary to an understanding of the general plan or scheme of organization, and the nature of the apparatus in which groups may be conveniently ascertained by reference to the figures of the drawing showing the circuits in detail. Such familiar pieces of apparatus as plugs, spring jacks, lamps, telephone receivers and transmitters, etc., are represented by their usual conventional symbols, so that in explaining the plan of organization illustrated in Fig. 2 it will be unnecessary to identify by reference numerals the elements to which there may be occasion to refer. The various apparatus referred to above as being indicated by squares in certain figures of the drawing will be described more fully hereinafter, and reference is here made to the paper by Colpitts and Blackwell entitled "Carrier current telephony and telegraphy", published in the Journal of the American Institute of Electrical Engineers, April 1921, and succeeding issues, for a disclosure of individual apparatus and subcombinations of apparatus of the general type employed in the present system.

The receiving antenna system is made aperiodic, or in any convenient and well known way is given as many degrees of freedom as are necessary to make it responsive to the range of frequencies that are to be received. The output circuit of the balanced amplifier is connected with as many tuned branches as there are carrier waves to be received from the various distant stations and from the base frequency generating station. The branches for responding to the carrier waves from station 2 are designated channel 1, channel 2, channel 3 and control channel respectively, these branches, as indicated, being responsive respectively to 614,000, 621,000, 628,000 and 635,000 cycles. The branches of the receiving antenna system adapted to respond to the carrier waves from station 3 are designated channel 1, channel 2, channel 3 and control channel and are respectively responsive to frequencies of 686,000, 679,000, 672,000 and 665,000 cycles. The branches of the receiving antenna system adapted for cooperation with station 4 are likewise designated channel 1, channel 2, channel 3 and control channel, and are respectively responsive to carrier waves of 714,000, 721,000, 728,000 and 735,000 cycles. The branch of the receiving antenna system

responsive to the base frequency waves, which branch is shown at the lower left hand corner of Fig. 2 is responsive to a range of frequencies from 100,000 to 107,000 cycles inclusive.

Figs. 1 and 2 have been referred to for illustration of the general layout of the system and of a station of the system, respectively, but these figures do not pretend to give the circuit arrangements since in these figures single lines are used for the various transmission paths whereas in reality two or more conducting or control or other wires would be needed. In the following description Figs. 1 and 2 may, on account of their outline nature, conveniently be consulted where reference is made to the general arrangement of a system or of an individual station, but Figs. 3 to 8, arranged as shown in Fig. 9, are relied on to show specific circuit arrangements; and wherever mention is made specifically of the circuit structures, reference should be had to Figs. 3 to 8 for the corresponding illustration.

Referring now to the branches of the receiving antenna system that constitute the incoming channels from the various distant stations, each of these is connected serially with the output circuit of the receiving antenna balanced amplifier through the medium of a tuned circuit which is provided with an anti-resonant shunt to aid in the diversion into the particular tuned circuit of the frequencies to which the circuit is tuned and the unattenuated passage through the series circuit of the frequencies to which the other tuned branches are responsive. For a more complete description of the action of these selecting circuits, reference may be had to the patent to Raymond A. Heising 1,313,483, August 19, 1919, in which similar selecting circuits are shown at a transmitting station. The spacing of the carrier waves is so close that the tuned circuit of each branch is not relied upon to effect in itself the exclusion of adjacent frequencies from the branch, but merely to effect as great a measure as possible of attenuation for all frequencies other than that for which the particular branch in question is tuned. The manner in which the selectivity of the channel for its particular frequency is increased and response to other frequencies prevented will be hereinafter described. The frequencies diverted from the common circuit by way of a tuned circuit are amplified and then passed to a balanced detector where they are combined with a locally generated wave developed in such a manner as to have identically the same frequency value as that of the modulated carrier that is received over this tuned branch. Among the demodulation products developed in the balanced detector as a result of the combination of these frequencies are the reproduced low voice or signaling frequencies with which the carrier wave was originally modulated at the

transmitting station. These low voice frequencies, or signal controlling frequencies in the case of the control channel, are segregated from the other demodulation products by the interposition of a low pass filter in the output circuit of the balanced detector. The voice or low frequency currents are then amplified and passed directly to the springjack which constitutes the incoming terminal of this channel.

In the case of the control channel incoming from each of the remote stations, the amplified low frequency products of demodulation which are obtained through the operation of a series of elements similar to those mentioned above, may include one or more of a number of low frequency controlling waves with which the carrier wave is modulated at the transmitting station in accordance with the particular associated communicating channel that is to be used in establishing the connection and the particular station that is being called. Consequently the output circuit of the last amplifier in the control channel is provided with a number of branches each of which is selective of a particular one of the controlling low frequencies with which the controlling carrier wave may be modulated. In the case of station 1 illustrated in Fig. 2 there are four selective branches of the control channel incoming from each of the distant stations, these selective branches being tuned to respond to 200 cycles, 1,000 cycles, 1,200 cycles and 1,400 cycles respectively. At the other stations of the system, as may be seen by reference to Fig. 1 the tuned branches of each receiving control channel are adapted to be selective of the same low control frequencies of 1,000 cycles, 1,200 cycles and 1,400 cycles, respectively, but the remaining branch is arranged to be selective of 400 cycles in the case of station 2, of 600 cycles in the case of station 3, and of 800 cycles in the case of station 4. Thus station 1 responds to the modulation of any of the control channel carrier waves with 200 cycles, station 2 responds to the modulation of a control channel carrier wave with 400 cycles, station 3 to its modulation with 600 cycles, and station 4 to its modulation with 800 cycles. The modulation of the corresponding control channel carrier with 1,000 cycles occurs when a transmitting station selects its transmitting channel 1 for use, the modulation of the corresponding control channel carrier with 1,200 cycles occurs when the transmitting station selects its channel 2 for use, and the modulation with 1,400 cycles occurs when the transmitting station selects its channel 3 for use. The devices associated with the various selective branches of each of the receiving system control channels interact and cooperate in such a way that the lamp signal associated with a particular incoming communicating channel at a particular station is lighted when

the transmitting station takes the corresponding channel for use and signals the station in question.

As has been stated there are at each of the stations four transmitting channels, three of which terminate upon springjacks at the operator's position and are used for communicating purposes, and the fourth of which is arranged to be used for calling and signal controlling purposes. The voice frequencies that are supplied to each of the communicating channels when connection is established by way of the terminal springjack of the channel are carried through a low pass filter which serves to suppress the upper harmonics and higher voice frequencies and thus hold the frequencies within a moderately restricted range. The voice frequencies that are conveyed through the low pass filter are supplied to the input circuit of a balanced modulator where they are combined with the appropriate one of the carrier waves developed from the base frequencies as will hereinafter be described. The products of modulation are then passed through a tuned circuit which serves to suppress all but the voice frequency modulations of the carrier wave and such unmodulated component of the carrier wave as is not balanced out and suppressed by the action of the balanced modulator. The voice modulated carrier then is amplified and passes into the common circuit of the transmitting antenna by way of a tuned circuit with a shunt that is anti-resonant to the frequency of this particular transmitting channel.

In the case of the fourth or control channel of the transmitting group the input circuit of the balanced modulator is arranged to receive the locally generated carrier wave which this channel employs, and also any one or more of the previously mentioned group of low frequency controlling waves. The controlling waves are generated as harmonics of a base frequency or fundamental produced in an oscillator, this fundamental frequency in the present instance being 200 cycles. Harmonics or multiples of this frequency are produced in a harmonic generator, are then amplified and distributed by means of tuned circuits to other amplifiers where each harmonic that is to be used is amplified to whatever degree may be desired, and is applied as required through a tuned branch to the input circuit of the control channel balanced modulator. In the case of station 1 illustrated in Fig. 2 the harmonics that are segregated and amplified for use are 400, 600, 800, 1,000, 1,200, and 1,400 cycles respectively. The 200 cycle frequency is not utilized at station 1 for the reason that this is the frequency with which the other distant stations modulate their controlling carrier waves to select station 1. In like manner as indicated in Fig. 1 station 2 omits the 400 cycle harmonic by means of

which it is adapted to be selected by other stations, station 3 omits the 600 cycle harmonic and station 4 omits the 800 cycle harmonic. Thus the control frequency generating apparatus of each station makes available for use all of the frequencies up to 1,400 cycles excepting the particular frequency or harmonic that is used in effecting the selection of this particular station. Such control frequency or combination of control frequencies as may be required in the establishment and control of connections are made effective by means of relays that control the energizing circuits of the amplifiers in the corresponding tuned branches of the harmonic distributing circuit. The three relays controlling the 1,000, 1,200 and 1,400 cycle branches, used to identify the particular transmitting channel selected are controlled through the agency of circuits completed when a connecting circuit plug is inserted into the spring jack of the selected channel; while the relays controlling the energizing circuits of the amplifiers in the other or station selecting branches of the harmonic distributing circuit are controlled respectively by the station selecting keys designated K—2, K—3 and K—4 in the case of station 1. Similarly there will be keys K—1, K—3 and K—4 (not shown) at station 2, keys K—1, K—2 and K—4 (not shown) at station 3, and keys K—1, K—2 and K—3 (not shown), at station 4.

As shown in Fig. 2, the operator's position is provided with three connecting circuits for establishing a two-way radio link with any one of the distant stations and for bringing this two-way link into connection with the lines local to the associated station. These connecting circuits are each provided with a receiving plug adapted for insertion in any one of the springjack terminals of the nine channels incoming from the three distant stations, a transmitting plug for insertion in any one of the three springjack terminals of the three communication transmitting channels of the associated station, and a local plug for insertion in the springjack of any one of the local lines. Each connecting circuit includes the usual hybrid coil and balancing network for rendering the receiving and transmitting branches of the circuit conjugate with respect to each other. The connecting circuits also have connection with the usual operator's telephone set and ringing generator by means of the customary listening and ringing keys, and in addition are provided with controlling keys for governing the application of the desired low frequency controlling currents for the modulation of the associated controlling channel, (see Figs. 5 and 6). These parts with their associated controlled and controlling elements and circuits will be described in connection with the detailed description of operation hereinafter. It may also be noted

at this point that each connecting circuit has associated with it a supervisory lamp that is under the control of the distant station through the medium of the corresponding receiving plug and receiving channel springjack and the controlling channel incoming from the distant station.

Referring now to the apparatus for developing the high frequency carrier and demodulating waves from the received base frequencies, the base frequencies of 100,000 and 107,000 cycles after passing through the band filter shown in the lower left hand corner of Fig. 2 pass to the input circuit of the detector. From the output circuit of the detector the base frequency of 100,000 cycles and the difference frequency of 7,000 cycles are separated out by means of tuned circuits, and each of these frequencies after amplification is caused to produce harmonics by means of harmonic generators included in each circuit. After amplification the 600,000 and 700,000 cycle harmonics of the 100,000 cycle base are selected and pass into a common distributing circuit. In like manner the harmonics developed in the harmonic generator of the 7,000 cycle circuit are amplified and the 14,000 cycle, 21,000 cycle, 28,000 cycle, and 35,000 cycle harmonics are then separated out by means of tuned circuits. Each of the last mentioned harmonics of the 7,000 cycle fundamental is then separately amplified and passes to the input circuit of a modulator where in each case it is combined with amplified 600,000 cycle and 700,000 cycle frequencies derived from the common distributing circuit. As a result there is present in the output circuit of the lower one of the four modulators the upper and lower side bands of 600,000 modulated by 14,000 and the upper and lower side bands of 700,000 modulated by 14,000; that is, the frequencies 586,000, 614,000, 686,000 and 714,000. In like manner the modulation of 600,000 and 700,000 by means of the 21,000 frequency in the second modulator produces the frequencies 579,000, 621,000, 679,000 and 721,000. In the third modulator the frequencies 572,000, 628,000, 672,000 and 728,000 are produced; and in the fourth or upper modulator the frequencies 565,000, 635,000, 665,000 and 735,000 are produced. There are also, of course, other products of modulation in the various output circuits; but they are widely separated in the frequency range from the groups of frequencies above mentioned, so that they are readily suppressed in the tuned circuits that take off for use from the output circuits the frequencies mentioned.

It will be noted that the frequencies specifically mentioned as the combination products of the harmonics developed from the two base frequencies are the same frequencies as those which have heretofore been mentioned as being employed for demodulation

of the incoming modulated carriers in the receiving channels and for modulation by the voice and lower controlling frequencies in the transmitting channels. The useful frequencies present in the output circuits of the four harmonic modulators are derived from the respective circuits by means of tuned circuits at the various points where they are to be used and are applied to the input circuits of the balanced detectors and the balanced modulators of the various channels through the medium of amplifiers connected with the tuned circuits.

Reference will now be had more particularly to Figs. 3 to 8 inclusive of the drawing, which illustrate as much of the preferred circuit organization of a single one of the stations of the system as is necessary to enable the invention to be understood. Before proceeding to a detailed description of the operation of the system, however, the organization and operation of that part of the system which serves to generate, modulate, transmit, receive and detect or demodulate the high frequency carrier waves will be described in sufficient particularity so that a detailed reference to the functions and mode of operation of these elements will not be needed in the description of the operation of the system as a whole which follows:

The receiving antenna system at each station includes a receiving antenna RA connected by way of a band filter BF—1 with one winding of an inductive coupling 101 the other winding of which is connected with the input circuit of a balanced amplifier BA—1. The band filter BF—1 is of the general type disclosed in the U. S. Patents to Geo. A. Campbell, Numbers 1,227,113 and 1,227,114 issued May 22, 1917. This band filter is designed in accordance with the principles of the said Campbell patents to shunt or divert from the circuit of the receiving antenna all frequencies in the bands of frequencies that are adapted to be propagated from the transmitting antenna TA of the corresponding station, (Fig. 8), and to permit to flow serially in the receiving antenna circuit without substantial attenuation all frequencies that are adapted to be received from the distant stations. To assist in dissipating the energy of the frequencies diverted through the band filter BF—1, the band filter is connected with an energy dissipating device 102 which may take the form of a resistance of such value as to perform the function stated without interfering with the selective characteristics of the band filter BF—1. The remaining frequencies, those which are not blocked or trapped by the band filter BF—1, act inductively through the medium of the windings of the inductive coupling 101 to control the operation of the balanced amplifier BA—1. This amplifier is of the well known the "push-pull" type, and serves as a

repeater having in effect a substantially linear characteristic throughout a large operating range to permit of the repeating of the carriers that pass through it without intermodulation between them. A balanced amplifier or repeater arranged to function in this manner is disclosed in U. S. patent to B. W. Kendall, No. 1,544,910, dated July 7, 1925.

After amplification in the balanced amplifier or repeater BA—1 the received carrier and base frequency waves pass by way of the common circuit 103 to a plurality of tuned branches where the different frequencies are selected and diverted into their separate channels. Referring first to the amplified base frequencies, which in the present embodiment of the invention are assigned the values of 100,000 and 107,000 cycles per second, these frequencies are selected from the common circuit 103 by way of the branch including the band filter BF—2. This filter is of the Campbell band filter type previously referred to, and is so constructed as to divert 100,000 and 107,000 frequencies with substantially negligible attenuation and to prevent the entrance into the corresponding branch of the other frequencies present in the common circuit. The base frequencies that flow through the band filter BF—2 pass to a detector D—1 from the output circuit of which the base frequency of 100,000 cycles is selected by means of a tuned circuit TC—8, while the difference frequency of 7,000 resulting from the demodulation of the 100,000 and 107,000 frequencies is selected by means of a tuned circuit TC—9. The base frequency of 100,000 thus selected is amplified by the amplifier A—8 and the amplified oscillations are impressed upon the input circuit of the thermionic tube HG—8. The magnitude of the oscillations is such as to overload this tube, with the result that, as disclosed in U. S. patent to B. W. Kendall, No. 1,446,752, dated February 27, 1923, the repeated oscillations are distorted into a series of currents the frequencies of which are the harmonics of the base frequency current, the tube HG—8 thus acting as a harmonic generator. The base frequency and its harmonics are then amplified by the amplifier A—8¹ and the sixth and seventh harmonics, 600,000 cycles and 700,000 cycles, respectively, pass by way of the transformer 105, are selected by the tuned circuits TC—6 and TC—7 and are impressed upon the distributing circuit 104.

In like manner the 7,000 cycle frequency selected by the tuned circuit TC—9 is amplified by the amplifier A—9 and the amplified oscillations are impressed upon the input circuit of the harmonic generator HG—9 where they are distorted into a series of currents the frequencies of which are the harmonics of the base frequency of 7,000 cycles. The base frequency and its harmonics are then amplified

by the amplifier A—9¹ and are impressed by way of the windings of the transformer 106 upon a distributing circuit 107.

The two harmonics of the base frequency 100,000 that are present in distributing circuit 104 and the four harmonics of the derived base frequency 7,000 that are present in the distributing circuit 107 are combined in a manner that will now specifically be described to produce sixteen carrier and demodulating frequencies which are conveniently generated in four groups of four frequencies in each group. As the selection of a plurality of frequencies from a common circuit presents some little difficulty when the percentage separation between the frequencies is slight, provision is made for combining the component or base frequencies in such a way that the combination frequencies produced in the output circuits of the combining devices or modulators shall be sufficiently far apart to enable them to be simply and easily segregated from each other by means of simple tuned circuits. To this end each of the harmonics of the lower base 7,000 is combined with the two harmonics of the higher base 100,000 in a modulator separate from that in which each other harmonic of the lower base is combined with the two harmonics of the higher bases. Thus the combination frequencies produced in the output circuits of the various modulators are separated from each other by a greater frequency interval than would be the case if the harmonics of the lower base were combined with the harmonics of the higher base in a common combining or modulating device, and the combination frequencies in the output circuits are therefore far enough apart to permit of their ready separation by means of ordinary resonance devices.

A description of one of the harmonic frequency combining circuits will serve for all of them, as they are all alike excepting with respect to the frequencies that are supplied to them from the various branches of the distributing circuit 107 of the lower base frequency harmonics. From the distributing circuit 107 the 14,000 cycle harmonic of the 7,000 cycle base is taken off by means of a tuned circuit TC—2 and is applied to the terminals of a potentiometer 108 by means of which such fraction of the oscillatory current potential as may be desired is applied to the input circuit of amplifier A—2. The output circuit of this amplifier is connected through a potentiometer 109 with the input circuit of the modulator M—1. The circuit arrangement of this modulator as shown is of the type shown in the United States patent to Van der Bijl 1,350,752 dated August 24, 1920. For a discussion of the action of a modulator in producing the combination frequencies of the impressed waves, the British Patent No. 102,503 may be referred to, or the Colpitts and

Blackwell publication above cited. At the same time the 600,000 and 700,000 cycle frequencies present in the distributing circuit 104 are applied by way of a potentiometer 110 to the input circuit of an amplifier A—2¹, and the output circuit of this amplifier is connected by way of potentiometer 111 and inductive coupling 112 with the input circuit of the same modulator M—1 with which the 14,000 cycle frequency from the distributing circuit 107 has been described as being connected. As a result there are present in the output circuit of the modulator M—1 the sum and difference frequencies of each of the higher frequencies 600,000 and 700,000 with the lower frequency 14,000. These frequencies are applied to the distributing circuit 113 by way of the windings of a coupling coil or transformer 117. In like manner the 21,000 frequency is selected from distributing circuit 107 by way of tuned circuit TC—3, is amplified by amplifier A—3 and is applied to the input circuit of modulator M—2 where it is joined by the 600,000 and 700,000 frequencies that are applied to the input circuit of modulator M—2 by way of amplifier A—3¹; and these frequencies are combined to produce sum and difference frequencies of the lower frequency 21,000 with each of the higher frequencies 600,000 and 700,000, which frequencies are supplied to the distributing circuit 114. Similarly the 28,000 lower harmonic frequency is supplied to the input circuit of modulator M—3 by way of tuned circuit TC—4 and amplifier A—4 and is there joined by the two higher harmonic frequencies supplied by way of amplifier A—4¹, and corresponding sum and difference frequencies are created in the output circuit of this amplifier, and are supplied to distributing circuit 115. Likewise the lower harmonic frequency 35,000 is supplied to the input circuit of modulator M—4 by way of tuned circuit TC—5 and amplifier A—5, is joined by the two higher harmonic frequencies supplied by way of amplifier A—5¹, and corresponding sum and difference frequencies appear in the output circuit of modulator M—4 and are supplied to distributing circuit 116. As a result there are present in the distributing circuit 113 the frequencies 586,000, 614,000, 686,000 and 714,000; in distributing circuit 114, the frequencies 579,000, 621,000, 679,000 and 721,000; in distributing circuit 115, the frequencies 572,000, 628,000, 672,000 and 728,000; and in distributing circuit 116, the frequencies 565,000, 635,000, 665,000 and 735,000. It may be seen that the frequencies in each of these distributing circuits are sufficiently spaced apart so that they are readily capable of clean-cut segregation by means of ordinary tuned circuits. Of course there are present in each of the distributing circuits the unmodulated components as well as the sum and difference frequencies of the

two higher component frequencies 600,000 and 700,000. But all of these frequencies are sufficiently widely separated in the frequency spectrum from the frequencies that are to be derived from the distributing circuits as carrier and demodulating waves to prevent them from passing through the tuned branches through which the useful frequencies are taken off.

Of the four modulating or frequency-combining branches, the three which feed distributing circuits 113, 114 and 115 are controlled by relays 13, 14 and 15 respectively and are normally inert. The fourth branch, that which feeds the distributing circuit 116, is permanently energized, as it is the frequencies produced in this branch that are supplied to the calling or controlling receiving channels, which channels are maintained in a normally responsive condition.

Of course it will be understood that the carrier and demodulating wave distributing circuits 113, 114 and 115 and 116 are to be so located and shielded from each other and the other circuits of the system as to prevent any objectionable interference and interaction arising from the high frequency currents that they carry as well as excessive attenuation of such currents. Ways in which this result may be accomplished are well known in the art.

Specific reference will now be made to the organization and operation of one of the communication receiving channels associated with the receiving antenna system. The receiving channels RC—43 will be described, and it will be understood that the other communication receiving channels are similar to this excepting in the matter of the particular frequencies to which they are adapted to be selective. The receiving branch RC—43 has connection with the common circuit 103 of the receiving antenna system by way of the shunted tuned circuit STC—43. The shunted tuned circuit STC—43 includes a series resonant circuit with an anti-resonant shunt in the common circuit 103, this shunt being anti-resonant to the same frequency to which the series resonant circuit is tuned. Consequently the particular carrier frequency to which this receiving branch is adapted to respond is caused to pass through the primary winding of the coupling coil that forms part of the series resonant circuit, while the other frequencies are provided with a path of low attenuation by way of the anti-resonant shunt. The secondary winding of the coupling coil is included in a circuit resonant to the frequency in question, and the carrier wave of corresponding frequency thus diverted from the common circuit is applied by way of a potentiometer 118 to the input circuit of an amplifier A—43. The output circuit of the amplifier is connected by way of a potentiometer 119 and a transformer 120 with the two input

circuits of a balanced detector BD—43. Associated with the communication receiving branch RC—43 there is a tuned circuit TC—43 that has connection with the distributing circuit 115 of the carrier frequency generating apparatus. The constants of this tuned circuit are such as to cause it to take off from the distributing circuit 115 the 728,000 cycle frequency, which is the same frequency as that to which the tuned circuit STC—43 is arranged to be responsive. The 728,000 cycle frequency that is diverted by the tuned circuit TC—43 is applied by way of a potentiometer 121 to the input circuit of amplifier A—43¹, and the output circuit of this amplifier is connected to the common conductor of the two input circuits of the balanced detector BD—43 by way of a potentiometer 122. As will hereinafter be explained and as is disclosed in British Patent No. 102,503 above referred to, and in United States patent to Carson 1,343,306, June 15, 1920, the carrier wave at the transmitting station is modulated by the speech or voice currents in a modulator of a type that operates to suppress the unmodulated component of the carrier and transmit merely the speech modulated side bands. As the frequency of 728,000 that is applied to the balanced detector BD—43 by way of tuned circuit TC—43, amplifier A—43¹ and the potentiometer 122 in the common conductor of the input circuit corresponds to the carrier frequency that was suppressed at the transmitting station, the detector acts, in accordance with the principle disclosed in U. S. Patent 1,343,306, to Carson, and in British Patent No. 102,503, above cited, to demodulate the voice modulated carrier side bands and immediately reproduce the voice currents in the output circuit of the modulator. The output circuit of modulator BD—43 is connected by way of the windings of transformer 123 with the low pass filter LPF—43. The constants of this filter, which is constructed in accordance with the principles disclosed in the Campbell patents hereinbefore referred to, are such that all of the higher frequencies resulting from demodulation are suppressed, and only the voice frequencies reproduced in the output circuit of the modulator are permitted to pass. The voice currents that are carried through the low pass filter LPF—43 are applied through the medium of the transformer 124 to the input circuit of the amplifier A—43² and the output circuit of this amplifier is connected by way of the windings of transformer 125 with the line contacts of the receiving springjack RJ—43 associated with this particular receiving channel. The conductors over which battery current is supplied for the energization of the thermionic tubes in the communication receiving channel RC—43 are controlled in contacts of a relay 16. These contacts are

normally open so that the tubes of the receiving channel are normally inert.

As has been stated, the other communication receiving channels are organized in exactly the same manner as channel RC-43, which has just been described, excepting that the constants of their associated tuned circuits are so adjusted as to divert from the common receiving antenna circuit 103 the particular modulated carrier waves to which the channels are respectively adapted to respond, and to select from the distributing circuits of the carrier frequency generating apparatus the particular corresponding frequencies that are required for the demodulation of the modulated carriers that enter the associated channels. The voice currents that are reproduced by the demodulating action in channel RC-41 are conducted to the line contacts of receiving springjack RJ-41, and the voice currents reproduced by the demodulating action in receiving channel RC-42 are conducted to the line contacts of receiving springjack RJ-42. As the organization of each of these communication receiving channels is the same as that of receiving channel RC-43, the channels RC-41 and RC-42 are merely represented by appropriately designated blank squares.

The calling or controlling receiving channel RC-44 is also substantially similar in its organization to the communication receiving channel RC-43. The modulated carrier wave to which the channel RC-44 is adapted to respond is diverted from the common receiving antenna circuit 103 by way of the anti-resonant shunted tuned circuit STC-44 and is impressed by way of a potentiometer upon the input circuit of the amplifier A-44. The current produced in the output circuit of this amplifier is impressed through a potentiometer upon the two input circuits of the balanced detector BD-44 through the medium of a transformer. At the same time the corresponding frequency is taken from distributing circuit 116 of the carrier frequency generating apparatus by way of tuned circuit TC-44 and after amplification in amplifier A-44 is applied to the common conductor of the two input branches of balanced detector BD-44. As in the case of receiving channel RC-43, the demodulating action which occurs in the balanced detector BD-44 is such as immediately to reproduce in the output circuit of the balanced detector the particular controlling frequencies with which the carrier waves of controlling channel RC-44 was modulated at the transmitting station. The low pass filter LPF-44 acts to suppress all of the higher frequency products of demodulation and to impress the reproduced low frequency controlling currents upon the input circuit of amplifier A-44. The output circuit of amplifier A-44 is

connected by way of the windings of transformer 126 with a distributing circuit 127. Connected with distributing circuit 127 are a number of branches 128, 129, 130 and 131 each made resonant to a different one of the controlling frequencies by the tuning devices TC-45, TC-46, TC-47 and TC-48, respectively. In each of the tuned circuits, and constituting a part of the inductance, is a relay so constructed and adjusted that it maintains a contact normally closed, but when traversed by alternating current of the frequency to which the associated branch is responsive, it holds its contact open. These relays in the four-tuned branches are designated respectively 18, 19, 20 and 21. The last mentioned relays cooperate with corresponding associated relays 22, 23, 24 and 25; and the relays 23, 24 and 25 have operatively associated with them corresponding relays 26, 27 and 28. The manner in which the above mentioned relays, together with relays 29, 30 and 31, associated respectively with the terminals of the communication receiving channels RC-41, RC-42, and RC-43, cooperate in controlling the display of the line signal lamps L-41, L-42 and L-43 of the three communication receiving channels respectively, will be explained hereinafter in connection with the description of the operation of the system.

Reference will now be made to the transmitting channels for modulating the high frequency carrier waves assigned for transmission purposes to this station with the low frequency voice and controlling currents. In Fig. 8 of the detail drawing these channels are designated C-11, C-12, C-13 and C-14. The first three are the communication transmitting channels and the last one is the calling or controlling transmitting channel. Inasmuch as the communication transmitting channels are substantially identical in their organization in all respects excepting in the matter of the value of the high frequencies that they are adapted to control, the organization of channel C-13 is the only one of the communication transmitting channels that is shown in detail, the other channels being represented merely by squares bounded by broken lines. As the organization of the controlling transmission channel C-14 differs slightly from that of the communicating transmission channels, it also is illustrated in detail.

The line contacts of the springjack TJ-3 in which the communication transmitting channel C-13 terminates, are connected by way of a low pass filter LPF-13 and a potentiometer 132 with the primary winding of a transformer 133. The low pass filter LPF-13 is constructed in accordance with the principles of the Campbell patents hereinbefore referred to, and its constants are so chosen and adjusted that it passes with sub-

stantially uniform negligible attenuation the voice frequencies up to, say, 2,500 cycles per second and suppresses or greatly attenuates all of the frequencies lying above this limit.

5 A frequency band of this width carries all of the frequencies necessary for the proper reproduction of speech, and prevents the higher frequencies and harmonics which may be present in the voice currents from causing
10 any overlapping of the closely spaced frequency bands of the communication carrier waves.

The transformer 133, through the primary winding of which the voice frequencies of channel C—13 flow, has two secondary windings, one included in each of the input circuits of the pair of thermionic tubes of the balanced modulator BM—13. In the common conductor of the input circuits of the
20 balanced modulator is a potentiometer 134 through which the corresponding carrier wave of this channel is impressed at the desired potential upon the two input circuits of the balanced modulator. The carrier wave is derived from the distributing circuit
25 115 of the carrier frequency generating apparatus by way of the tuned circuit TC—13¹. The carrier frequency selected by the tuned circuit is applied by way of the potentiometer
30 135 to the input circuit of amplifier A—13¹, and the output circuit of the amplifier is connected with the common conductor of the balanced modulator BM—13 by way of potentiometer 134, as described. The balanced
35 modulator BM—13 is constructed and organized in accordance with the disclosure in U. S. Patent 1,343,307 issued June 15, 1920 to John R. Carson, and the operation of this modulator is such that the carrier wave is
40 suppressed excepting at such times as the low frequency voice currents are being impressed upon the input circuit of the modulator by way of the inductive coupling or transformer 133.

45 The output circuit of modulator BM—13 is connected by way of the windings of transformer 136 with a tuned circuit TC—13 which is tuned to the carrier wave frequency of the associated channel. In the case assumed, the
50 carrier wave is of such high frequency that the side bands resulting from the modulation of the carrier by the speech waves have only a very small percentage frequency difference from the carrier wave frequency value, and
55 the simple tuned circuit TC—13 is in such a case sufficient to transmit the speech-modulated waves with little or no appreciable distortion. At the same time the tuned circuit TC—13 operates to suppress the undesired
60 lower and higher products of modulation present in the output circuit of the balanced modulator BM—13. The speech modulated side bands that pass through tuned circuit TC—13 are applied by way of potentiometer
65 137 to the input circuit of amplifier A—13,

and the output circuit of the amplifier has connection by way of the shunted tuned circuit STC—13 with the conductor extending to the transmitting antenna TA. The inductance values of the transformer or inductive
70 coupling included in the tuned circuit STC—13 and the capacity values in the circuits of the two windings of the transformer are such that there is series resonance for the frequencies of the carrier side bands that are
75 to be transmitted; while the anti-resonant shunt included in the tuned circuit STC—13 is anti-resonant to these same frequencies, but permits the frequencies applied to the transmitting antenna conductor by the other
80 transmitting channels to pass through it with substantially negligible attenuation, as described in the Heising Patent 1,313,483 above cited. As in the case of the receiving antenna
85 system, the transmitting antenna by the proper adjustment of its constants may be made substantially aperiodic, or may be given the desired number of degrees of freedom necessary for the transmission of the required
90 frequency bands in any convenient one of the ways that are well known in the art. Of course, the coupling between the transmitting and receiving antenna circuits and their
95 respective pluralities of branches will be made such as to permit the transfer of energy to take place without introducing interference effects between the different branches.

The low frequency controlling waves with which the carrier wave of the control transmitting channel C—14 is modulated are supplied by control frequency generating apparatus, which will be described hereinafter, by way of a pair of conductors 138. The control frequencies present in these conductors are applied by way of potentiometer 139 and coupling coil or transformer 140 to a balanced
100 modulator BM—14 of the Carson carrier suppression type like the balanced modulator BM—13 described above. The carrier wave that is to be modulated by these control frequencies is diverted from the distributing circuit 116 of the carrier frequency generating
105 apparatus by way of tuned circuit TC—14¹, the carrier wave, after selection by the tuned circuit, being applied by way of the potentiometer 141 to the input circuit of amplifier A—14¹. The output circuit of the amplifier is connected by way of the potentiometer 142 with the common conductor of the balanced
110 modulator input circuit. The output circuit of the balanced modulator BM—14 is connected by way of transformer 143 with one side of the tuned circuit TC—14, and the other side of the tuned circuit is connected by way of the potentiometer 144 with the input
115 circuit of amplifier A—14, the output circuit of the amplifier having connection by way of the shunted tuned circuit STC—14 with the transmitting antenna conductor. The tuned circuit TC—14, like tuned circuit TC—13 pre-
120
125
130

viously described, is adapted to pass with slight and substantially negligible attenuation the frequencies in the side bands resulting from the modulation of the carrier wave with the relatively low control frequencies. The tuned circuit STC—14 is resonant to this narrow band of frequencies; and the presence of the anti-resonant shunt comprising part of the element STC—14 prevents these frequency bands from being shunted, but permits the serial passage through the antenna conductor of the frequency bands produced by modulation in the other transmitting channels.

The supply of current for energizing the thermionic tubes of the control transmitting channel C—14 is controlled in contacts of relay 32. These contacts are normally open, and therefore the control transmitting channel is normally inert. In like manner the supply of battery current for energizing communication transmitting channel C—13 is controlled in normally open contacts of relay 33, and other similar relays control the energization of the other communication transmitting channels C—11 and C—12 in like manner.

Referring now to the organization by means of which the lower control frequencies are generated, as shown in Fig. 8, these frequencies are derived as multiples or harmonics of a fundamental or base frequency generated by the oscillator O—1. This oscillator may be of any usual and well known thermionic type with a feed back connection from its output into its input circuit. The frequency of the oscillator current produced may be regulated by an adjustable condenser and may conveniently be, say, 200 cycles per second. The oscillator O—1 supplies substantially sinusoidal oscillations to the input circuit of the harmonic generator HG—1. An inductance is bridged across the input circuit, and the magnitude of the oscillations supplied is such as to overload the tube HG—1; that is, to supply an input wave of greater amplitude than the tube can repeat without distortion. As a result the repeated oscillations in the output circuit of the harmonic generator HG—1 are of non-sinusoidal wave form, which is the equivalent of a base frequency current of sinusoidal form and a series of currents of frequencies which are multiples or harmonics of the base frequency. The action is the same as that previously described in connection with the harmonic generators illustrated in Fig. 5 of the drawing. The harmonic frequencies produced by the harmonic generator HG—1 are amplified in the amplifier A—1 and are then supplied to the distributing circuit 145 by way of the windings of a transformer 146. From the distributing circuit 145 the second, third, fourth, fifth, sixth and seventh harmonics are selected by means of the tuned circuits

TC—52, TC—53, TC—54, TC—61, TC—62 and TC—63 respectively. Each of the harmonics thus selected is supplied through a potentiometer to the input circuit of the corresponding series of amplifiers A—52, A—53, A—54, A—61, A—62 and A—63 respectively. The output circuits of these amplifiers are respectively connected by way of the tuning devices TC—52', TC—53', TC—54', TC—61', TC—62' and TC—63' with the common collecting circuit 147, and the circuit 147 is connected by way of the windings of the transformer 148 with the circuit 138 which has previously been described as supplying the control modulations to the control transmission channel C—14. The frequencies of 400, 600, 800, 1,000, 1,200 and 1,400 cycles per second are thus produced and made available for application to the modulating circuits of the control transmitting channel C—14. The constants of the tuning devices in the respective branches are of course adjusted to pass the particular frequency that each corresponding branch is intended to pass and to bar out the other frequencies. The supply of battery current for energizing the tubes of amplifiers A—52, A—53, etc., is controlled in the normally open contacts of a series of relays 52, 53, 54, 61, 62 and 63 associated respectively with the corresponding amplifiers. The manner in which these relays are controlled to bring about the energization of their respectively associated amplifiers will be described hereinafter.

The specific organization of the portions of the system that have not thus far been particularly explained will best be understood in connection with the detailed description of the operation of the system which follows.

We will assume that the operator at station 1 wishes to get into communication with the operator at one of the other radio stations or centers in order to establish telephonic connection between one of the local lines of station 1 and one of the local lines of the other station. For initiating the call there are available to the operator at the calling station three communication transmitting channels which terminate respectively upon the springjacks TJ—1, TJ—2 and TJ—3. The calling operator also has available for establishing the connection the three connecting circuits CC—1, CC—2 and CC—3, each of which has a plug for connecting with the local line and two other plugs for connecting respectively with the receiving and transmitting channels that are temporarily associated to constitute the two-way radio link.

Noting that one of the communication transmitting channels, say the channel terminating in springjack TJ—3, is available for use, and that one of the connecting circuits, say the connecting circuit CC—3, is also avail-

able, the operator first momentarily presses the key K—31 associated with and individual to the connecting circuit CC—3. The depression of this key closes a circuit that extends from battery through the winding of relay 34, right hand switch spring and resting contact of that relay, closed contacts of key K—31, and right hand back contact and armature of relay 35 to ground. Relay 34 operates, and before breaking its original circuit completed in the contacts of key K—31 it closes a circuit that extends from battery through the winding of relay 34, right hand switch spring and armature of that relay, guard lamp GL—3, right armature and back contact of relay 36 of the common station selecting apparatus, and inner left hand armature and front contact of relay 34 to ground. The last mentioned contact of relay 34 is adjusted to close before the right hand switch spring of relay 34 separates from its resting contact. A locking circuit for relay 34 is thus completed which includes the guard lamp GL—3, so that that lamp remains lighted to indicate to the operator that a calling operation is in progress.

Having thus appropriated the common station selecting apparatus for the use of the chosen connecting circuit CC—3, the operator then presses the particular one of the keys K—2, K—3 and K—4 of the station selecting apparatus that corresponds to the distant station that is being called. We will assume that this is the key K—4 which corresponds to station 4. When this key is pressed a circuit is closed that extends from battery through the winding of the slow-acting device or timer 40, left resting contact and switch spring of relay 36, winding of relay 39, contacts of key K—4, back contact and armature of relay 41, right armature and back contact of relay 36, and inner left hand armature and front contact of relay 34 to ground.

The timer 40 is of the type disclosed in U. S. patent to Samuel B. Williams, Jr. and Walter P. Albert No. 1,332,680, dated April 20, 1920. It may be noted, however, that in the case of the timer 40, the outward or return movement of the solenoid core is retarded, as well as the inward movement. The result is that an interval which may be regulated as desired elapses from the time when the timer 40 is energized until it closes its inner contact, and another regulable interval elapses between the deenergization of the timer and the opening of its outer contact, which contact was closed an instant after the energization of the device.

The closure of the station selecting key K—4 need be only momentary, for relay 39 in operating completes a locking or holding branch for maintaining its energization that includes the right front contact and armature of relay 39 and the winding of relay 41. As long

as the key K—4 remains depressed, the locking branch including the right contacts of relay 39 and the winding of relay 41 remains short circuited in the contacts of the key K—4. But when the key K—4 is released this short circuit is opened and current passes through the branch containing the winding of relay 41, thus bringing about the energization of that relay. When relay 41 operates it opens at its back contact the conductor over which the station selecting keys K—2, K—3 and K—4 have control over their associated relays 37, 38 and 39. Therefore, after, one of these keys is depressed and subsequently released all the keys are thereafter deprived of control over their relays until the end of the calling operation.

The instant the station selecting key K—4 is pressed and the associated relay 39 operated, a circuit is closed that extends from battery by way of left front contact and armature of relay 39, conductor 44, and winding of relay 54 (Fig. 7) to ground. Relay 54 in operating energizes the amplifier A—54 and thus makes effective the branch 154 of the control frequency generating apparatus. As a result the 800 cycle control frequency is applied to the common circuit 138 extending to the input circuit of the balanced modulator BM—14 of the control transmitting channel C—14. At the same time a circuit is closed that extends from battery through the winding of relay 32 (Fig. 8), conductor 45 and outer right hand armature and front contact of relay 54 to ground. Relay 32 in operating energizes the thermionic tubes of control transmitting channel C—14 and thus makes that channel effective to apply to the transmitting antenna TA the carrier wave of 565,000 cycles derived from distributing circuit 116 modulated with the 800 cycle control frequency derived from the common circuit 138.

The modulated carrier wave of 565,000 cycles thus propagated from the transmitting antenna of station 1 is received over the receiving antenna systems of all of the distant stations and is selected at each of these other stations by the control receiving channel of the group identified with station 1 that is responsive to the 565,000 cycle control frequency of that station. This is most clearly indicated in the schematic diagram of Fig. 1. As has been stated, in order to simplify the showing the wiring of station 1 only has been illustrated in detail. But inasmuch as the arrangements of all the control receiving channels of all of the stations are alike excepting in the matter of the specific frequencies to which they are made responsive, it may be assumed for the time being that the receiving channels illustrated in Fig. 3 are those of distant station 4 that is being called. That channel RC—44 is responsive to the 565,000 cycle frequency of station 1 and

that the tuned branch 128 of channel RC—44 is responsive to the 800 cycle control frequency used for calling station 4 instead of the 200 cycle control frequency used for calling station 1. Proceeding for the time being under these assumptions, channel RC—44 at station 4 responds to the modulated control frequency of 565,000 cycles from station 1, and, as the control receiving channel is in a constantly responsive condition, the modulated 565,000 cycle frequency is immediately demodulated and the 800 cycle low frequency component is selected by branch 128 of the common circuit 127 and energizes relay 18 to open its normally closed contacts.

The continued energization of relay 18 which now occurs breaks the normally closed energizing circuit of the associated relay 22; and that relay thereupon releases its armature and closes its back contact. For the present we will assume that communication transmitting channels C—11 and C—12 of station 1 are both at this time in use, and that communication transmitting channel C—13 of station 1 is the only one that is available for use. Under these circumstances, as will subsequently be described, relays 23 and 24 at each of the distant stations, including the called station 1, are inert as a result of the energization of their associated relays 19 and 20, and the corresponding relays 29 and 30 associated with the two busy channels RC—41 and RC—42 that cooperate with channel C—11 and C—12 of station 1 may also be energized, depending upon whether the channels C—11 and C—12 are already in use for establishing connection with the same station that is now being called. Under these assumptions, when relay 22 at called station 4 releases as a result of the energization of relay 18, it closes a circuit that extends from battery through resistance 49, back contact and armature of relay 22, left back contact and armature of relay 31 associated with communication receiving channel RC—43, front contact and armature of relay 25, and the winding of relay 28 to ground. Relay 28 then operates and closes a locking circuit for itself that extends from battery through resistance 50 and the closed contacts and winding of relay 28 to ground. Thus relay 28 associated at the called station with an available channel from the calling station is operated when the calling station sends out its control carrier wave modulated with the particular control frequency to which the called station is responsive. Relays 26 and 27 at the called station are not operated, as they are associated with channels that are in use; and none of the corresponding relays 26, 27 and 28 is operated at the other stations, as the calling control frequency sent out is not that to which the relays 18 of these other stations are responsive.

Thus far nothing has happened at the

called station excepting the operation of relays 18, 22 and 28. No signal is as yet displayed. Returning now to the actions that are taking place at the calling station, it will be remembered that the energization of the control transmitting channel C—14 and the application of the modulated 565,000 cycle carrier was effected immediately upon the pressing of station selecting key K—4 and the energization of corresponding relay 39. At the same instant, as has been described, the timer 40 is energized and starts to operate, and, at the expiration of the interval for which the device is set, closes its inner contacts. A path is thereupon closed that extends from battery through the right winding of relay 36, closed outer contacts of the timer 40, inner left hand armature and front contact of relay 34 of connecting circuit CC—3 that has been selected for use, and winding of relay 35 to the sleeve contact of transmitting plug key TP—3 of connecting circuit CC—3. If the plug has not yet been inserted into one of the associated transmitting springjacks, the apparatus continues in the condition that it has now reached, with the core or plunger of the timer 40 in its fully attracted position and the inner timer contacts closed. Therefore, if for any reason the operator delays in inserting the transmitting plug into an available transmitting channel springjack, the delay does not affect the proper sequence of operation of the subsequent stages of action. If the plug TP—3 is inserted in an available transmitting channel springjack at the time the timer 40 completes the inward movement of its plunger, or whenever the plug is inserted at any time subsequent to the completed inward movement of the timer plunger, the path heretofore traced as far as the sleeve contact of the plug TP—3 is extended by way of the corresponding contact of transmitting channel springjack TJ—3, assuming that channel C—13 is the one selected for use, and thence by way of conductor 48 and the winding of relay 63 (Fig. 7) to ground.

When relay 63 of the control frequency generating apparatus is operated as a result of the closure of the circuit just traced, it brings about the energization of amplifier A—63 and makes effective the branch 163 that is adapted to apply the 1,400 cycle control frequency to the input circuit of balanced modulator BM—14 of the control transmitting channel. There are thus now two control frequencies modulating the 565,000 cycle control carrier of calling station 1; one being the 800 cycle frequency that is operating to select the particular station that is being called, in the manner that has been described, and the other being the 1,400 cycle frequency which acts, as will be explained to identify the particular communicating channel that the calling station has selected for use in

completing the connection. The closure of the previously traced circuit, upon the insertion of plug TP—3 into springjack TJ—3 and the closure of the inner contacts of timer 40, energizes the relay 35 which thereupon completes a locking circuit for itself that extends from battery by way of resistance 51, lefthand armature and front contact of relay 35, and thence to ground by way of the previously traced path including the registering sleeve contacts of plug TP—3 and springjack TJ—3. The resistance 51 is of such value that while enough current passes through it to maintain the energization of relay 35, it does not act to render ineffective the energizing action of the right winding of relay 36 that is included in a branch parallel with branch including resistance 51. Therefore the closure of the circuit by way of the registering contacts of plug TP—3 and springjack TJ—3 energizes and operates relay 36. Relay 36 in operating breaks at its left switch spring and resting contact the energizing circuit of timer 40, and the timer thereupon starts the backward or return movement of its plunger. This is immediately followed by the breaking of the inner contacts of the timer; but relay 36 is maintained energized by a circuit that extends from battery through the lower winding and the lower armature and switch spring of relay 36, winding of relay 39, upper front contact and armature of that relay, winding of relay 41 and closed outer contacts of timer 40 to ground. Thus the energizing circuit of relay 39 is maintained after relay 36 has been operated, and relay 39 remains energized to continue the application of the 800 cycle station selecting control frequency to the 565,000 cycle control carrier wave during the interval measured by the return movement of the timer plunger. During this interval the relay 41 is also held energized to deprive the station selecting keys K—2, K—3 and K—4 of control over their associated relays 37, 38 and 39, and relay 34 and guard lamp GL—3 associated with the key K—31 are also kept energized until the complete restoration of timer 40 and the consequent opening of the outer timer contacts marks the completion of the sending operation. As the left or locking winding of relay 36 is also under control of the path to ground that is now maintained solely by the outer timer contacts, the relay 36 is also held energized until the end of the calling operation. The return of the timer plunger therefore brings about the restoration to normal of the parts that are involved in the station selecting operation, and the accompanying release of relay 39 deenergizes relay 54 of the control frequency generating apparatus (Fig. 7) and thus withdraws the 800 cycle station selecting modulation of the 565,000 cycle control carrier wave. The relay 35

of the connecting circuit CC—3, however, continues operated by virtue of the path by way of its left hand locking contacts and resistance 51. The circuit in which the winding of relay 35 is thus included also extends by way of the registering sleeve contacts of plug TP—3 and springjack TJ—3 and the winding of relay 63 of the control frequency generating apparatus to ground, so that as long as the plug remains in the springjack the relay 63 continues energized to keep the 1,400 cycle control frequency applied to the 565,000 carrier wave.

Returning now to the actions which are taking place at the called station, station 4, and further referring to the circuits of station 1 illustrated in Fig. 4 in order to explain these actions, the relay 18 remains energized and the relay 22 remains deenergized as long as the control frequency of 800 cycles assigned for the calling of station 4 continues to be applied to the control carrier wave of station 1. When the plug TP—3 is inserted in the communicating channel TJ—3 at station 1, the 1,400 cycle control frequency also modulates the control carrier wave that is being propagated from the transmitting antenna of station 1. As soon as this occurs the tuned branch 131 of the control receiving channel responds and the associated relay 21 operates. This action occurs not only at the called station, station 4, but also at the other stations remote from station 1. As will be explained, this does not lead to the display of signals at the stations that are not being called; but at the station 4 the energization of relay 21 opens the energizing circuit of relay 25, and that relay in releasing its armature closes a circuit that extends from battery through resistance 50, thence by way of the closed contacts of relay 28, armature and back contact of relay 25, inner armature and back contact of relay 31 of the communication receiving channel corresponding to the communication channel that station 1 has selected for use, and thence by way of resistance 55 and line lamp L—43 to ground. There is a branch to ground from this circuit by way of the winding of relay 28; but the resistance of this branch is such as not to divert enough current to prevent the energization of line lamp L—43, which thereupon becomes illuminated. For an interval, as has been described in the foregoing, the station selecting frequency of 800 cycles as well as the channel identifying frequency of 1,400 cycles are both applied to the control carrier wave of the calling station, the station selecting frequency remaining applied for a space determined by the time required for the restoration of the timer 40 to normal. When the station selecting frequency of 800 cycles is withdrawn relay 18 in the tuned circuit 128 is deenergized and closes the energizing circuit of relay 22 which thereupon operates to

break the battery connection of its armature and substitute a connection to ground. The result of the closure of this path to ground at the front contact of relay 22 will herein-
 5 after be described. As the relay 28, originally energized by the operation of relay 22, is now under the control of its locking winding, the circuit for the energization of lamp L-43 remains closed and the lamp contin-
 10 ues illuminated.

When the operator at the called station, station 4, sees the line lamp L-43 lighted, she knows that she is being called over the communication receiving channel that terminates in the springjack RJ-43 with which the illu-
 15 minated lamp is associated; and because, this lamp and springjack are in the group of channels that are incoming from station 1, she knows that it is station 1 that is calling. She therefore performs the same operations that she would perform if she were originating a call for station 1. That is, she presses the key K-11, K-21 or K-31 of one of her connect-
 20 ing circuits that is at the time idle, then presses the station selecting key K-1 that is used for calling station 1, and then inserts the transmitting plug of the idle connecting circuit that she has selected for use into the transmitting springjack of one of the com-
 30 munication transmitting channels that is at the time available for use. The effects of these acts are exactly the same as have been described at length in explaining the actions that occur when station 1 calls station 4. The
 35 result of them is that station 4 sends out the 735,000 control carrier wave of that station modulated with the frequency of 200 cycles used in calling station 1, and also with the particular one of the channel identifying fre-
 40 quencies 1,000 cycles, 1,200 cycles and 1,400 cycles; that corresponds to the particular communication transmitting channel that the operator at station 4 has chosen for use. Assuming that the operator at station 4 selects
 45 the third of her communication transmitting channels for use, the channel that employs the 728,000 carrier, the control carrier wave of 735,000 cycles sent out from station 4 will be modulated with the 200 cycle control fre-
 50 quency and also with the 1,400 cycle control frequency. The 200 cycle control frequency reproduced by demodulation in the control receiving channel RC-44 of station 1 is selected by tuned branch 128 and operates relay
 55 18. The 1,400 cycle control frequency subsequently applied is selected by the tuned branch 131 and operates relay 21. As a result relays 18, 22 and 28 are first actuated, then
 60 relays 21 and 25 are actuated, and then relays 18 and 22 are released and relays 21, 25 and 28 remain operated. The energizing circuit of lamp L-43 at the calling station, station 1, is thus closed and the lamp lighted. The lighting of the lamp L-43 indicates to the op-
 65 erator at station 1 that there is a call incom-

ing over the communication receiving channel RC-43 that terminates in springjack RJ-43 associated with line lamp L-43; and inasmuch as this incoming call is from the
 70 particular distant station, station 4, that has just been called, it indicates to the calling operator that this is the return call, and that the operator at the called station, station 4 has selected this particular channel for the com-
 75 pletion of the two-way radio link between the calling and the called stations. The operator at the calling station, station 1 now inserts the receiving plug RP-3 of the chosen connect-
 80 ing circuit CC-3 in receiving springjack RJ-43 identified by the lighting of lamp L-43. As the mate plug TP-3 of connecting circuit CC-3 has already been inserted in transmitting springjack TJ-3, as here-
 85 inbefore described, communication transmitting channel C-13 of calling station 1 and communication receiving channel RC-43 incoming from called station 4 are now asso-
 90 ciated at calling station 1 to constitute a two-way radio link. At the same time the operator at the called station 4 has completed the establishment of the two-way radio link at
 95 that station by inserting into the receiving springjack terminal of the incoming channel from calling station 1, identified by the light-
 100 ed lamp, the receiving plug of the connecting circuit that she has used to make the return call to calling station 1. Thus the two-way radio link is completed at both the calling and called stations, and a condition has been
 105 established that enables the operators at the two stations to communicate with each other.

Provision is made for bringing about the energization of any of the communication receiving or transmitting channels into the
 110 terminal springjack of which any of the connecting circuit plugs is inserted. When, for instance, the plug RP-3 of connecting circuit CC-3 is inserted in springjack RJ-43 that constitutes the terminal at station 1 of
 115 the channel selected for use by called station 4, a circuit is closed that extends from battery through supervisory lamp SL-3, registering sleeve contacts of plug RP-3 and springjack RJ-43, winding of relay 31 and
 120 winding of relay 16 to ground. Relay 16 in operating connects the filament and plate batteries to the thermionic tubes of communication receiving channel RC-43 and, by
 125 energizing relay 15, causes the application of the locally generated waves to the detecting circuits. This channel is therefore made operative. When transmitting plug TP-3 of
 130 connecting circuit CC-3 is inserted in springjack TJ-3, which constitutes the terminal of communication transmitting channel C-13 chosen for use by calling station 1, a
 135 circuit is completed that extends from battery through relay 33 of channel C-13 and thence to ground by way of local contacts of springjack TJ-3 moved into engagement
 140

when the plug is inserted. The operation of relay 33 connects the filament and plate batteries to the thermionic tubes of channel C—13 and thus makes that channel operative.

5 When receiving plug RP—3 is inserted in springjack RJ—43 of channel RC—43, not only is relay 16 operated to energize the channel, but relay 31 is also energized to break at its left armature and back contact
10 the circuit that up to this time has been closed for the illumination of calling lamp L—43. Therefore, when a plug is inserted in the springjack RJ—43 the associated line lamp L—43 is extinguished. At the same
15 time relay 31 in operating closes a locking circuit for itself and relay 16 that extends from battery through resistance 50, armature and front contact of relay 28, armature and back contact of relay 25, inner armature and
20 front contact of relay 31, winding of relay 31 and winding of relay 16 to ground. The value of resistance 50 is such in relation to the resistance of supervisory lamp SL—3 as to reduce the current flowing in the branch
25 including lamp SL—3 to the point where the lamp does not receive enough current for its illumination. Therefore, as long as this circuit condition exists, the supervisory lamp SL—3 remains dark although plug RP—3 is
30 inserted in springjack RJ—43 and relays 31 and 16 are energized.

Precisely the same actions as those described above take place at the called station when the receiving plug of the connecting
35 circuit is inserted into the springjack of the communication receiving channel incoming from the calling station; that is, the receiving channel is energized and made operative, the calling lamp associated with the spring-
40 jack terminal of this channel is extinguished, and the supervisory lamp associated with the receiving plug is brought into operative relation with the controlling channel but remains dark.

45 Having established the two-way radio link between stations, the operators at the calling and called stations may now communicate with each other by pressing the listening keys LK of their respective connecting circuits
50 and thus bringing their telephone sets OT into connection with the talking conductors of their circuits. The receiving and transmitting high frequency branches and the low frequency branch of each of the connecting
55 circuits are associated through the medium of a hybrid coil with a balancing network N to render the receiving and transmitting high frequency branches conjugate with respect to each other. Associated with the low fre-
60 quency branch of each connecting circuit is an artificial line AL, the connection of which with the talking conductors of the low frequency branch is controlled in normally closed resting contacts of relay 56. The arti-
65 ficial line AL has constants such as approxi-

mately to balance the network N associated with the hybrid coil of the connecting circuit. When the operator presses her listening key LK to connect her telephone set OT with the
70 low frequency branch, local contacts of the listening key LK bring about the closure of a circuit which causes the energization of relay 56 to disconnect the artificial line AL so that a balance is maintained between the receiving
75 and transmitting high frequency branches of the connecting circuit, the bridge through the operator's telephone set being substituted for the normally closed bridge by way of the artificial line AL. In order to extend the con-
80 nection to the local lines at their respective stations, the calling and called station operators insert the local plugs LP of their respective connecting circuits into the springjacks LJ of the local lines that are to be brought
85 into communication. When the plug LP is inserted, a circuit is completed that extends from battery through the winding of relay 56, normally closed contacts of ringing key RK, registering sleeve contacts of plug LP and
90 springjack LJ, and resistance 57 to ground. Thus the extension of the low frequency branch of the connecting circuit to the local line is accompanied by the operation of relay 56 to disconnect artificial line AL from the
95 low frequency branch of the connecting circuit. When ringing key RK is operated, however, the resultant opening of the low frequency branch is accompanied by the breaking of the energizing circuit of relay 56 in
100 the local contacts of ringing key RK and the consequent reconnection of artificial line AL to maintain the balance in the connecting circuit. When the local subscribers at the two
105 stations respond to the ringing of their bells, they may converse through the medium of the two-way radio link established between the radio toll stations.

The operators at the calling and called radio stations may supervise the connection by means of their listening keys LK; or, if
110 desired, the operators may be provided with a monitoring connection depending upon the unbalance of the hybrid coil such as that disclosed in the application (Case 10) of Lewis M. Clement, Serial No. 466,548, filed May 3,
115 1921. It will be understood that, if desired, the local lines and the corresponding portions of the connecting cord circuits may be of the well known central energy type, in which case the condition of use or disuse of
120 the lines will be indicated to the operators by the usual supervisory signals.

If for any reason it is necessary after the connection has been established for one operator to signal the other, she may do so by
125 pressing key K—32 of the connecting circuit over which the connection is established, (or in the case of the other connecting circuits the corresponding key 12 or 22). It will be remembered that the associated relay 35 re-
130

mains operated during the continuance of the connection, being maintained energized by way of a circuit that extends from battery through resistance 51, left hand armature and front contact of relay 35, registering sleeve contacts of plug TP—3 and springjack TJ—3, conductor 48, and winding of relay 63 to ground, the operated condition of relay 63 serving to keep the control transmitting carrier wave modulated with the 1,400 cycle control frequency. When key K—32 is pressed it short circuits the winding of relay 63 by closing a direct path to ground that extends by way of the contacts of key K—32 and the right hand front contact and armature of relay 35. Therefore, the pressing of key K—32 withdraws the 1,400 cycle modulation of the control transmitting carrier wave, but does not release relay 35 of the connecting circuit. The effect of the withdrawal of the 1,400 cycle control modulation of the control carrier wave is to permit the release of the relay in the corresponding tuned branch of the control receiving channel at the distant station. Assuming that the control frequency thus withdrawn is the frequency that has been maintaining energized the relay 21 associated with tuned branch 131 of the control receiving channel RC—44 (Fig. 3), the result is to release relay 21 and close the energizing circuit of relay 25. When the relay 25 attracts its armature as a result of the deenergization of relay 21, it breaks at its back contact the branch path that has extended from battery through resistance 50, armature and front contact of relay 28, armature and back contact of relay 25, and right armature and front contact of relay 31, which branch path has acted as a shunt of the other branch extending from battery through supervisory lamp SL—3 and registering sleeve contacts of plug RP—3 and springjack RJ—43. As a result, as long as the control frequency of 1,400 cycles is withdrawn from the control carrier wave, the shunt of the supervisory lamp SL—3 is broken and that lamp is illuminated by way of the current that flows through it and to ground by way of the windings of relays 31 and 16 in series. The temporary release of relay 25 does not otherwise affect the associated circuits, for the reason that relay 28 remains locked up over an independent branch of the path through resistance 50 from battery; nor does the attraction of the armature of relay 25 short circuit and release relay 28 by way of the path to ground that has now closed at the front contact of relay 22, for the reason that this path is interrupted at the left armature and back contact of relay 31, which relay is at this time energized. Either operator thus by pressing a key corresponding to K—32 of connecting circuit CC—3 is able to cause the lighting of a supervisory lamp corresponding to SL—3 of the connecting circuit at the station of the other opera-

tor; and when the key K—32 is released, the control frequency is reapplied and lamp SL—3 extinguished, and the connection continues as it was before the key was pressed.

When the operators ascertain that the conversation is ended, they disconnect by withdrawing the three plugs of the connecting circuit that has been employed. The withdrawal of transmitting plug TP—3 from transmitting springjack TJ—3 releases relay 33 of channel C—13 and thus brings about the deenergization of the associated transmitting channel. It also opens the circuit extending by way of the registering sleeve contacts of plug TP—3 and springjack TJ—3 and deenergizes relay 35 of connecting circuit CC—3 and relay 63 of the control frequency generating apparatus and permits the release of these relays. Relay 35 in releasing returns to key K—31 the control over relay 34 of which it was deprived by the energization of relay 35 during the course of the station calling operation, and at the same time deprives key K—32 of the control over relays 35 and 36 which might otherwise improperly be exercised prior to the insertion of plug TP—3 into the springjack terminal of a transmitting channel. The release of relay 63 of the control frequency generating apparatus (Fig. 8) deenergizes amplifier A—63, thus withdrawing the 1,400 cycle control frequency, and also opens the energizing circuit of relay 32 (Fig. 8) that has been held closed at the outer right hand front contact and armature of relay 63 by way of conductor 45. Relay 32 thereupon releases and deenergizes the associated control transmitting channel C—14. The withdrawal of receiving plug RP—3 from springjack RJ—43 interrupts the branch that extends from battery through supervisory lamp SL—3 and the registering sleeve contacts of plug RP—3 and springjack RJ—43 to the common portion of the circuit including the windings of relays 31 and 16 and to ground. This, however, does not release relays 31 and 16, as they are still held energized through the locking branch controlled at the inner front contact and armature of relay 31. Therefore, the relays 31 and 16, after the plug is withdrawn, are left under the sole control of the relays associated with the tuned branch of the control receiving channel corresponding to the communication receiving channel with which relays 31 and 16 are associated.

The withdrawal of the transmitting plug at either station from the transmitting springjack in which it has been inserted causes the release of the relay 61, 62 or 63, depending upon the particular transmitting springjack in which the plug has been inserted and the withdrawal of the corresponding control frequency. The effect at the remote station of the withdrawal of the control

frequency upon disconnection is the same as the previously described effect when the withdrawal of the control frequency resulted from the pressing of the cord circuit signaling key K—32. That is, the effect is to light the supervisory lamp SL of the connecting circuit that is at the time in association with the corresponding communication receiving channel. Thus, whichever of the two operators is first apprized of the completion of the conversation, automatically calls the attention of the other operator to the connection by withdrawing the connecting circuit transmitting plug from the springjack in which it has been inserted. The second operator may then supervise and withdraw the three plugs of the connecting circuit that has been employed for establishing the connection, the results of the withdrawal of the plugs at one station being the same as that at the other station.

As has been pointed out, the relays 31 and 16 of the communication receiving channel that has been in use are held energized after the plug has been withdrawn from the associated springjack, and are thus held energized until the transmitting plug has been withdrawn from the springjack of the corresponding communication transmitting channel at the distant station. When this occurs the withdrawal of the corresponding control frequency modulation of the control carrier wave releases relay 21, which energizes associated relay 25; and relay 25 in operating opens at its back contact and armature the circuit by way of the inner armature and contact of relay 31 which has been maintaining relays 31 and 16 energized. Therefore, both relays are released. If relay 31 had been permitted to release as soon as plug RP—3 was withdrawn from springjack RJ—43 and before relay 25 had responded to the withdrawal of the control frequency at the distant station, the associated line lamp L—43 would have been relighted, thus giving a false signal. As relay 25 is now in its normal energized condition and relay 31 is released, a circuit is closed that extends from ground by way of the front contact and armature of relay 22, left back contact and armature of relay 31 and front contact and armature of relay 25 to the winding of relay 28. This direct path to ground short circuits and releases relay 28. This completes the restoration to normal of the apparatus associated with the receiving channels. As the apparatus associated with the transmitting channel and with the control frequency generating apparatus has been released by the withdrawal of the transmitting plug from the transmitting channel springjack, as has hereinbefore been described, all of the apparatus is now in its normal condition.

In the preceding description of the estab-

lishment of the two-way radio link between the calling and called stations it has been assumed that none of the other communication transmitting channels of the calling station was at the time in use. A condition will now be assumed in which station 1 receives a call from station 4 over communication receiving channel RC—43 (Fig. 3) at a time when the associated channels RC—41 and RC—42 incoming from station 4 are both in use, channel RC—41 being in use for connecting station 4 with station 1 and channel RC—42 being in use for connecting station 4 with some distant station other than station 1. Under the conditions assumed relay 19 associated with tuned branch 129 corresponding to receiving channel RC—41 is in its operated condition as a result of the modulation of the 735,000 cycle control carrier wave with the 1,000 cycle control frequency, and the associated relay 23 is released. The other associated relays 26 and 29 are both operated, as one of the connecting circuit receiving plugs is inserted in springjack RJ—41 of receiving channel RC—42. In the case of communication receiving channels incoming from station 4, RC—42, relay 20 associated with the corresponding tuned branch 130 of the control channel is energized as a result of the modulation of the 735,000 cycle control carrier wave of station 4 with the 1,200 cycle control frequency; and as a result of the energization of relay 20, associated relay 24 has released its armature. But for a reason which will presently be explained neither associated relay 27 nor associated relay 30 of corresponding communication receiving channel RC—42 is energized. Now with a condition existing such as has been outlined above, station 4 calls station 1 by modulating its 735,000 cycle carrier wave first with the 200 cycle control frequency to select station 1 and then with the 1,400 cycle control frequency to identify channel RC—43 incoming from station 4 at station 1 as the channel over which communication is to be established. The modulation of the 735,000 carrier wave of station 4 with the 200 cycle control frequency energizes the tuned branch 128 at called station 1. The corresponding branches at the other stations, stations 2 and 3, are not affected, as these branches at stations 2 and 3 are responsive only to the 400 cycle and 600 cycle modulations. As a result of the energization of tuned branch 128, relay 18 operates and breaks the energizing circuit of relay 22, thus releasing that relay. Relay 22 in releasing breaks the normal connection of its armature to ground and completes a circuit that extends from battery through resistance 49, back contact and armature of relay 22, and thence by way of whichever of the branch paths extending from the armature of relay 22 are closed. The first encountered of these branch paths, that as-

sociated with tuned branch 129 and corresponding receiving channel RC—41, is open at the left back contact and armature of relay 29 associated with channel RC—41, as it has
 5 been assumed that this channel is in use at station 1 as a result of which relay 29 is energized. The next branch path from the armature of relay 22 is closed at the left back contact and armature of relay 30 associated with
 10 receiving channel RC—42, as this channel is not in use at station 1; but it is open at the front contact and armature of relay 24, for the reason that as long as the corresponding channel is in use for connection with any station
 15 relay 20 is operated and corresponding relay 24 is released. Therefore, the only one of the branches from the armature of relay 22 that becomes energized as a result of the release of that relay is the one which extends
 20 by way of the left back contact and armature of relay 31 and front contact and armature of relay 25 associated with the non-busy communication receiving channel RC—43 incoming from station 4. Consequently the result
 25 of the response of relay 18 to the 200 cycle modulation of the 735,000 cycle control carrier wave of station 4 is the energization of relay 28 alone. Relay 28 in operating locks up and applies battery by way of resistance
 30 50 to the armature of relay 25, so that when relay 25 releases shortly thereafter in response to the modulation of the control carrier wave with the 1,400 cycle control frequency, it causes the lighting of line lamp
 35 L—43 associated with the springjack RJ—43 of channel RC—43 that calling station 4 has taken for use.

It will now be assumed that when station 4 calls station 1 all of the communication transmitting channels of station 4 are available
 40 for use. As a result, when relay 18 of station 1 operates and associated relay 22 releases as a result of the application of the 200 cycle control frequency to the 735,000 cycle carrier
 45 wave, all of the branch paths from the armature of relay 22 to ground by way of relays 26, 27 and 28 are in a closed condition, and consequently all of these three relays are energized. Each of three relays 26, 27 and 28 is
 50 thereupon locked up by way of the path from battery through the armature and front contact of the relay, and battery is thus applied to the armature of each of the corresponding
 55 relays 23, 24 and 25. But as none of the communication transmitting channels of calling station 4 is as yet in use, the relays 23, 24 and 25 are in their normally energized condition and have no connection with ground to make
 60 effective the potential that has been applied to the armatures. Assuming now that the operator at calling station 4 chooses for use the communication transmitting channel that corresponds to communication receiving
 65 channel RC—43 of called station 1; a predetermined interval after the 735,000 cycle

carrier wave is modulated with the 200 cycle control frequency for calling station 1, the carrier wave is also modulated with the 1,400 cycle control frequency. To this modulation relay 21 responds by way of tuned
 70 branch 131, and the response of relay 21 causes the release of associated relay 25. Relay 25 thereupon closes its back contact and the potential that is applied to the armature of relay
 75 25 by way of the closed contacts of relay 28 becomes effective to light line lamp L—43 of the corresponding communication receiving channel. As the 1,000 and 1,200 cycle control frequencies to which tuned branches
 80 129 and 130 are responsive have not been applied to the control carrier wave, relays 19 and 20 remain inert and associated relays 23 and 24 remain energized. Therefore, the line lamps L—41 and L—42 of the corresponding communication receiving channels
 85 are not lighted. As has heretofore been explained, the station calling control frequency, in this case 200 cycles, is withdrawn from the control carrier wave a predetermined interval
 90 after the channel identifying frequency is applied. Consequently the relay 18 is released and the relay 22 is energized shortly after the line lamp L—43 has been lighted in response
 95 to the energization of relay 21 and release of relay 25. When this occurs relay 22 in operating connects its armature directly to ground at its front contact; and as relays 23 and 24 are still in their normally operated conditions and relays 29 and 30 of the corresponding channels are inert, this ground is
 100 immediately applied as a short circuit of the windings of associated relays 26 and 27, and these relays are thereupon released, and the normal condition of the circuit is established excepting as to the relays associated with
 105 communication receiving channel RC—43 which has been taken for use.

The application of the channel identifying control frequency to the control carrier wave at any of the stations causes the response of
 110 the relays in the corresponding tuned branches of the corresponding control receiving channel at all of the distant stations; and this response or operative condition of the relays continues as long as the channel
 115 identifying control frequency is applied. But as the station selecting relay 22 does not operate at the distant stations other than the called station, the response of the relays 19, 20 or 21 at these other stations is without
 120 effect in so far as the lighting of the corresponding communication receiving channel lamp is concerned, and is effective only to establish a condition that prevents a calling
 125 indication from subsequently being given upon the lamp of the corresponding channel as long as the channel continues in use at some other station.

One set of resistance values for the elements that are included in the branches of the sig- 130

nal controlling network associated with the control receiving channel may conveniently be approximately as follows: the resistance element 49 may have a resistance of 100 ohms; the resistance elements 50 may have resistances of 40 ohms each; the relays 26, 27 and 28 may have resistances of 500 ohms each; the relays 31 and 16 may each have a resistance of 60 ohms; the supervisory lamps SL of the connecting cord circuits and the line lamps L of the communication receiving channels may have resistances of 120 ohms each; and the resistance element 55 associated with each line lamp may have a resistance of 40 ohms. These resistance values are upon the basis of an electromotive force of 24 volts for the battery that supplies current for the energization of the various devices in this network. Other sets of electromotive force and resistance values may of course also be employed. The circuits over which the other relays of the organization are energized are simpler and subject to less variation of current flow under the different operating conditions set up than the network for the elements of which the above values have been assigned; and it is believed that the resistance and electromotive force values suitable for the other circuits will be readily apparent to those skilled in the art who may desire to practice the invention.

What is claimed is:

1. In a multiplex carrier signaling system, a plurality of groups of carrier wave communication channels, a plurality of stations to which said channels have access, each group of channels serving for transmitting exclusively from one of said stations and having receiving terminals in each of the other stations, a call signal associated with each channel receiving terminal, means controlled from a station in transmitting to operate one of said call signals at a distant call station to the exclusion of all the call signals both at that and at the other stations to indicate the channel over which communication is to take place and the station that is calling.

2. In a wave communicating system, a multiplicity of stations, a group of carrier wave channels terminating at each station and serving for transmitting from the respective station exclusively, receiving channel terminals at the other stations for all of the transmitting channels of the distant stations, circuits for pairing any one of the transmitting channels at each of two stations with the corresponding receiving channel at each of the two stations to form a two-way conversational channel, and calling means associated with said circuits for marking at the distant one of said two stations, to the exclusion of the other stations, the receiving channel to be taken as one of the pair, and the station in which the transmitting end of the channel so marked terminates.

3. In a multiplex carrier signaling system, a plurality of groups of communication channels employing carrier waves transmitted over the same medium, stations to which said channels have access, signals for the respective channels at said stations, a separate high-frequency control channel for each group of communication channels, and means controlled over each respective control channel for selectively actuating the individual signals of the associated group of communication channels.

4. In a high frequency communicating system having a plurality of stations, means at each station for transmitting a carrier wave differing from the carrier waves transmitted by the other stations, and means at each station selectively responsive to the carrier waves transmitted by the other stations and operating to identify the particular station that is transmitting.

5. In a high frequency communicating system having a plurality of stations, means at each station for transmitting a carrier wave differing from the carrier waves transmitted by the other stations, means at each station selectively responsive to the carrier waves transmitted by the other stations and operating to identify the transmitting station, and means at each station for transmitting and at each other station for receiving modulations of the transmitted carrier wave to identify the particular station that is being called.

6. In a high frequency communicating system having a plurality of stations, means at each station for transmitting a carrier wave differing from the carrier waves transmitted by the other stations, means at each station selectively responsive to the carrier waves transmitted by the other stations and operating to identify the station that is transmitting, means at each station for transmitting and at each other station for receiving modulations of the transmitted carrier wave for identifying the particular station that is being called, other communicating carrier waves adapted to be transmitted by each station and received by each other station, and means at each station for transmitting and at the called station for receiving modulations of said first mentioned carrier wave to indicate the particular communicating carrier wave that the transmitting station is about to employ for communicating purposes.

7. In a high frequency communicating system having a plurality of stations, means at each station for transmitting a carrier wave differing from the carrier waves transmitted by the other stations, means at each station selectively responsive to the carrier waves transmitted by the other stations and operating to identify the transmitting station, other communicating carrier waves adapted to be transmitted by each station and received

by each other station, and means at each station for transmitting and at each other station for receiving modulations of said first mentioned carrier wave to indicate the particular communicating carrier wave that the transmitting station is about to employ for communicating purposes.

8. In a high frequency communicating system having a plurality of stations, means at each station for transmitting communicating carrier waves differing from the communicating carrier waves transmitted from the other stations, means at each station for receiving the carrier waves transmitted by each of the other stations, and other high frequency means at each station controlled from each other station for indicating the particular communicating carrier wave that said other station is about to employ for communicating purposes.

9. In a high frequency communicating system having a plurality of stations, a plurality of one-way high frequency communicating channels for the interconnection of said stations, each of said channels being individual to a particular station for transmitting and common to all of the other stations for receiving, means at each station for establishing transmitting relation with one of said channels and receiving relation with another of said channels for two-way communication with any desired one of said other stations, and high frequency responsive means at each station controlled by each of the other stations for indicating the station that is calling and the station that is called in the establishment of two-way communication over said channels.

10. In a high frequency communicating system having a plurality of stations, a plurality of high frequency one-way communication channels adapted to be temporarily operatively associated in oppositely directed pairs to constitute two-way communicating trunks between said stations, and high frequency transmitting and receiving means separate from the communication channels at each station for exclusive use in controlling the establishment of said two-way high frequency communicating trunks between the stations of said system.

11. In a carrier telephone system, a group of carrier telephone channels, a call signal for each of said channels, terminal circuits adapted to be connected with said channels for extending calls, a disconnect signal for each of said channels, a separate control channel, means to transmit simultaneously a plurality of control indications over said control channel, and means selectively responsive to certain of said control indications for actuating certain of said signals and responsive to other of said indications for actuating other of said signals.

12. In a wave signaling system, a receiving station having a plurality of terminal

circuits over which carrier waves may be received, connection-extending circuits, a distant transmitting station having means to transmit a pair of high frequency waves, means at the receiving station responsive to one of said pair of waves for designating the terminal circuit over which the other of said pair of waves may be received, and means responsive to the connection of a connection-extending circuit to the designated terminal circuit for enabling communications to be carried on by means of the carrier wave received over the connected terminal circuit.

13. In a high frequency communicating system having a multiplicity of stations and a plurality of high frequency communicating channels for the interconnection of said stations, transmitting terminals for certain different ones of said channels and receiving terminals for the rest of said channels at each station, selectively operated call indicating means associated with the receiving terminals at each station, a plurality of high frequency controlling channels each having transmitting means individual to a particular one of said stations and receiving means at the other stations, and mechanism under the control of said receiving means for controlling said selectively operated call indicating means at the corresponding station.

14. In a high frequency communicating system having a plurality of stations and a plurality of high frequency communicating channels for the interconnection of said stations, transmitting terminals for certain different ones of said channels and receiving terminals for the rest of said channels at each station, a signal for each of said receiving terminals at each station, and high frequency means independent of said high frequency communicating channels for giving each station control over the associated signals of the channel receiving terminals at all of the distant stations.

15. In a high frequency communicating system having a plurality of stations and a plurality of high frequency channels for the interconnection of said stations, transmitting terminals for certain different ones of said channels and receiving terminals for the other of said channels at each station, a local communicating circuit at each station, means for temporarily associating said local communicating circuit with any desired one of said transmitting channel terminals, call indicating signals associated with the receiving terminals at each station, and means made operative in the temporary association of said local communicating circuit with one of said transmitting channel terminals to cause the operation of the associated signal of the corresponding receiving channel terminal at a distant station.

16. In a high frequency communicating

system having a plurality of stations and a plurality of high frequency channels for the interconnection of said stations, transmitting terminals for certain different ones of said channels and receiving terminals for the other of said channels at each station, a local communicating circuit at each station, means for temporarily associating said local communicating circuit with any desired one of said transmitting channel terminals, a call indicating signal associated with each of said receiving channel terminals at the various stations, and means associated with said local communicating circuit and made operative in the temporary association of said local communicating circuit with a transmitting channel terminal for operating the call indicating signal of the corresponding receiving channel terminal at a particular one of the remote stations of the system.

17. In a high frequency communicating system in which each of a multiplicity of stations has assigned for its sole use a certain number of carrier waves for transmitting purposes and is receptive of the carrier waves transmitted by each of the other stations, the method of interconnecting the stations which consists in each of the two stations selecting and transmitting any available one of the carrier waves assigned for its sole use, transmitting a signal indication to the distant station to indicate the particular carrier wave that has been selected, and temporarily operatively relating the selected transmitted carrier wave with the received carrier wave transmitted by the distant station, as identified by the signal indication, to constitute a communicating pair of waves between the two stations.

18. In a high frequency communicating system in which a number of normally non-paired one-way carrier waves are employed for the interconnection of the various stations of the system, the method of interconnecting the stations which consists in selecting two carrier waves, transmitting one of said waves from each of the stations to be connected and receiving the wave at the other station, transmitting to each station a signal identification of the wave that the other station is transmitting, and temporarily operatively relating at each station as a communicating pair the carrier wave transmitted from that station and the carrier wave received from the other station.

19. In a high frequency communicating system having a plurality of stations, the method of producing carrier wave frequencies which consists in transmitting to each station from a common source a higher base frequency and a lower base frequency, generating certain desired harmonics from each of said base frequencies, selecting each desired harmonic of the lower base frequency and

combining it separately with a plurality of the harmonics of the higher base frequency taken collectively, and selecting for use the combination products of each of the lower base frequency harmonics with each of the higher base frequency harmonics.

20. The method of deriving a series of radio carrier frequencies relatively closely spaced in the frequency range from two base frequencies, which consists in separately generating certain desired harmonics from a relatively high base frequency and a relatively low base frequency, separately modulating the individual desired harmonics generated from the higher base frequency with a part of the desired harmonics generated from the lower base frequency, and selectively separating for use the sum and difference modulation products of each of the higher base frequency harmonics with the particular lower base frequency harmonics with which in each case they have been collectively modulated.

21. In a high frequency communicating system, means for producing and receiving a relatively high base frequency and a relatively low base frequency, means for separately generating certain desired harmonics of each of said base frequencies, means for separately selecting each desired harmonic of the lower base frequency, a plurality of modulators in each of which a plurality of the higher base frequency harmonics collectively are modulated with a particular different one of the lower base frequency harmonics, a distributing circuit for each modulator, and a plurality of tuned circuits branching from each distributing circuit, each tuned circuit being adapted to divert from its associated distributing circuit a particular different one of the modulation products of the plurality of higher base frequency harmonics with the particular lower modulating base frequency harmonic of the corresponding modulator.

22. In a high frequency communicating system, means for producing a relatively high base frequency and a relatively low base frequency, means for separately generating certain desired harmonics of each of said base frequencies, means for separately selecting each desired harmonic of the lower base frequency, a plurality of modulators in each of which a plurality of the higher base frequency harmonics collectively are modulated with a particular part of the lower base frequency harmonics, and means for selectively deriving from each modulator the sum and difference modulation products of each of the higher base frequency harmonics and the particular part of the modulating lower base frequency harmonics.

23. In a high frequency communicating system having a plurality of stations, means at one station for transmitting a high frequency carrier wave modulated by low fre-

quency communicating currents, means at another station for receiving said modulated carrier wave, means at the receiving station for producing a wave identical with said carrier wave, a communicating terminal at said receiving station associated with the receiving means of said modulated carrier wave, and means made operative in making connection with said communicating terminal for applying said identical frequency for the demodulation of said modulated carrier wave to reproduce immediately and make available at said communicating terminal the low communicating frequency with which the transmitted carrier wave is modulated.

24. In a high frequency communicating system having a plurality of stations, means at each station for producing a number of carrier waves for the exclusive use of the station in transmitting and a number of other carrier waves identical with the carrier waves employed by the other stations of the system in transmitting, means at each station for modulating its exclusive carrier waves with communicating currents, means at each station for receiving the modulated carrier waves transmitted from the other stations, means at each station for applying the corresponding locally generated carrier wave to the received modulated carrier wave to demodulate the same and reproduce the communicating current with which the carrier wave is modulated at the distant station, a connection terminal for establishing communicating relation with the received modulated carrier wave, and means made operative in making connection with said connection terminal for applying to said received modulated carrier wave the corresponding locally generated frequency to demodulate said carrier wave and immediately reproduce the low frequency communicating current with which the carrier wave is modulated at the distant station.

25. In a selective signaling system, a sending station, a plurality of receiving stations, a plurality of indicating devices at each receiving station selectively responsive to different wave characteristics, the corresponding device at each station being responsive to the same wave characteristic, means at each receiving station responsive to a wave characteristic different from those to which the said devices are responsive, said means at said stations responding each to a different wave characteristic, said means at each station acting to prevent the response of any of said devices at the same station except said means be actuated in response to its characteristic wave, sources of waves of different characteristics at the sending station and means to send a wave of a characteristic adapted to actuate the said means at any desired station and a wave of a characteristic to which a de-

sired indicating device is responsive, whereby said device is actuated to the exclusion of the other devices at the same station and at the other stations.

26. In a selective controlling system, a plurality of stations, a plurality of devices to be controlled situated at each station, a corresponding plurality of receiving wave responsive elements at each station responsive to waves of different frequency, the elements at the different stations being responsive respectively to waves of the same respective frequencies, another wave responsive element individual to each station and each responsive to a different frequency of waves, means to transmit a wave of a frequency to which one of the receiving elements at each of a plurality of stations is responsive, means to transmit a wave of a frequency to which only the element individual to a desired station is responsive, and means dependent upon the actuation of both the element individual to the station and the selected receiving element for actuating the desired device.

27. In a selective controlling system, a plurality of stations, a plurality of devices to be controlled situated at each station, a corresponding plurality of selecting elements at each station each selectively responsive to a wave of a different frequency, the corresponding selecting element at each of a plurality of stations being responsive to the same frequency of wave, an element individual to each station and responsive each to a wave of a different frequency means to send out a station-selecting wave having a frequency to which only the element individual to the desired station is responsive, means to send out to all of said stations a wave to which the receiving element for controlling the desired device is selectively responsive and to which the corresponding receiving element at the one or more other stations is also responsive, to select the desired device, and means effective only upon the actuation of the element individual to a station and a receiving element at the same station for actuating the corresponding device at said station.

28. In a selective controlling system, a plurality of stations M in number, a plurality of devices to be controlled up to N in number at each station, means to transmit waves of M different frequencies, each selective of a station, and to transmit waves of N different frequencies, each selective of a device at each station, and wave responsive means whereby any one of the M times N devices may be selected and controlled by the conjoint action of any of the M different waves and one of the N different waves.

29. In a selective controlling system, a plurality of stations, a frequency selective element individual to each station, a plurality of devices to be controlled situated at each

station, a corresponding plurality of frequency-selective elements at each station, the corresponding frequency-selective element of said last mentioned plurality at each station being responsive to the same frequency, means to select a given device at a desired station comprising means for transmitting a wave of the frequency to which the element individual to that station is selective and a wave of the frequency to which the element corresponding with the desired device is selective, and means to prevent the other devices from being actuated.

30. In a multiplex signaling system, a plurality of discrete high frequency communication channels for transmitting over the same medium, signals associated with the respective channels, a separate high frequency controlling channel for transmitting control indications over said medium, means to transmit a high frequency wave continuously over said controlling channel throughout the time that any of said plurality of communication channels is in use, means to impress upon said high frequency wave separate indications corresponding to the individual communication channels, and means responsive to said indications for actuating the corresponding signals associated with said communication channels.

31. In a multiplex signaling system, a plurality of distinct high frequency communication channels for transmitting over the same medium, a separate high frequency controlling channel for transmitting over said medium, a plurality of stations to which all of said channels have access, a signal for each channel at each station, means to transmit a plurality of indications over said controlling channel for individually identifying said communication channels and a second plurality of indications for identifying the stations, and means responsive to the joint action of a stations-designation indication and a channel-designating indication for actuating the signal of a particular channel at a particular station.

32. In a multiplex signaling system, a plurality of distinct high frequency communication channels, means to connect telephone circuits to said channels and to carry on separate telephone conversations over the respective channels, supervisory signals for said channels, a separate high frequency control channel, and means controlled over said control channel for actuating said supervisory signals for said channels.

33. In a multiplex telephone system, a carrier telephone channel, supervisory signals for said carrier telephone channel, a high frequency control channel, means controlled over said control channel for transmitting calling indications for said carrier telephone channel and for exercising a continuous control over said supervisory signals during a conversation over said carrier telephone channel, a second carrier telephone channel, and means to transmit a calling indication over said control channel for said second carrier telephone channel simultaneously with the exercising of said control over said supervisory signals.

34. In a multiplex telephone system, a group of carrier telephone channels, stations to which said channels have access, a call signal at each station for each channel, a supervisory signal at each station for each channel, a high-frequency control channel common to said groups of carrier telephone channels, and means controlled over said control channel for actuating each of said signals.

35. In a carrier telephone system, a group of carrier telephone channels, a call signal for each of said channels, a disconnect signal for each of said channels, a separate control channel, means to transmit separate indications over said control channel, and means responsive to said indications for selectively actuating signals of both of said kinds.

36. In a multiplex carrier signaling system, a plurality of groups of carrier wave communication channels, a plurality of stations to which said channels have access, each group of channels serving for transmitting exclusively from one of said stations and having receiving terminals in each of the other stations, a separate control channel associated with each group of channels, means at any station for temporarily associating any receiving terminal at that station with one of the channels serving as a transmitting channel for that station to form the two sides of a two-way communication trunk between the last-mentioned and another of said stations, and means controlled over one of said control channels for indicating the receiving terminal that is to be so associated with a transmitting channel.

In witness whereof, I hereunto subscribe my name this 18th day of December A. D., 1922.

EDWIN H. SMYTHE.