Dec. 22, 1936. L. ESPENSCHIED ET AL 2,064,895

COMMON MEDIUM MULTICHANNEL EXCHANGE SYSTEM

Filed May 26, 1934 2 Sheets-Sheet 1

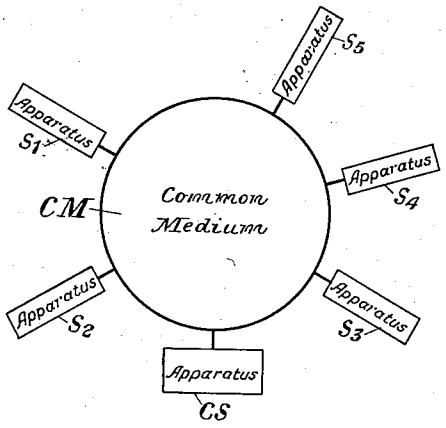


Fig. 1

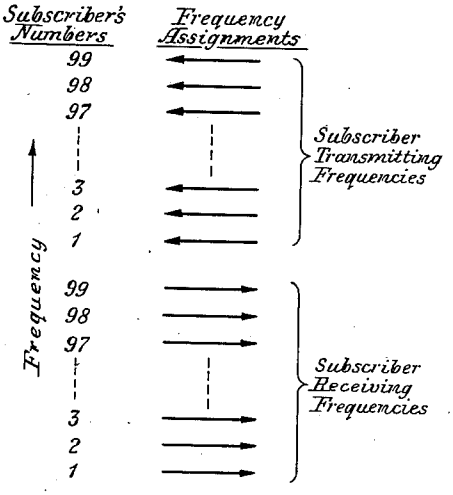


Fig. 3

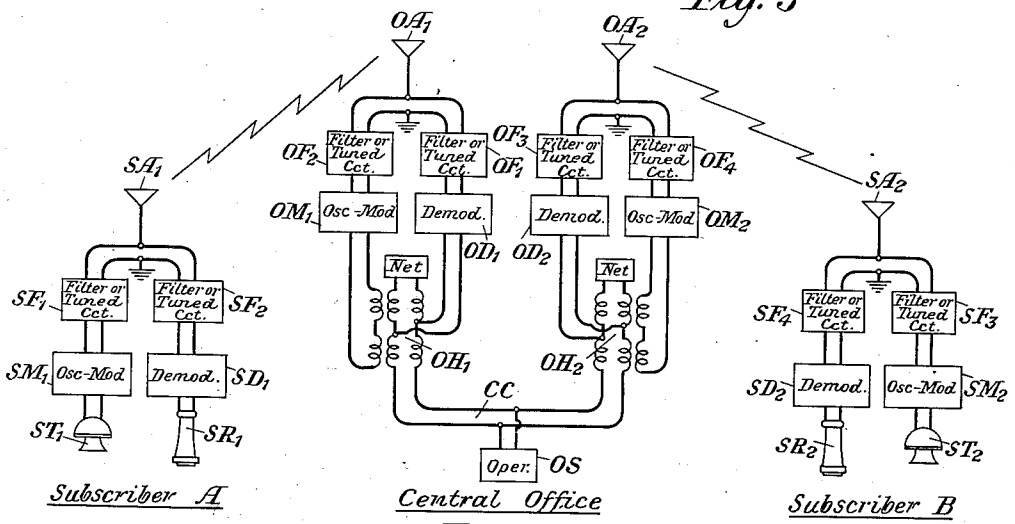


Fig. 2

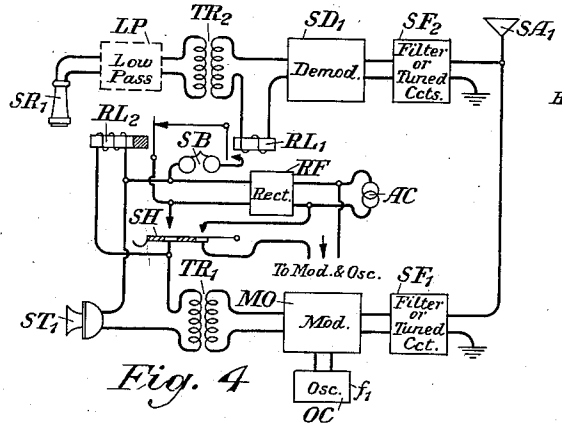


Fig. 4

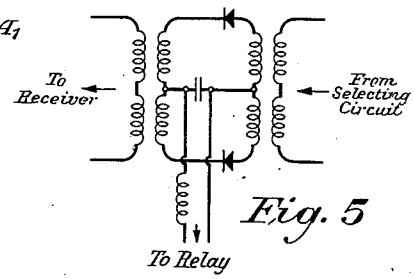


Fig. 5

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Dec. 22, 1936. L. ESPENSCHIED ET AL 2,064,895

COMMON MEDIUM MULTICHANNEL EXCHANGE SYSTEM

Filed May 26, 1934 2 Sheets-Sheet 2

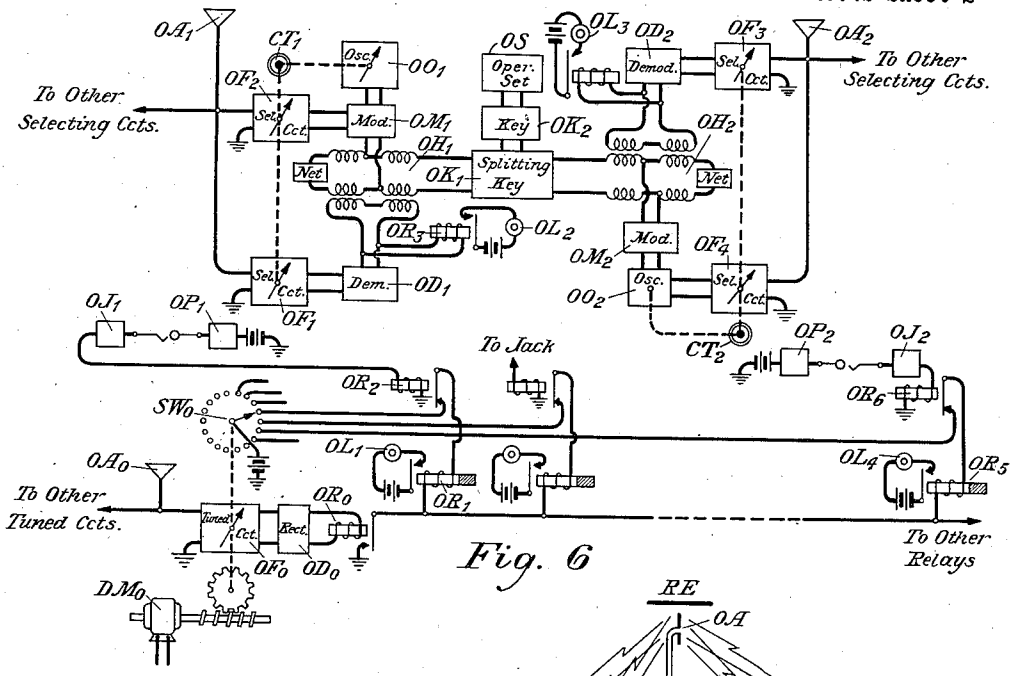


Fig. 6

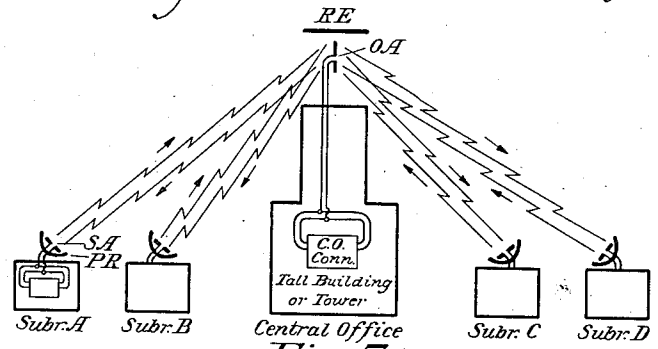


Fig. 7

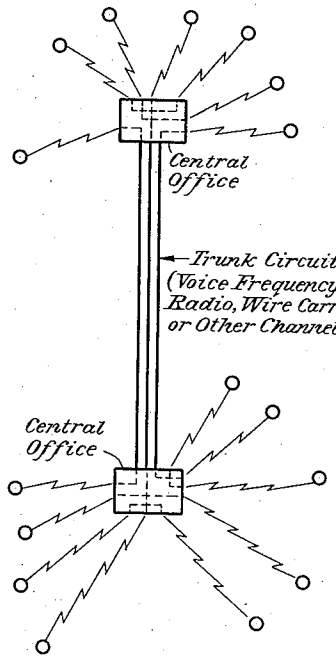


Fig. 8

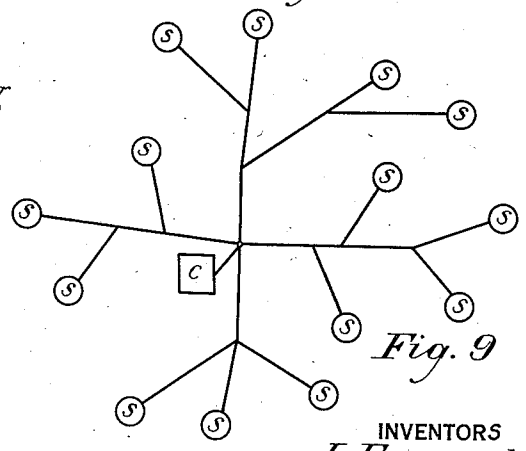


Fig. 9

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UNITED STATES PATENT OFFICE

2,064,895

COMMON MEDIUM MULTICHANNEL EXCHANGE SYSTEM

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Application May 26, 1934, Serial No. 727,808

14 Claims. (Cl. 250—6)

This invention has for its object the provision of an exchange system in which communication between subscribers is carried out over channels of different frequency derived from a common transmission medium. More particularly, the invention is designed to utilize as a substitute for the many subscriber pairs which are employed in the ordinary telephone exchange system the many channels which are obtainable in the high frequency art as it is now unfolding and to provide means whereby these channels may be employed by subscribers for interconnections.

In the telephone exchange systems which have heretofore been provided it has been the practice to group subscribers in central office areas. Each subscriber is connected to his own central office by means of an individual wire circuit or by a party line arranged for nonsimultaneous use by a few subscribers. When a subscriber desires to call another subscriber he utilizes his own line to the central office, and upon passing the desired number either to an operator or to an automatic switching mechanism is connected to another line which extends either directly or via another office or offices to the called party. For a system of this kind many thousands of subscriber circuits are necessary in each central office area. These are commonly provided in the form of a network of multiple pair cables extending over the area.

In accordance with the present invention, it is proposed to substitute for such individual wire circuits extending to each subscriber a transmission medium which is common to all subscribers and which will accommodate a range of frequencies sufficiently wide for a large number of telephone channels. Interconnection between subscribers is then carried out over these high frequency channels.

The essence of the invention resides in making available to a large number of subscribers a transmission medium capable of accommodating a wide range of frequencies so that the subscribers may utilize, for the purposes of intercommunication, a plurality of signaling channels derived from the wide band medium. A transmission medium capable of handling the large number of channels required for the exchange system of the invention may be obtained by utilizing either radio transmission in space or high frequency transmission over a conducting or guiding medium.

This type of system is not known to have been heretofore invented, apparently because the necessary wide frequency spectrum which is required has not been available to the art either by radio or wire methods. A conception of the band width which is required may be had by assuming that there is taken as a unit a local exchange system of 1,000 subscribers and that each subscriber is allotted an individual channel of 10,000 cycles, making a total band width of some 10,000,000 cycles. Any such band width as this has not been available in the art until very recently.

In the case of radio, until the recent opening up of the ultra-high frequency (ultra-short wave) range, the art has not permitted the invention to be realized, for three reasons: First, there was not sufficient space in the frequency range, which until recently did not go beyond about 30 mc., to accommodate this type of service along with all the other demands upon the radio spectrum; second, the characteristics of the waves vary widely through this spectrum (up to 30 megacycles), so that it is difficult to obtain a wide band having sufficiently uniform characteristics for the purpose; third, the waves in this range do not cut off very sharply with distance, and as a result their interfering effects extend to great distances, in many cases thousands of miles, making it impossible to operate a local service in one area without giving rise to interference in distant areas. With the opening of the ultra-high frequency range, frequencies above 30 mc. (wave lengths below about 10 meters), an entirely new prospect is presented, making it for the first time physically possible to set up by radio the system comprising the invention. Of course, this is not saying that the system will either prove to be desirable or economical for actual operation. This will not be known until a great deal of development work is done and the general art is much further advanced.

It will be appreciated also that the invention has not been feasible heretofore as a wire proposition because it has not been possible until very recently to transmit over wire circuits for considerable distances frequency bands greater than some tens of thousands or, at most, hundreds of thousands of cycles. The transmission of bands of some millions of cycles as required by the invention has become possible by wire methods only recently through the development of radically new types of wire systems, as exemplified by the coaxial conductor type of line, as described in U. S. Patent No. 1,835,031, to L. Espenschied and H. A. Affel. These new wire systems are characterized by the provision of means for quite completely shielding the transmission path from outside disturbances. This is done in the co-

axial circuit by the outer conductor which serves both as a shield and one of the line conductors. By virtue of the skin effect at these very high frequencies, the desired transmission is confined to the inner surface of the tube and interference originating from without is confined to the outer surface. Thus, the shielded type of circuit permits of blocking off a wide frequency band for the purposes of the invention and subjecting the transmitting medium to full control in respect to the exclusion of interference, the prevention of overhearing on the part of outsiders and the general knitting together of the system as a self-contained unit. In other words, in this wire embodiment of the invention there are retained the advantages of wire transmission, plus the advantage of radio in respect to the availability of a wide frequency spectrum.

In general, these recent developments, whereby the frequency range of radio and of wire transmission is being greatly extended, are the basis of the present invention. The extension of the frequency range is so great as to amount to the imparting to the art of a new dimension of development, the frequency dimension, whereby it becomes possible to derive large numbers of telephone channels and to handle them as a group. Thus, there is obtained on a frequency basis large numbers of identical channels comparable to the large number of physical circuits which are obtained in the local telephone plant in the familiar telephone cables.

Considering, first, the use of radio as the medium for transmitting the wide band of frequencies contemplated by the invention, the invention is designed to employ whatever part of the frequency range may be available. Heretofore, however, the radio frequency spectrum has scarcely afforded sufficient frequency space to yield the channel capacity required for a local telephone exchange system. With the opening up of the field of ultra-short waves this limitation as to channel capacity is removed. Thus, for example, between one and two meters there is a total frequency range of 150 megacycles while the range between 10 and 20 centimeters is 1,500 megacycles. The frequency ranges obtainable through the use of still shorter waves are much greater.

With these ultra-high frequencies, however, nature imposes another limitation, i. e., the tendency of the waves to take on quasi-optical characteristics, so that they project only in straight lines and do not bend around corners to any considerable extent. Thus, it becomes necessary that subscribers utilizing such waves have a fairly clear line of sight between their antennas. Some diffraction around obstacles may, of course, be obtained, but, in general, reasonably clear line-of-sight projection without intervening obstacles appears to be called for. This, of course, has the advantage of making it possible to utilize the same ultra-high frequencies in different areas.

The line-of-sight characteristics of the ultra-short waves must be recognized in the design of a telephone exchange system utilizing this technique. In one form of the invention it is proposed to provide in the center of a community a central station with antennas mounted sufficiently high above the surrounding buildings to make possible the necessary directness of transmission between these antennas and practically any point in the territory to be served. One subscriber's station is then placed in connection with another by transmitting first to the central station and thence through the central station to the desired other subscriber located in another part of the community. The central station acts as a means for catching the waves from one subscriber at a relatively high point and transmitting them down again to a second subscriber, thus lifting the transmission path above any obstacles lying between the subscribers' antennas.

In order that such a central station may be economical, it is proposed to make it capable of handling simultaneously a wide band of frequencies such as would accommodate hundreds or perhaps thousands of channels. The particular arrangement of the central station will be hereinafter described.

As an alternative to the use of a radio transmission medium, the invention contemplates the employment of a guiding or conducting transmission path suitable for the required band of frequencies. Such a transmission path would be provided in the form of a network, extending to all the subscribers within a given area. Conceivably, such a network might be composed of ordinary wire circuits branched and interconnected so as to make the common circuit available to each subscriber. Thus, the wire network might be somewhat similar to the network employed for distributing light and power currents, except that a simple two-wire network without multi-phase connections, voltage transformation arrangements, etc., would suffice. It would, however, be possible to carry out the invention by employing the light and power network itself and this is contemplated within the scope of the invention.

The preferred form of guiding transmission medium, however, is one which is designed for the transmission of a wide band of frequencies with comparatively low attenuation and preferably also with shielding to minimize the effect of external disturbances. Such a transmission medium may be found in a circuit consisting of two conductors disposed coaxially with respect to one another. In a properly designed coaxial circuit, low attenuation at high frequencies may be attained by the employment of conductors of suitably low high-frequency resistance and the use of a substantially gaseous dielectric between the conductors. With this type of circuit the outer conductor serves also as a shield whose protective effect becomes more nearly perfect as the frequency is increased, so that at high frequencies practically complete immunity from external disturbances may be obtained.

The invention contemplates also as an alernative to the coaxial circuit a high frequency transmission medium comprising a circuit consisting of two conductors surrounded by a shield. Here, again, the high frequency attenuation may be minimized by proper design with substantially gaseous insulation and the thickness of shield may be determined so as to minimize interference from external disturbances.

Yet another form of transmission medium suitable for carrying out the invention is a dielectric wave guide comprising a cylindriform dielectric material which may or may not be surrounded by a conductor. An advantageous form of such a transmission path is a hollow cylindrical conductor containing air or some other gas as the dielectric. This type of circuit is particularly adapted to transmit waves of very high frequencies, for example, of the order of a few centimeters or less in wave length.

Using any of the above types of transmission

media, the interconnection of subscribers at will from the available channels involves a number of new and difficult problems which are solved by the various features of the invention as hereinafter disclosed.

In general, the invention contemplates the assignment to each subscriber of two particular frequencies which might preferably be related to his telephone number. The assignment of frequencies should be such as to facilitate the interconnection of subscribers and one scheme of frequency allocation is suggested in the invention for this purpose.

The foregoing outline having indicated some of the principles of the invention as well as a few of its major objects, the complete invention with its various details, features and purposes will now be understood from the following description when read in connection with the accompanying drawings, in which Fig. 1 shows a schematic representation of the principal idea of the invention wherein a plurality of stations are connected to a common transmission medium, Fig. 2 shows in schematic form a system for connecting subscribers through a central office using space radio transmission; Fig. 3 shows one possible allocation of frequencies for a multi-channel exchange system; Fig. 4 shows a subscriber station arrangement which may be used in the system of Fig. 2; Fig. 5 shows a modulating device which may be used in various applications of the invention; Fig. 6 shows a central office arrangement which may be used in association with the subscriber station arrangement of Fig. 4; Fig. 7 shows an antenna arrangement for use in a system of the type described; Fig. 8 is a schematic diagram indicating how connections between stations in different areas may be completed through central stations over trunk circuits; and Fig. 9 is a schematic diagram of a guiding or conducting network which is available in common to a central station and a number of individual stations.

Referring to Fig. 1, there is illustrated one of the principal aspects of the invention. In this figure is shown a common medium CM, to which are connected a plurality of stations S_1, S_2, S_3, etc., each of which includes transmitting, receiving and associated apparatus. This apparatus, which will be hereinafter described, is arranged to permit intercommunication between different pairs of stations over the common medium CM employing different frequency bands to permit simultaneous communication between different pairs of stations. Connection between any pair of stations, for example, S_1 and S_3, takes place through the common central station CS.

Fig. 2 shows in schematic form a telephone exchange system in which a number of subscribers may be interconnected through a central office, the connection between each subscriber and the central office being accomplished by radio transmission through space. Each subscriber is provided with transmitting apparatus including an oscillator-modulator and receiving apparatus including a demodulator, together with the necessary selecting circuits. At the central office a plurality of circuits such as the one shown are provided for interconnecting between subscribers. Each connecting circuit includes two separate sets of apparatus, each of which comprises a radio transmitter and receiver, and a connection to which the operator has access, between the two sets of apparatus.

Transmission from subscriber A to subscriber B is effected by means of the transmitter ST_1, the oscillator-modulator SM_1, the tuned circuit or filter SF_1, the antenna SA_1, the antenna OA_1, the tuned circuit or filter OF_1, the demodulator OD_1, the hybrid coil OH_1, the connecting circuit CC (across which is bridged the operator's set OS), the hybrid coil OH_2, the oscillator-modulator OM_2, the tuned circuit or filter OF_4, the antenna OA_2, the antenna SA_2, the tuned circuit or filter SF_4, the demodulator SD_2 and the receiver SR_2. Transmission in the opposite direction is accomplished in an analogous manner, employing the transmitter ST_2, the oscillator-modulator SM_2, the selecting circuit SF_3, the antenna SA_2, the antenna OA_2, the selecting circuit OF_3, the demodulator OD_2, the hybrid coil OH_2, the connecting circuit CC, the hybrid coil OH_1, the oscillator-modulator OM_1, the selecting circuit OF_2, the antenna OA_1, the antenna SA_1, the selecting circuit SF_2, the demodulator SD_1 and the receiver SR_1.

It is proposed that different frequencies be employed for the oppositely directed transmissions in Fig. 2 and that the frequencies employed between the calling subscriber and the central office be different from those used between the central office and the called subscriber. Transmission might be on either a double or a single sideband basis with the carrier frequency transmitted.

In order that simultaneous conversations may take place between a number of pairs of subscribers, it is necessary that the frequencies employed in the system of Fig. 2 be properly selected. One way of arranging the frequencies would be to assign to each subscriber a separate pair of frequencies, one for transmitting and one for receiving, and to provide apparatus at the central office for receiving and transmitting the various required frequencies. Thus, subscriber A might be assigned a transmitting frequency f_1 and a receiving frequency f_2, and subscriber B transmitting and receiving frequencies f_3 and f_4, respectively. This would mean that in Fig. 2 the modulators SM_1 and SM_2 would operate with carrier frequencies f_1 and f_3, respectively, and the modulators OM_1 and OM_2 with carrier frequencies f_2 and f_4, respectively.

With such a scheme it might prove desirable, in order to facilitate the allocation of frequencies and the interconnecting of subscribers, to have a constant difference between the transmitting and receiving frequencies of each subscriber or, in other words, to make

$$f_1-f_2=f_3-f_4=D \qquad (1)$$

The frequencies f_1, f_3, etc., might then be grouped in one part of the frequency spectrum and the frequencies f_2, f_4, etc., in another part. A diagram of a frequency allocation of this sort, assuming a total of 99 subscribers, is given in Fig. 3. It will be noted that the order of the frequency assignments corresponds to that of the subscriber numbers. This scheme, while not essential to all embodiments of the invention, is a very desirable feature.

Detailed arrangements of apparatus which might be used at the subscriber's station and at the central office in a scheme of this sort are illustrated in Figs. 4 and 6. While some of the apparatus shown in these figures is more particularly adapted to radio frequencies lying below the ultra-short wave range, it will be understood that such apparatus is shown merely to illustrate the principles of the invention, and is not intended in any way to limit its scope.

The operation of the subscriber's apparatus

illustrated in Fig. 4 is as follows: When the subscriber desires to make a call, the receiver SR_1 is removed from the switchhook SH. Through the contacts of the switchhook this closes a circuit which furnishes power supply to operate the oscillator and modulator OC and MO. The operation of the switchhook also provides D. C. supply for the transmitter ST_1, this supply being derived through a rectifier RF which is connected to the A. C. supply. The speech currents produced in the transmitter, after passing through the transformer TR_1, are modulated upon the assigned frequency, here assumed to be f_1. The oscillator and modulator may be separate units of any desired types, or a self-oscillating modulator may be used. The carrier and sidebands in the modulator output, after passing through the selecting circuit SF_1, are radiated by the antenna SA_1 to the central office. When communication with the central office is established in a manner hereinafter to be described, the number of the called subscriber is passed orally to the operator and after the proper arrangements are set up at the central office, communication is established with the called subscriber who is provided with apparatus identical with that of Fig. 4 except for the frequency assignments used.

In the case of an incoming call, the carrier frequency f_2 and its associated sidebands are received by the antenna SA_1, selected by the selecting circuit SF_2 and demodulated by the demodulator SD_1. This demodulator may be of the vacuum tube type, in which case it should be kept always in operating condition so that a call may be received. Preferably, however, the demodulator might comprise some passive element or elements, as, for example, copper-oxide units as shown in Fig. 5. Associated with the demodulator is a relay RL_1 which is operated by the rectified current resulting from the incoming carrier frequency and which in turn operates the call bell SB. When the subscriber answers the call, the switchhook SH is operated, which, in addition to completing the contacts previously mentioned, operates the slow-release relay RL_2, which breaks the circuit of the bell SB. The received voice frequency currents, after passing through the transformer TR_2, are applied to the receiver SR_1 and two-way communication is thus established. If desired, a low-pass filter LP (shown dotted in Fig. 4) may be included in the receiver circuit to suppress unwanted high frequency components in the demodulator output. It will be understood that a similar filter may be provided in the arrangements hereinafter described. When the subscriber hangs up, the slow release feature of RL_2 prevents his bell from ringing before the other party also hangs up.

Fig. 6 illustrates central office apparatus which may be used in conjunction with the subscriber's apparatus shown in Fig. 4. The apparatus is so arranged that a call coming in at any frequency is automatically picked up and brought to the operator, who completes the connection to the called subscriber. Referring to Fig. 6, the antenna OA_0 is designed to receive incoming carrier frequencies within a range corresponding to all of the subscribers assigned to the central office or to a group of subscribers. The received frequencies are delivered to the tuned circuit OF_0 whose frequency of response is being continuously varied by the driving motor DM_0. The same motor also rotates the switch SW_0 which is provided with a number of contacts, one for each subscriber whose incoming frequency may be selected by the selecting circuit OF_0. The switch is arranged so that the contact corresponding to any given subscriber is made at the same moment that the frequency of that subscriber is picked out by the selecting circuit.

The carrier frequency of an incoming call is selected momentarily by OF_0 and is rectified in the rectifier OD_0. The resultant current operates the relay OR_0, which closes a circuit through the winding of the slow release relay OR_1, the back contact of the relay OR_2 and the switch SW_0. The operation of the relay OR_1 lights the subscriber's line lamp OL_1 thereby calling the attention of the operator to the incoming call. Similarly, as the selection and switching are being varied, the line lamps corresponding to other incoming calls will be lighted.

When the operator observes the lamp OL_1 she inserts a plug, for example, OP_1, which is associated with one end of a cord circuit, in the subscriber's jack OJ_1. This action completes a circuit through the relay OR_2, whose operation deenergizes the relay OR_1 and thus extinguishes the lamp OL_1. After insertion of the plug in the jack OJ_1, the operator adjusts manually by means of the control CT_1, the response frequency of the variable selecting circuit OF_1 to the transmitting frequency of the calling subscriber, which at the same time brings the oscillator OO_1 and the selecting circuit OF_2 to the receiving frequency assigned to the calling subscriber. The incoming carrier frequency of the calling subscriber is rectified in the demodulator OD_1 and operates the relay OR_3, thereby lighting the supervisory lamp OL_2 during the time when the calling subscriber's receiver is off the hook.

Having ascertained from the calling subscriber the number which is desired, the operator completes the connection by inserting the other cord circuit plug OP_2 in the jack OJ_2 which corresponds to the number of the called party and at the same time adjusts by means of the manual control CT_2 the frequencies of the oscillator OO_2 and the selecting circuits OF_3 and OF_4 to the frequency assignments of the called subscriber. The connection established by the jack OJ_2 energizes the relay OR_6, thereby preventing the line lamp of the called subscriber from lighting when he answers the call. The supervisory lamp OL_3 is lighted when the called subscriber answers, and remains lighted until he hangs up. The conversation then proceeds with the apparatus functioning in a manner similar to that described in connection with Fig. 2. When the conversation is completed the lamps OL_2 and OL_3 are extinguished as the subscribers hang up and the operator takes down the connection. By means of keys such as OK_2 the operator may connect her set to different cord circuits and using the key OK_1 she may split the connection and talk to either subscriber without the other.

As noted, the selecting circuit OF_0 and the switch SW_0 might serve for all the subscribers assigned to the office, or these subscribers might be divided into groups, with one selecting circuit and switch taking care of each group, and all such circuits and switches driven by a common motor.

It is apparent that the arrangement of Fig. 6 permits the employment of a relatively simple arrangement at the subscriber's station, inasmuch as the frequencies used by the subscriber

are always the same. The cord circuit arrangement at the central office is somewhat complicated, but the number of cord circuits required will be only a small fraction of the total number of subscribers.

It will be appreciated in connection with Fig. 4 and Fig. 6 that other known methods of modulation and demodulation may be employed. Particularly, direct modulation and demodulation whereby the modulation process takes place in the electro-acoustical device itself are contemplated within the scope of the invention. An example of this method of modulation using a carbon transmitter may be found in chapter VIII, Fig. 1 of "Principles of Radio Communication" by J. H. Morecroft. A condenser transmitter may be similarly employed as a modulator.

In the various arrangements shown in Fig. 2 to Fig. 6, radio transmission between the subscribers and the central office may be accomplished directly using any suitable type of antenna. However, in order to permit the use of ultra-short waves, for which substantially line-of-sight projection may be desired, it may be necessary to carry the transmission path above any obstacles lying between the antennas of individual subscribers. For this purpose an arrangement of the type shown in Fig. 7 may be employed.

Referring to Fig. 7, it will be seen that in this case a single central office antenna OA serves for receiving all frequencies from subscribers and transmitting all frequencies to subscribers. This antenna may be mounted on a tall building or tower so that substantialy a line-of-sight transmission path is obtained between the central office and each subscriber's antenna within the central office area. The subscriber's antenna should preferably be designed for radiating a beam toward the central office antenna and for receiving radiation from that antenna. Thus the subscriber's antenna might be a balanced doublet SA as shown in Fig. 7, placed near the focus of a parabolic reflecting surface, PR, directed toward the central office antenna OA. The central office antenna, however, is designed for radiating to and receiving from all subscribers. For this purpose there might be employed an antenna capable of radiating in all directions and receiving radiations from all directions throughout the range of frequencies utilized. Such an antenna, for example, might be a balanced doublet OA as shown in Fig. 7. Another possibility would be to employ a central office antenna so designed that it is capable of radiating into and receiving from a conical space which comprehends all subscribers' locations. This might be accomplished by adding the reflector RE above the doublet antenna OA.

It is also contemplated that instead of employing a single central office antenna a multiple antenna arrangement might be used at the central office building, each antenna being designed for handling a part of the total range of frequencies. It would also be possible to employ two antennas for each subscriber instead of one.

Although the arrangements described in connection with Figs. 2, 4, and 6 are designed to provide a radio connection between the subscribers within a given area, it is proposed to interconnect such stations with subscriber stations in other areas by providing in each area a central office, so that a radio connection may be established between a subscriber and his central office, using a frequency or frequencies assigned for that purpose, and the connection completed over suitable inter-office trunks. The method is illustrated schematically in Fig. 8. The central office apparatus to be used in carrying out this method might be patterned after that shown in Fig. 6. The types of trunks which may be used to interconnect the central offices are well known in the art.

In the arrangements thus far described, with the exception of Fig. 1, it has been assumed that free space is employed as the common transmitting medium. It is contemplated, however, that transmission over a high frequency conducting or guiding path may be employed instead of radio transmission. Such a path would take the form of a network extending to all subscribers within a given area and to the central office for that area. A network of this kind is shown schematically in Fig. 9, where each line represents a complete circuit, C designates the central office and S a subscriber's station.

Probably the simplest form of such a network would be one comprised of ordinary two-conductor circuit suitably interconnected and branched so that the common circuit will be available at all desired points. The circuits comprising the network might, for example, consist of pairs of open-wire or cable conductors.

It is contemplated also in accordance with the invention that the wire network employed for distributing light and power currents might be used as the common medium from which to derive high frequency channels for the telephone exchange system. The high frequency channels would be superposed upon the power network by carrier methods which are well known in the art.

Another form of transmission medium, and one which is peculiarly advantageous in that it is capable of transmitting a wide band of frequencies with comparatively low attenuation and which may be so shielded as to be practically immune to external disturbances, may be found in a network of circuits consisting of two conductors disposed coaxially with respect to one another. A circuit of this type has been disclosed in the patents to L. Espenschied and H. A. Affel, No. 1,835,031, December 8, 1931, H. A. Affel and E. I. Green, No. 1,781,092, November 11, 1930, etc.

As an alternative to the coaxial circuit the high frequency transmission medium might comprise a net-work of circuits, each consisting of two parallel conductors surrounded by a shield. Circuits of this type are disclosed in the applications of Green, Curtis and Mead, Serial No. 674,762, Green and Curtis, Serial No. 674,763 and Green and Leibe, Serial No. 674,764, all filed June 7, 1933.

The invention contemplates also utilizing as the high frequency transmission medium a dielectric wave guide comprising a cylindriform dielectric material which may or may not be surrounded by a conductor. Such dielectric guides are disclosed in the patent applications of G. C. Southworth, Serial No. 661,154, filed March 16, 1933, and Serial No. 701,711, filed December 9, 1933.

It is contemplated in accordance with the invention that the subscriber set and central office arrangements which have been described may be employed with any of the above types of transmission paths. For this purpose, it is necessary merely to substitute the transmission net-

work for the radio path, replacing the connection of the apparatus to the radio antenna by a connection suitable to the type of medium employed.

It will be obvious from the preceding discussion that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. A common transmission medium extending to each of a plurality of more than two subscribers' stations and to a central station, carrier current transmitting apparatus of a certain frequency at each subscriber's station, carrier current receiving apparatus of a certain frequency at each subscriber's station, all such frequencies being different for different stations, individually means at said subscribers' stations and translating means at said central station common to all of the subscribers' stations whereby a two-way carrier frequency signaling path may be established over said medium through the same translating means at said central station between any one and any other of said subscribers' stations, and additional common translating means including frequency selective apparatus whereby a plurality of such paths may be established and simultaneously maintained without interference between different pairs of stations.

2. A common transmission medium extending to each of a plurality of more than two subscribers' stations and to a central office, carrier current transmitting apparatus of a certain frequency at each subscriber's station, carrier current receiving apparatus of a certain frequency at each subscriber's station, all such frequencies being different for different stations, individually means at said subscribers' stations and translating means at said central office common to all of the subscribers' stations whereby a two-way carrier frequency telephone connection may be established over said medium through the same translating means at said central office between any one and any other of said subscribers' stations, and additional common translating means including frequency selective apparatus whereby a plurality of such connections may be established and simultaneously maintained without interference between different pairs of stations.

3. A system whereby intelligence may be interchanged between any one and any other of a plurality of more than two subscribers' stations through a central station, said system comprising radio transmitting equipment of one carrier frequency and radio receiving equipment of another carrier frequency at each of said stations, said frequencies being different for different stations, a translating device at the central office common to all of the subscribers' stations including a radio transmitter and radio receiver adjustable to the frequencies assigned to any station which is calling, and connected therewith a radio transmitter and radio receiver adjustable to the frequencies assigned to any station which is called, whereby any subscriber's station may communicate with any other subscriber's station through the same translating device, and additional translating devices at the central office whereby a plurality of two-way interchanges of intelligence may be carried out simultaneously between different pairs of stations on different frequency assignments.

4. A system for telephone communication between any one and any other of a plurality of more than two subscribers' stations, said system comprising a plurality of groups of subscribers' stations and a central station all in readiness for connection either way through a single common medium, each subscriber's station comprising transmitting and receiving apparatus adapted for respective fixed frequencies, these frequencies being different for different subscribers' stations, a translating device at the central office common to all of the subscribers' stations including a radio transmitter and radio receiver adjustable to the frequencies assigned to any station which is calling, and connected therewith a radio transmitter and radio receiver adjustable to the frequencies assigned to any station which is called, whereby any subscriber's station may communicate with any other subscriber's station through the same translation device, and additional translating devices at the central office by which simultaneous two-way telephone interconnections may take place between different pairs of stations within the group over the common medium and through the central office on different frequency assignments, and means whereby stations in different groups may be interconnected over trunk circuits connecting the central offices associated with the different groups.

5. A system whereby telephone communication may be carried out between any one and any other of a plurality of more than two subscribers' stations, said system comprising a common transmission medium extending to each of said subscribers' stations and to a central office, carrier current transmitting apparatus of a certain frequency at each subscriber's station, carrier current receiving apparatus of a certain frequency at each subscriber's station, all such frequencies being different for different stations, a translating device at the central office common to all of the subscribers' stations including a radio transmitter and radio receiver adjustable to the frequencies assigned to any station which is calling, and connected therewith a radio transmitter and radio receiver adjustable to the frequencies assigned to any station which is called, whereby any subscriber's station may communicate with any other subscriber's station through the same translation device, and additional translating devices at the central office whereby a plurality of two-way telephone connections between different pairs of stations over said medium may be manually established at said central office and simultaneously maintained on different frequency assignments.

6. In a system for the communication of intelligence between any one and any other of a plurality of more than two subscribers' stations taken in pairs, a plurality of subscribers' stations each having assigned thereto a fixed carrier frequency for transmission and a different fixed carrier frequency for reception, said frequencies differing from those assigned to all other subscribers' stations and being employed both when the station is a calling station and when it is a called station, and a central station having translating means capable of such frequency adjustment that any subscriber's station may be put into communication with any other subscriber's station through the same translating means over the frequencies assigned to the two stations.

7. In a system in which telephone communication between any one and any other of a plurality of more than two subscribers' stations may be effected at carrier frequencies over a common transmission medium, and in which a plurality of such communications may be carried out simultaneously between different pairs of stations, a plurality of subscribers' stations and a central office, means for transmitting to the central office and receiving from the central office at each of said subscribers' stations telephone signals modulated upon preassigned carrier frequencies, the transmitting and receiving frequencies for each subscriber's station being different from one another and from those of any other station, and means at the central office to interconnect any two subscribers' stations, said means including arrangements for translating in frequency at the central office the signals received from each station to those received by the station with which it is connected, said translating arrangements being capable of such frequency adjustment that the same translating arrangement may be used to interconnect any pair of subscribers' stations.

8. In a system for the exchange of intelligence, a common transmission medium extending to a plurality of more than two subscribers' stations and to a central office, means at each subscriber's station for transmitting to said medium signals modulated upon a carrier frequency and for receiving from said medium signals modulated upon a different carrier frequency, said frequencies differing from those assigned to other subscribers' stations, and translating means at the central office common to all the subscribers' stations whereby the signals transmitted from any station may be received, converted to a different frequency position and transmitted to any other station desired, and whereby signals from the desired station may be received, converted and transmited to the other station, a plurality of similar translating means being provided so that a plurality of such interchanges may be carried out simultaneously between different pairs of stations.

9. In a telephone exchange system, a common transmission medium extending to a plurality of more than two subscribers' stations and to a central office, said transmission medium being capable of transmitting a plurality of carrier frequency telephone bands, means at each subscriber's station for selecting a preassigned pair of said bands to be employed both when the station is calling and when it is called, one band being employed for transmitting telephone signals and the other for receiving telephone signals, the bands assigned to each subscriber's station being different from those assigned to other subscriber's stations, and translating means at the central office common to all of the subscribers' stations whereby the signals transmitted from any station may be received, translated to a different frequency position and transmitted to any other station desired, and whereby signals from the desired station may be received, converted and transmitted to the other station, a plurality of similar translating means being provided so that a plurality of such interchanges may be carried out simultaneously between different pairs of stations.

10. In a telephone exchange system, a transmission medium extending to a plurality of more than two subscribers' stations and to a central office, means at each subscriber's station for transmitting carrier frequency telephone signals of one frequency to said medium and receiving carrier frequency telephone signals of another frequency from said medium, said frequencies being different for different stations, translating means at the central office common to all the subscribers' stations whereby the carrier frequency signals transmitted by any first subscriber's station may be received, brought down to the voice range, translated to a new frequency location and transmitted to any second station and likewise from said second station to said first station, and a plurality of similar translating means at the central office whereby a plurality of such interchanges may be carried out simultaneously.

11. In a system whereby a plurality of interchanges of intelligence may be carried out between any one and any other of a plurality of more than two subscribers' stations, a common transmission medium extending to each of said subscribers' stations and to a central office, transmitting means for one frequency and receiving means for another frequency at each subscriber's station, said frequencies being different for different stations, means at the central office and common to the subscribers' stations whereby any subscriber's station may signal an operator at the central office, means at the central office and common to the subscribers' stations whereby the number of another station may be passed to the operator, means at the central office and common to the subscribers' stations whereby the operator may complete a connection to any called station, means at the central office and common to the subscribers' stations whereby a signal may be operated at the called station, and means at the calling and called stations whereby intelligence may be interchanged over the carrier frequencies respectively assigned thereto.

12. In a system whereby a plurality of telephone communications may be carried out between any one and any other of a plurality of more than two subscribers' stations, a common transmission medium extending to each of said subscribers' stations and to a central office, transmitting means for one frequency and receiving means for another frequency at each subscriber's station, said frequencies being different for different stations, means at the central office and common to the subscribers' stations whereby any subscriber's station may signal an operator at the central office, means at the central office and common to the subscribers' stations whereby the number of another subscriber's station may be passed to the operator, means at the central office and common to the subscribers' stations whereby the operator may complete a connection to the called station, means at the central office and common to the subscribers' stations whereby a signal may be operated at the called station, and means at the calling and called stations whereby telephone communication may be carried out over the carrier frequencies respectively assigned thereto.

13. In a system whereby a plurality of telephone communications may be carried out between any one and any other of a plurality of more than two subscribers' stations, a common transmission medium extending to each of said subscribers' stations and to a central office, transmitting means for one frequency and receiving means for another frequency at each station, said frequencies being different for different stations, means at the central office and common to the

subscribers' stations whereby any subscriber's station may signal an operator at the central office by transmitting an unmodulated carrier frequency over said medium, means at the central office and common to the subscribers' stations whereby the number of another subscriber's station may be passed to the operator, means at the central office and common to the subscribers' stations whereby the operator may complete a connection to the called station, means at the central office and common to the subscribers' stations whereby a signal may be operated at the called station by a carrier frequency transmitted from a central office, and means at the calling and called stations whereby telephone communication may be carried out over the carrier frequencies respectively assigned thereto.

14. In combination, a plurality of more than two terminal stations and a central station with which they are permanently in readiness for connection either way through a single common medium, carrier current transmitting apparatus and carrier current receiving apparatus at each terminal station adapted to operate at respective frequencies which are different from the frequencies for the other terminal stations, signal indicating means at the central station responsive respectively to the transmitting carrier frequencies of the terminal stations, means at the central station to signal to the terminal stations on their respective receiving frequencies, and a plurality of sets of adjustable means at the central station, each such set being adapted to convert modulated currents received on their respective transmitting frequencies from each of any two terminal stations and to transmit correspondingly modulated currents on their inversely respective receiving frequencies.

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