

Oct. 16, 1945.

R. V. L. HARTLEY  
COMMUNICATION SYSTEM

2,387,018

Filed Aug. 5, 1942

5 Sheets-Sheet 1

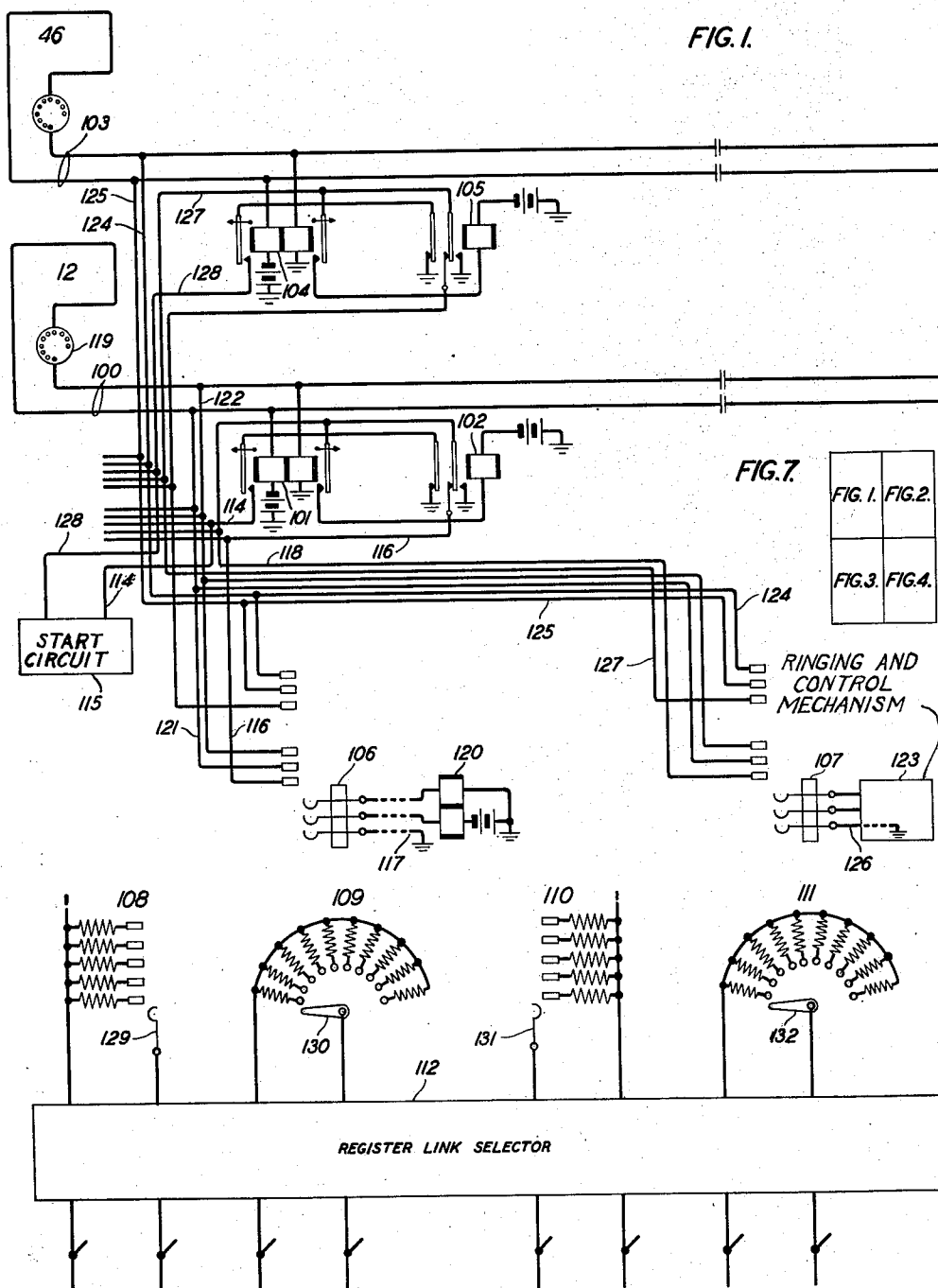


FIG. 7.

|         |         |
|---------|---------|
| FIG. 1. | FIG. 2. |
| FIG. 3. | FIG. 4. |

RINGING AND  
CONTROL  
MECHANISM

REGISTER LINK SELECTOR

INVENTOR

R.V.L. HARTLEY

BY: *W. R. McManey*  
ATTORNEY

**Oct. 16, 1945.**

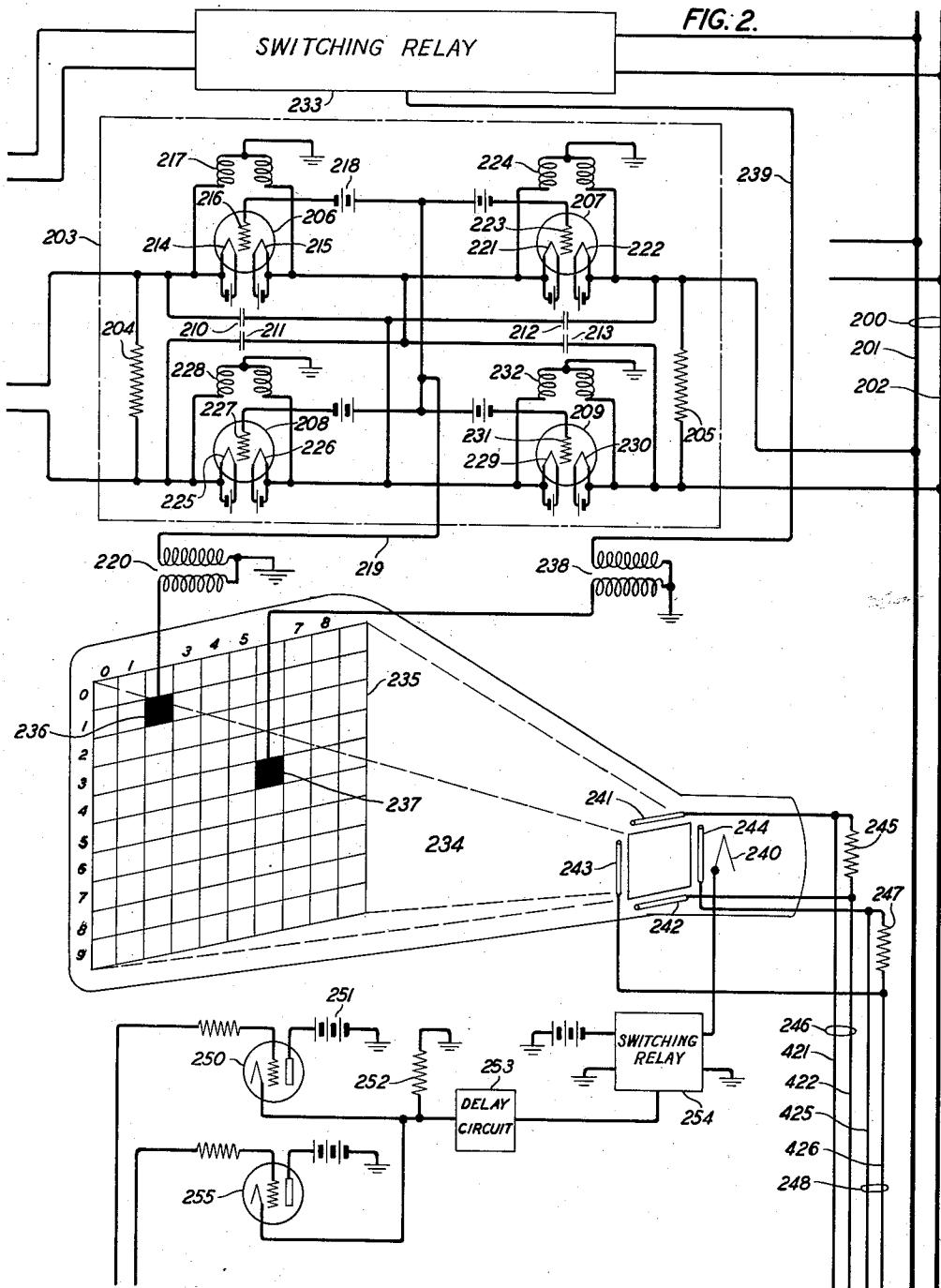
R. V. L. HARTLEY

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COMMUNICATION SYSTEM

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5 Sheets-Sheet 2



INVENTOR  
R.V.L. HARTLEY

BY: *M. P. McKenney*  
ATTORNEY

**Oct. 16, 1945.**

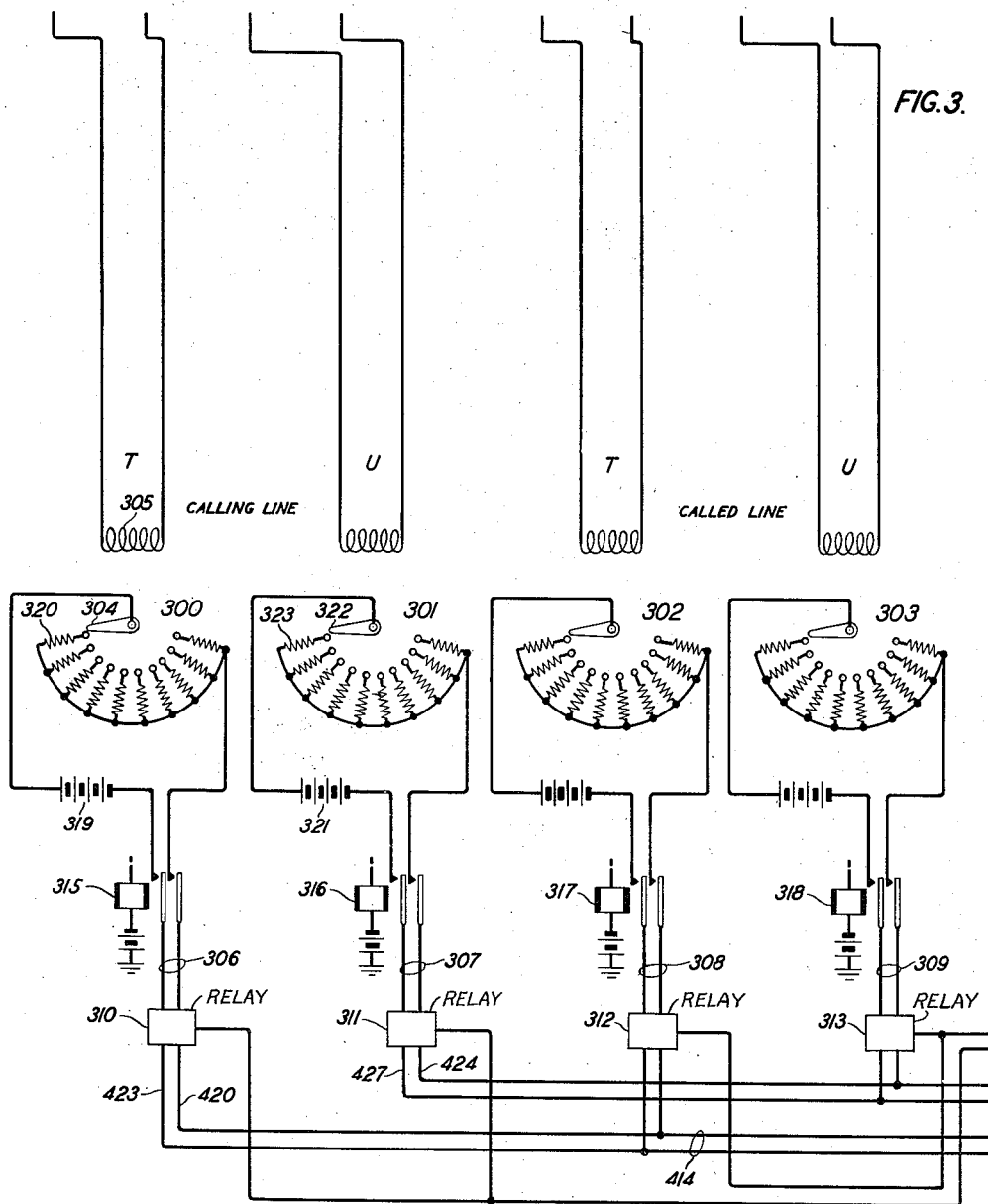
R. V. L. HARTLEY

**2,387,018**

COMMUNICATION SYSTEM

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5 Sheets-Sheet 3



INVENTOR  
R.V.L. HARTLEY  
BY: *M.V. Mackenney*  
ATTORNEY

Oct. 16, 1945.

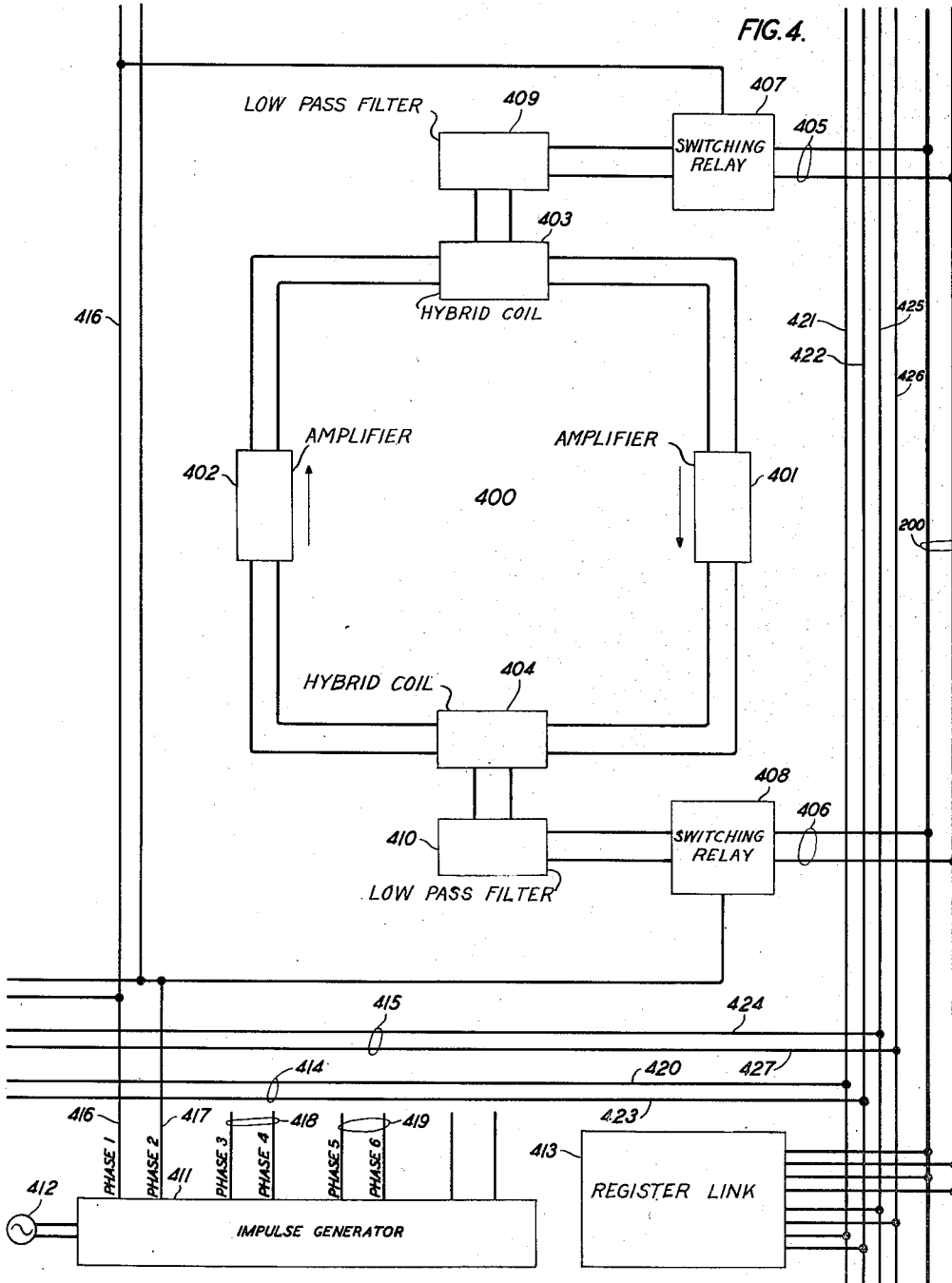
R. V. L. HARTLEY

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COMMUNICATION SYSTEM

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5 Sheets-Sheet 4



INVENTOR

R.V.L. HARTLEY

BY: *M. R. W. Gurney*  
ATTORNEY

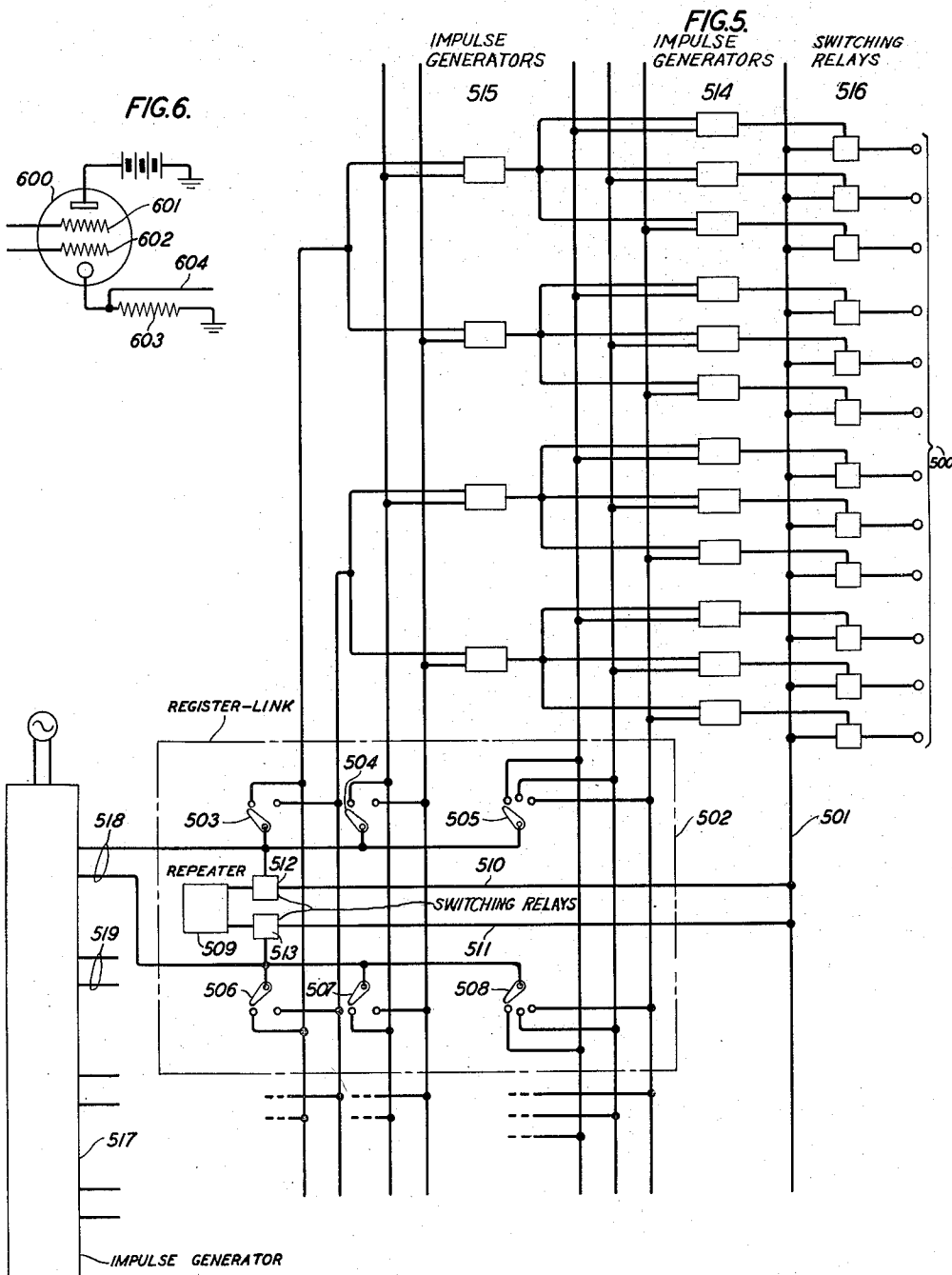
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R. V. L. HARTLEY  
COMMUNICATION SYSTEM

2,387,018

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5 Sheets-Sheet 5



INVENTOR  
R.V.L. HARTLEY  
BY: *W. S. McJannet*  
ATTORNEY

## UNITED STATES PATENT OFFICE

2,387,018

## COMMUNICATION SYSTEM

Ralph V. L. Hartley, Summit, N. J., assignor to  
Bell Laboratories, Incorporated, New York,  
N. Y., a corporation of New York

Application August 5, 1942, Serial No. 453,675

13 Claims. (Cl. 179-15)

This invention relates to electrical switching and signaling particularly when applied to communication systems.

An object of the invention is to effect both simplicity and economy in the switching and controlling devices used for the multiplex transmission of signals, conversations, or other forms of communication.

Another object of the invention is to enable the transmission of conversation or other forms of signals in both directions in a multiplex system.

These and other objects of the invention are realized by means of a multiplex transmission and switching system comprising a plurality of lines, all of which are arranged to transmit two-way telephone conversations or other forms of signaling, together with high-speed switching means for connecting momentarily and rapidly to a common medium each of the lines of each of a plurality of pairs concurrently engaged in communication, each of said communication pairs comprising any desired line and any other desired line, depending on the busy or idle condition thereof.

More specifically the multiplex system embodying this invention is one in which all lines are connected permanently to a common transmission circuit or medium, each line including a high-speed relay comprising a transmission network, the normal open condition of which prevents transmission of signals between the line and the common medium; in which a plurality of register links, each including a two-way voice current repeater, are provided in common to the lines, these register links being appropriated to serve the respective pairs of lines engaged in concurrent communication, each of the terminal circuits of each repeater being connected directly to said common medium through one of said high-speed switching relays; in which the designations of the two lines of a communication pair are registered in the appropriate one of said links; and in which the registered designations in each link serve to cause the momentary closure, in each of a succession of rapidly recurring cycles, of the switching relays in each of the lines of the corresponding communication pair and of the switching relays in the terminal circuits of the associated repeater. In the case of each communication pair the switching relay of one line and the switching relay in one terminal circuit of the repeater are closed simultaneously in a particular phase in each of said cycles to permit the passage of signal energy in either di-

rection between the line and the repeater, and the switching relay of the other line of the pair and the relay in the other terminal circuit of the repeater are closed simultaneously in a different phase in each of said cycles to permit the passage of signal energy between said other line and the repeater. Furthermore, the repeater circuit is provided with means for sustaining the signal energy entering from either line during any cycle for an interval at least as long as one of said cycles, whereby the signal energy originating in either line of a pair passes during each cycle over the common medium and into the repeater where it is sustained until it later passes from the repeater over the common medium and into the other line of the communication pair. Thus a plurality of pairs of lines may participate in concurrent communications over the same transmission medium without mutual interference. The circuit closures for the lines of each pair occur in phases differing from those of other pairs and in such rapid succession that continuous communication connections are realized.

A feature of the invention is a system of this kind in which the designations of the two lines of a desired communication pair are utilized jointly to control the simultaneous application of impulses for selecting and operating in the proper phases the transmission relays interposed between the lines of the pair and the common transmission medium.

These and other features of the invention will be discussed more fully in the following detailed specification.

In the drawings accompanying the specification:

Figs. 1 to 4, when arranged as illustrated in Fig. 7, disclose a telephone system incorporating the features of this invention;

Fig. 1 shows two subscribers' lines together with the line circuits, a pair of designation registers, and a register link selector;

Fig. 2 discloses the transmission switching relays through which the subscribers' lines are connected to a common transmission circuit or medium together with a high-speed beam switch for selecting and operating the transmission switching relays;

Fig. 3 discloses a part of one of a plurality of register links;

Fig. 4 discloses the remainder of the register link shown in Fig. 3, illustrates conventionally a second one of these register links, and shows a common impulse generator which furnishes operating impulses to the system;

Fig. 5 discloses a modified form of the invention in which the switching relays are operated by impulse generators; and

Fig. 6 shows one form of impulse generator suitable for use in the system of Fig. 5.

The invention in its broader aspects contemplates a multiplex system in which a plurality of communication channels are established concurrently for voice communication, telegraph, or transmission of any other desired type. In the present disclosure, however, a telephone system has been chosen for the purpose of illustrating the invention. It is also assumed that there are one hundred lines in this system, all of which may be subscribers' lines, if desired, or a part of which may be trunks interconnecting one telephone office with another. In any event it will be obvious that the invention is not limited to any particular capacity nor to any particular division or disposition of the circuits comprising 20 this system.

Referring to the drawings, each one of the subscribers' lines in the system appears at the central office in a line circuit. For example, the subscriber's line 100 appears in the line circuit 25 comprising the individual line relay 101 and the cut-off relay 102. Likewise, the subscriber's line 103 is provided in the central office with a line relay 104 and cut-off relay 105; and the same is true of all other lines in the system.

Furthermore, all of the subscribers' lines in the system are connected permanently to a common transmission medium 200 which comprises a pair of conductors 201 and 202. Each line is also provided with an individual high-speed switching relay which is connected in series with the line between the line circuit and the common medium. These high-speed relays consist of transmission networks, including space discharge tubes and condensers, which in their normal balanced condition prevent the transmission of energy between the associated lines and the common medium. The switching relay 203, which is connected in series with the line 100, comprises the input and output resistors 204 and 205, the four discharge tubes 206, 207, 208 and 209, and the bridging condensers 210, 211, 212 and 213. The resistors 204 and 205 are bridged across the talking conductors of the line, one on the input side and the other on the output side of the switching relay 203. 50

Each of the discharge tubes 206, 207, 208 and 209 of the relay 203, includes a pair of symmetrically disposed electrodes serving both as anodes and cathodes, and a control grid, together with means for biasing the grids and for applying operating impulses thereto to render the tubes conducting. The tube 206, for example, comprises the heated filaments or cathodes 214 and 215 and the control grid 216. The filaments 214 and 215 are connected in one side of the line so that the gap formed between these filaments normally serves as a high impedance opening in the line to prevent the flow of transmission currents. An inductance coil 217, the midpoint of which is grounded, has the free ends of its windings connected respectively to the filaments 214 and 215, and the control grid 216 is connected in a circuit including the biasing battery 218, conductor 219 and the winding of coil 220 to ground. The battery 218, therefore, applies a negative biasing potential to the grid 216 with respect to the filaments 214 and 215, and the value of this bias is sufficient to prevent the tube from conducting between the electrodes 214 and 215 in either direction. The coil 217 is 75

wound in such a manner that it presents a high impedance to currents flowing serially in the line conductor and therefore does not act as a short circuit around the gap between the electrodes 214 and 215. In a similar manner the tube 207 is provided with filament electrodes 221 and 222, with a control grid 223 and the inductance coil 224; and tubes 208 and 209 are provided respectively with filaments 225, 226, grid 227 and coil 228 and with filaments 229, 230, grid 231 and coil 232. Condensers 210, 211, 212 and 213 are included in diagonal bridges which extend as shown across the talking conductors of the line.

By applying brief impulses to the control grids of the tubes the bias is overcome to render them conductive in either direction, thus closing the relay repeatedly for transmission in either direction between the line and the common medium. At the instant each switching pulse is received on the control grid of any one of the tubes the polarity of the talking voltages in the line or in the common medium will determine the direction of conductivity in the tube. In either event one filament will serve as an anode and the other as a cathode or vice versa, depending on the polarity of the talking voltages. The relay 203, therefore, is in effect a transmission bridge or network including space discharge tubes in series with the line conductors and condensers included in paths connected diagonally across these conductors. By choosing the proper relation between the capacity of the tubes when no current is flowing and the capacity of the condensers a balanced condition of the network is obtained in which it offers a high impedance to the passage of speech currents. When, however, the tubes are discharged by the application of momentary pulses thereto, the resistance or impedance balance is upset, and the network offers a relatively low impedance to the passage of voice currents between the line and the common medium 200.

The discharge tubes used in these switching relays are preferably of the vacuum type since high-speed operation is desirable.

The switching relay 203 for the line 103 is shown conventionally, and it is understood that all other lines, trunks or other circuits connected to the common medium 200 are provided with one of these high-speed relays.

The mechanism for controlling the switching relays for connecting the conversational pairs of lines to the common medium in rapid succession and in their proper phases comprises a plurality of registers for making a preliminary registration of the calling and called line designations of a conversational pair, a plurality of common register links to which the preliminary registrations are transferred, and a beam switch which operates under the control of the register links to select the individual switching relays in the line circuits in the proper order and applies the operating impulses thereto.

The registers on which the preliminary registrations of the designations of the calling and called lines are made comprise a pair of two-motion switches 106 and 107, which may be of the well-known step-by-step line finder and connector types. The finder 106 and the connector 107, constituting one of the register pairs, are common to the subscribers' lines and may be taken in use to serve a calling line by any well-known allotment method. The finder 106 in addition to its usual terminal banks and brushes is provided with a vertical commutator 108 and with a

rotary commutator 109. The ten segments of the vertical commutator 108 are connected to resistors of graduated values, the value of each resistor representing the tens digit of all subscribers' lines appearing in the corresponding level. Similarly, the ten segments of the rotary commutator 109 are connected to ten resistors graduated in value, and the value of each resistance represents the units digit of all lines appearing in the corresponding rotary position of the switch. The connector switch 107 is also provided with a vertical commutator 110 and with a rotary commutator 111; and the graduated resistors associated with the vertical commutator 110 represent the values of the tens digits of the called lines, while the resistors associated with the rotary commutator 111 represent the different values of the units digits of the called lines. Briefly stated, therefore, the automatic vertical and rotary movements of the finder 106 performed in the act of finding the calling subscriber's line serve to register the tens and units digits of the calling line number on the vertical and rotary commutators 108 and 109 respectively. And the vertical and rotary movements of the connector 107 in response to the calling subscriber when he dials the number of the called subscriber serve to register the tens and units digits of the called line on the vertical and rotary commutators 110 and 111 respectively.

Each finder-connector register is provided with a link selecting switch 112 serving to select an idle one of the register links in order that the preliminary registration of the calling and called line numbers may be transferred to the registers of the selected link. The register link shown in Fig. 3, which is identical with the other links not shown in the drawings, comprises four registers 300, 301, 302 and 303 and certain other controlling devices. The registers 300 and 301 serve to register the tens and units digits of the calling line, and the registers 302 and 303 serve to register the tens and units digits of the called line of the conversational pair. Each of these registers, such as the register 300, comprises a rotatable brush 304, a series of ten contacts connected respectively to graduated resistance elements, an operating coil 305 together with a polarized armature and suitable power rotating elements for driving the brush 304 in either direction, depending upon the polarity of the energizing current, to select the particular resistor to satisfy an electrical bridge including the selected resistor as well as the resistors associated with the commutators of the finder and connector registers above described. For the sake of simplicity some of the structural details of the link registers, the bridge circuits for setting them, and the details of the register link selector 112 have been omitted. These elements, however, may be the same as those disclosed more fully in the patent to F. A. Hubbard, No. 2,356,519 of August 22, 1944. It will be understood, however, that the link register 300 is positioned under the control of the vertical commutator 108 to register in the link the tens digit of the calling line, that the register 301 is positioned under the control of the rotary commutator 109 to register the units digit of the calling line, and that registers 302 and 303 are positioned respectively by the vertical and rotary commutators 110 and 111 to register the tens and units digits of the called line.

As above explained, the lines in the system, including the subscribers' lines 100 and 103, appear in accordance with their numerical designation in

the ten levels of stationary terminals of the switches 106 and 107 of the preliminary register shown in the drawings. Moreover, these lines are multiplied to appear correspondingly in each of the other sets of preliminary registers not disclosed in the drawings. Moreover, each one of the register link selectors, like the selector 112, has access in common to all of the register links, including the one shown in detail in Figs. 3 and 4.

The purpose of the tens and units registers 300, 301, 302 and 303 of the register link is to control the beam of a beam switch 234, which is common to all of the register links, and which in turn serves to operate the individual high-speed switching relays in the line circuits. To this end the output circuits 306, 307, 308 and 309 of the registers 300, 301, 302 and 303 respectively, are connected through high-speed switching relays 310, 311, 312 and 313 respectively, to the control elements of the beam switch 234. Although not disclosed in detail, the high-speed switching relays 310, 311, 312 and 313 may be of the same type as the relay 203 shown in the circuit of line 100.

Each of the register links includes a voice current repeater in addition to the digit registers. The repeater 400 shown in Fig. 4, which is individual to and forms a part of the link including the registers 300, 301, 302 and 303, is a device of the well-known type including amplifiers 401 and 402 and hybrid coils 403 and 404. The terminal circuits 405 and 406, both of which may serve either as an input or an output circuit, depending upon the direction of transmission, are connected permanently to the common medium 200. The terminal circuit 405 includes a high-speed switching relay 407, similar to the relay 203. Similarly, the terminal circuit 406 includes a high-speed relay 408. Also the terminal circuits of the repeater are provided with low-pass filters 409 and 410 inserted respectively between hybrid coils and the high-speed switching relays. These filters permit the passage of voice frequency currents and have a cut-off point at the upper limit of the voice frequency range.

As will be explained more fully hereinafter, the switching relay of each line in conversation closes for a brief portion of each cycle of a high frequency source of impulses. The energy wave in the common medium 200, which is a replica of the voice wave in the line in conversation, is therefore made up of a succession of discrete pulses the magnitude and direction of which correspond to said voice wave. The purpose of the relays 407 and 408 is to effect rapid connections and disconnections between the repeater and the common medium 200 to permit this energy in the common medium to pass into the repeater and then back into the common medium in the proper phases. To this end the relays are operated by impulses, produced by a common impulse generator 411, which occur during brief portions of each cycle of a source 412 of suitable frequency, such as 6000 cycles per second. The relays 407 and 408 respond to these impulses and are closed once during each cycle and for a small fraction of the cycle. If the voice current energy is arriving in one of the terminal circuits from the common medium, a pulsating current will enter the associated low-pass filter having a magnitude and direction which is determined by the instantaneous value of the voice current. The voice current components which pass through the filter constitute a reproduction of the incoming voice current wave, and so far as the repeater opera-

tion is concerned this voice wave is indistinguishable from what it might receive from an ordinary line. Hence the repeater delivers an amplified reproduction of the wave to the other terminal circuit, and the voice current components pass into the common medium as a replica of the output of the repeater amplifier. It should be noted that the repeater 400 is capable of restoring the loss introduced in the switching relays without introducing balancing difficulties beyond those which depend on the impedances of the lines.

Moreover, since all traces of the part of the cycle at which the high-speed relays operate are eliminated in the filters it is not necessary that the two relays 407 and 408 operate at the same time. Therefore, by designing the filters and the repeater in such a manner that an appreciable sustaining effect is introduced between the time that the transmission arrives over one terminal circuit and the time when it emerges over the other terminal circuit, it is possible to operate the relays 407 and 408 in different phases and to connect first one side of the repeater to the common medium 200 and then the other side of the repeater to the same common medium. For example, if transmission energy is arriving over the common medium and entering the terminal circuit 405, the operation of relay 407 for a brief interval at a given phase in the cycle of source 412 permits this energy to enter the repeater circuit where it is sustained for an interval of time which is at least as long as a full cycle of the source 412. Later, therefore, the relay 408 may be operated for a brief instant and in a different phase, whereby the sustained energy in the repeater 400 passes out over the terminal circuit 406 and into the common medium 200 from which the original energy has fully vanished. The repeated energy then flows over the common medium and into the other line circuit of the connected pair as will be explained more fully hereinafter.

As above mentioned, the system is equipped with a plurality of register links, each of which includes the tens and units digits registers and the voice frequency repeater circuit. A second one of these register links 413 is illustrated conventionally in the drawings, and as many more would be provided as are needed to handle the permissible number of simultaneous connections.

The beam switch 234 has a screen 235 comprised of one hundred separate elemental areas or electrodes arranged in ten horizontal and ten vertical coordinate rows. Each of these elemental areas is individual to one of the subscribers' lines, and their numerical arrangement in the screen 235 corresponds to the numerical appearances of the subscribers' lines in the register switches 106 and 107. More specifically, the ten horizontal rows of elements in the screen 235, starting at the top, correspond to the successive values of the tens digit; and the ten vertical rows starting at the left correspond to the ten successive values of the units digit of the line designations. These individual sensitive elements are connected respectively to the high-speed switching relays 203, 233, etc., individual to the corresponding subscribers' lines. For example, the elemental area 236 (No. 12) is connected through the transformer 220 and over conductor 219 to the control grid circuits of the discharge tubes of the high-speed relay 203, which is individual to line 100; and elemental area 237 is likewise connected over transformer

238 and conductor 239 to the control grids of the tubes in the high-speed relay 233 which is individual to subscriber's line 103.

The electron beam of the switch 234, which is produced in any suitable manner by an emitting cathode, is directed over the screen 235 by two sets of deflecting plates 241, 242 and 243, 244. The plates 241 and 242 are connected across the resistor 245, which in turn is connected over circuits 246 and 414 and through the high-speed relays 310 and 312 to the tens registers 300 and 302. When, therefore, the high-speed relay 310 or the high-speed relay 312 is closed momentarily in the proper phase, a potential is produced on the plates 241 and 242 which is a measure of the value of the tens digit registered on the register 300 or on the register 302. Therefore, the beam is positioned on the particular horizontal row of elements which corresponds to the tens digit of the calling line or of the called line, as the case may be. In like manner the plates 243 and 244 are connected across resistor 247, which in turn is connected over circuit 248, circuit 415 and through the high-speed relays 311 and 313 to the units registers 301 and 303. The operation of either relay 311 or 313 produces a voltage across the plates 243 and 244 which directs the beam to the vertical row of elements corresponding to the units digit of the line. Thus it is possible by operating the relays 310, 311, 312 and 313 in the proper phases to direct the beam of the switch 234 first into engagement with one line and then into engagement with the other line of any pair of lines engaged in conversation.

The impulses for operating the high-speed relays which connect the link registers to the deflecting plates of the beam switch 234 and for operating the high-speed relays which open and close the circuits between the voice current repeater and the common medium 200 are supplied from the impulse generator 411 which is common to all of the register link circuits. To this end the generator 411 is designed to produce impulses of a plurality of phases and to repeat these impulses once per cycle of the energizing source 412. The repeated impulses of the several phases appear respectively in outgoing impulse conductors which are assigned in pairs to the respective register links. For example, the pair of conductors 416 and 417, on which impulses of phase No. 1 and phase No. 2 appear, are assigned to the register link shown in Figs. 3 and 4. Likewise, other pairs of impulse conductors 418, 419, etc., in which appear impulses of other pairs of phases, are assigned respectively to the other register links. It will be noted that impulse conductor 416, bearing impulses of phase No. 1, is connected to the high-speed relays 310 and 311 associated with the calling line designation registers and to the high-speed relay 407 included in the terminal circuit 405 of the repeater 400, whereas impulse conductor 417 is connected to the high-speed relays 312 and 313 associated with the called line registers and to the high-speed relay 408 connected in the terminal circuit 406 of said repeater. Each time, therefore, the generator 411 produces an impulse of phase No. 1, relays 310, 311 and 407 are operated to close the circuits in which they are located, and each time the generator produces an impulse of phase No. 2, relays 312, 313 and 408 are operated to close the circuits in which they are located. In other words, each impulse of phase No. 1 enables the calling line registers 300 and 301 to position the beam of switch 234 to operate the high-speed relay connected in the circuit with the call-

ing line and connects one side of the repeater 400 to the common medium 200; and each impulse of phase No. 2 enables the registers 302 and 303 to position the beam of switch 234 to cause the operation of the high-speed relay connected in series with the called line of the pair and connects the other side of the repeater 400 to the common medium 200. Although the phases of each pair assigned to a register link are indicated in the drawings as being adjacent phases in the cycle, it will be understood that the several phases of each cycle may be assigned and paired in any desired manner. The impulse generator 411 is shown in conventional manner since it may be of any well-known and suitable type. For example, the brief impulses of the desired phases may be produced by the operation of discharge tubes of the well-known types when energized by means of a source of alternating voltage 412. Impulse generators of this general character are disclosed in the Holden Patents 2,324,394 of July 13, 1943, 2,252,766 of August 19, 1941, and 2,285,815 of June 9, 1942.

A detailed description will now be given of the operation of the system. Assume that the subscriber of line 100 having the designation "12" desires to converse with the subscriber of line 103 having the designation "46." The initiation of the call by the calling subscriber results in the closure of a circuit from battery through the left winding of relay 101 thence over the loop of the subscriber's line 100 and returning over the other side through the right winding of relay 101 to ground. Relay 101, which is slow to release in character, attracts its armatures and applies ground potential to the usual line finder start conductor 114. The grounded start conductor 114 affects the usual common start circuit 115 and causes an idle switch 106 to operate in its vertical and rotary movements to seize the calling line 100. When the switch 106 reaches the calling line, a circuit is closed from battery through the winding of cut-off relay 102, contacts of relay 101, back contacts of relay 102, conductor 116, terminal and brush of switch 106 to the control conductor 117. The presence of battery potential on conductor 117 serves in any well-known manner to terminate the hunting movement of the switch 106, whereupon ground potential applied to conductor 117 in the switch 106 causes the operation of the cut-off relay 102. Before this operating circuit is opened, the cut-off relay 102 closes a locking circuit for itself traceable from battery through the winding of said relay, closed contacts of relay 101 to ground at the front contacts of relay 102. Relay 102 at its outer left armature opens the start conductor 114 to prevent the starting of another hunting switch and at its inner armature removes the hunting condition from conductor 116 and applies ground potential over conductor 118 to render the line busy in the terminal banks of connector switch 107 and other similar switches, not shown.

The calling subscriber now proceeds to manipulate his dial 119 to transmit first the tens digit 4 and then the units digit 6 of the called line 103. The impulse circuit for this purpose may be traced from battery through the lower winding of impulse relay 120, brush and terminal of the switch 106, conductor 121 over the loop of the subscriber's line and returning over conductor 122, terminal and brush of switch 106 to ground through the upper winding of the impulse relay 120. In the well-known manner the impulse relay 120 responds to these series of impulses to

operate the switch 107 in a vertical direction to the level representing the tens digit "4" and in a rotary direction to a set of terminals in the level representing the units digit "6." When the switch 107 positions its brushes on the terminals of the called line 103, the ringing and control mechanism 123 associated with the connector applies ringing current over the conductors 124 and 125 to the called line 103. The response of the called subscriber causes the disconnection of ringing current and the closure of a circuit from ground over conductor 126 through the brush and terminal of the connector, conductor 127, closed contact of line relay 104, which is operated when the called party answers, winding of cut-off relay 105 to battery. Relay 105 operates and locks in a circuit traceable from battery through its winding, closed contacts of relay 104 to ground at the inner left contact of relay 105. Relay 105 opens the start conductor 128 and applies ground potential to conductor 127 to render the line 103 busy in the banks of the other connector switches.

The setting of the finder and connector switches 106 and 107 in their vertical and rotary positions as above explained, serves to register the tens and units of the calling and called lines respectively. The switch 106 comes to rest with its vertical commutator brush 129 on the No. 1 terminal and with its rotary commutator brush 130 on the No. 2 terminal; and the connector switch 107 comes to rest with its vertical commutator brush 131 on the No. 4 terminal and with its rotary commutator brush 132 on the No. 6 terminal. Following the setting of the switches 106 and 107 the register link selector 112 hunts for and seizes an idle one of the register links, such as the one shown in Figs. 3 and 4. Thereafter and in the manner fully described in the patent to F. A. Hubbard, No. 2,356,519 of August 22, 1944, the registers 300 and 301 are positioned in accordance with the setting of the switch 106 to select graduated resistors representing the tens digit "1" and the units digit "2" of the calling line; and the registers 302 and 303 are positioned in accordance with the setting of switch 107 to select graduated resistors representing the tens digit "4" and the units digit "6" of the called line. Following the setting of registers 300, 301, 302 and 303, the relays 315, 316, 317 and 318 operate, and the system is now ready to switch the calling and called lines over the common medium 200 to the voice frequency repeater 400. Following the transfer of the registrations from switches 106 and 107 to the register link, the switches 106 and 107 may be released in any well-known manner and restored to the common use of other lines.

As soon following the operation of relays 315 and 316 as the impulse generator 411 reaches phase No. 1, an impulse is produced in conductor 416 and is applied to the high-speed relays 310 and 311. In response to this impulse relays 310 and 311 assume a low impedance condition and close their circuits for operating the beam switch 234. The circuit closed through relay 310 may be traced from one pole of battery 319, brush 304, resistor 320, contacts of relay 315, relay 310, conductor 420, conductor 421, resistor 245, conductor 422, conductor 423, relay 310, contacts of relay 315 to the other pole of battery 319. The circuit through relay 311 may be traced from one pole of battery 321, brush 322, resistor 323, contacts of relay 316, relay 311, conductor 424, conductor 425, resistor 247, conductor 426, conductor

427, relay 311, contacts of relay 316 to the opposite pole of battery 321. The voltages developed across the resistors 245 and 247 are applied to the plates of the switch 234, causing the beam, which is in a virtual state at this instant, to select the elemental area 236 representing the calling subscriber's line 100. The presence of the impulse in conductor 416 causes the application of potential to the control electrode of tube 250, and space current flows from battery 251 through the resistor 252 to ground. The impulse thus developed in the resistor 252 is subjected to a brief interval of delay by means of any well-known delay circuit 263 and is then applied to a high-speed relay 254 similar to the relay 203. The delay introduced by the circuit 263 enables the switch 234 to position its virtual beam upon the selected element 236, and at the end of this delay interval the relay 254 operates to apply operating voltage to the cathode 240. Thereupon the beam assumes its real character, and electrons impinge upon the element 236 producing an impulse in the transformer 220, which in turn applies this impulse over conductor 219 to the relay 203. The impulse applied to conductor 219 conditions the tubes 206, 207, 208 and 209 for operation provided talking voltages are being applied to the network 203. If, therefore, the calling subscriber is speaking into his microphone at this instant, the talking currents present in the line 100 are permitted to flow through the conducting gaps of the tubes 206, 207, 208 and 209 into the common medium 200.

At this same instant the impulse of phase No. 1 appearing in conductor 416 is applied to the high-speed relay 407, causing the relay to lower its impedance and close the terminal circuit 405 interconnecting the common medium 200 and the repeater 400. Therefore, the talking currents flowing from the calling subscriber's line through the relay 203 and into the common medium 200 pass from the common medium through the closed relay 407 into the repeater circuit 400. By reason of the delay characteristics of the filter circuit 409, the energy entering the common repeater circuit from the medium 200 is sustained in the repeater circuit for a substantial interval following the passing of phase No. 1. Upon the abatement of the impulse of phase No. 1 in conductor 416, relays 310 and 311 assume their high impedance condition to remove the beam control voltages from the plates of switch 234, tube 250 extinguishes to open relay 254 and disconnect the operating source from the cathode 240, and relay 407 assumes its high impedance condition to disconnect the terminal circuit 405 from the common medium 200. Later in the cycle the impulse generator 411 reaches its phase No. 2, and an impulse is applied to conductor 417 to cause the operation of relays 312, 313, and 408 and the operation of discharge tube 255. Relays 312 and 313 close their circuits to cause the positioning of the virtual beam of the switch 234 on the element 237 representing the called subscriber's line 103, and relay 408 closes the terminal circuit 406 between the repeater 400 and the common medium 200. Following the brief delay introduced by circuit 263, the beam of the switch 234 assumes its real character, an impulse is applied through transformer 238 over conductor 239 to the high-speed relay 233, and this relay operates to extend the called line 103 through to the common medium 200. Since, as assumed, the calling subscriber is speaking at this instant and a portion of the transmission energy produced in

his line is being sustained in the repeater circuit 400, this sustained energy now flows out through the closed relay 408 into the common medium 200 through the closed relay 233 and into the called subscriber's line 103. This process is repeated at a high rate of speed determined by the frequency of the generator 411, and as long as voice currents endure in the calling line 100 they are permitted to flow during a brief portion of each cycle of the generator 411 over the common medium and into the repeater circuit 400 from whence they are permitted during another brief portion of each cycle to flow out into the common medium and into the called subscriber's line, and in this way the effect of a continuous conversational connection is obtained. The same process takes place during the time that the called subscriber is speaking. The talking energy in his line passes over the common medium and into the repeater 400 for a brief interval during each cycle of the impulse generator and is sustained in the repeater until the generator reaches the other phase assigned to the repeater 400, whereupon the energy flows out of the repeater over the common medium and into the calling subscriber's line.

Other pairs of subscribers' lines that may be engaged concurrently in conversation also make use of the common beam switch 234 and the repeaters assigned respectively to such pairs of lines, enabling them to converse with each other without any mutual interference.

When the subscribers of lines 100 and 103 finish their conversation, they replace their receivers permitting the line relays 101 and 104 to release. These relays cause the release of cut-off relays 102 and 105.

In the modification illustrated in Fig. 5, the high-speed switching relays in the line circuits are operated by impulse generators under the control of digit registers. This system, which is illustrated in conventional manner in the drawings, comprises a plurality of lines 500, each of which is connected to the common medium 501 through an individual high-speed relay of the type already described. A number of register link circuits, such as the register link 502, are provided and are taken in use when needed to serve the different pairs of subscribers' lines engaged in conversation. Each one of these links includes a pair of registers, one for the calling line number and one for the called line number, a voice current repeater and the other necessary controlling equipment. In the register link 502, the calling line register comprises three separate register switches 503, 504 and 505 serving respectively the three digital places of a three-digit designation. In other words, the register 503 assumes a position corresponding to the value of the first digit of the calling line number, the register 504 assumes a position corresponding to the second digit, and the register 505 a position corresponding to the third digit. In like manner the called line register comprises the three digit switches 506, 507 and 508. The voice current repeater 509 of the register link 502 has its terminal circuits 510 and 511 connected to the common medium 501 through the high-speed switching relays 512 and 513 respectively.

The register link 502 having the calling and called line designations registered therein serves to operate alternately and repeatedly the high-speed relays in circuit with the calling and called lines of the conversational pair by applying impulses to different combinations of the impulse

generators 514 and 515. Each one of these impulse generators consists of any suitable device such as the discharge tube (illustrated in Fig. 6) which is designed to operate and produce a momentary pulse in its output circuit in response to the simultaneous application of impulses over both of its input circuits. In Fig. 6, for example, if impulses are applied simultaneously to both of the grids 601 and 602 of the tube 600, the tube discharges, and current flows in the resistor 603, thus producing an impulse in the output circuit 604. However, the tube will not discharge if an impulse is applied to either one of the grids alone. With this explanation in mind it will be found from an inspection of Fig. 5 that the impulse generators in the groups 514 and 515 are connected to the terminal points of the registers 503, 504 and 505 in such a manner that the settings of these registers in accordance with the designation of a calling line will cause the application of an impulse by a single one of the generators 514 to the particular one of the high-speed switching relays 516 which is connected in series with the calling line. And in like manner the settings of the registers 506, 507 and 508 in accordance with the digits of the called line cause the application of an impulse by a single one of the generators 514, to the high-speed switching relay in circuit with the called line.

The impulses for operating the generators 515 and 514 and for connecting the repeater 509 to the common medium 501 are supplied from the common impulse generator 517. The generator 517, as hereinbefore explained, produces impulses in its output circuits 518, 519, etc., in pairs of phases which are allotted individually to the register links 502, etc.

It will be obvious that numerous alternatives will suggest themselves to those skilled in the art. Among others it should be noted that the cathode beam of switch 234 may be changed between its virtual state and its real state under control of a grid electrode located near the cathode.

What is claimed is:

1. The combination in a signaling system of a plurality of lines, each of which is characterized by a different designation, a common transmission medium to which all of said lines are permanently connected, individual switching devices for said lines, each one of said switching devices being connected in series with its line and normally serving to prevent the transmission of signal currents between the line and said common medium, designation means and means for variably operating the same to represent the designations of any pair of lines of said plurality of lines, and means controlled automatically by said designation means for rendering effective momentarily in each of a succession of rapidly recurring cycles the switching device in each of the lines of said pair to enable the transmission of signal currents from one line of said pair to the other by way of said common medium.

2. The combination in a signaling system of a plurality of lines, each of which is characterized by a different designation, a common transmission medium to which all of said lines are permanently connected, individual switching devices for said lines, each one of said switching devices being connected in series with its associated line and normally serving to prevent the transmission of signal energy in either direction between the line and said common medium, designation means and means for variably operating the same

to represent the designations of a pair of lines comprising any one of said lines and any other one of said lines, and means controlled by said designation means and any other one of said lines for rendering effective for a brief interval in each of a succession of recurring cycles the switching device in each of the lines of said pair to enable the transmission of signal energy from either line of the pair to the other line of said pair by way of said common medium.

3. The combination in a signaling system of a plurality of lines, a common transmission medium to which all of said lines are connected, means including said common medium for transmitting energy from any one of said lines to any other one of said lines, a plurality of transmission bridges each individual to one of said lines and connected in series therewith, each of said bridges normally being in a balanced condition to prevent the transmission of energy between its associated line and said common medium, means for automatically selecting the bridges of a pair of said lines comprising any one of said lines and any other one of said lines, and means controlled by said selecting means for altering the balance of each of the bridges of said pair for a brief interval during each of a succession of rapidly recurring cycles to enable the transmission of signal energy from one of the lines of said pair to the other line of said pair by way of said common medium.

4. The combination in a signaling system of a plurality of lines, a common transmission medium to which all of said lines are connected, a plurality of transmission bridges each individual to one of said lines and connected in series therewith, each of said bridges normally being in a balanced condition to prevent the transmission of energy between its associated line and said common medium, a signal repeater having its terminal circuits connected to said common medium, transmission bridges included in said terminal circuits normally effective to prevent the transmission of signal energy between the repeater and said common medium, and automatic means for altering the balance of each of the bridges of a pair of said lines comprising any desired one of said lines and any other desired one of said lines and for altering the balance of each of the bridges in the terminal circuits of said repeater for a brief interval during each of a succession of rapidly recurring cycles to enable the transmission of signal energy from one of the lines of said pair to the other line of said pair by way of said common medium and repeater.

5. The combination in a communication system of a plurality of lines, each of which is characterized by a different designation, a common transmission medium to which all of said lines are connected, individual transmission relays for said lines, each relay being connected in series with its line and normally offering a high impedance to prevent the transmission of energy between the line and said common medium, a plurality of register mechanisms common to said lines, means for appropriating one of said mechanisms for use and for registering therein the designation of any one of said lines and the designation of any other one of said lines, said two lines constituting a pair between which communication is desired, means for producing a succession of impulses of different phases in each of a succession of rapidly recurring cycles, and means controlled in accordance with the designa-

nations registered in said register mechanism for reducing the impedance of the transmission relay in each of the lines of said communication pair in response to the impulses of a particular phase in each of said successive cycles to enable the transmission of communication energy between the lines of said pair by way of said common medium.

6. The combination in a communication system of a plurality of lines, each of which is characterized by a different designation, a common transmission medium to which all of said lines are connected, individual transmission relays for said lines, each relay being connected in series with its line and normally offering a high impedance to prevent the transmission of energy between the line and said common medium, a plurality of register mechanisms common to said lines, means for appropriating one of said mechanisms for use and for registering therein the designation of any one of said lines and the designation of any other one of said lines, said two lines constituting a pair between which communication is desired, a plurality of transmission repeaters common to said lines, means for appropriating one of said repeaters for use in a connection between said communication pair, and automatic means controlled in accordance with the designations registered in said register mechanism and effective during a brief interval in each of a succession of recurring cycles for lowering the impedance of the transmission relay in each of the lines of said communication pair to enable the transmission of communication signals from one of said lines to the other by way of said common medium and said common repeater.

7. The combination in a communication system of a plurality of lines, a common transmission medium to which said lines are connected, individual switching devices for said lines, each one of said switching devices being connected in series with its line and normally in an open condition to prevent the transmission of energy between the line and said common medium, a repeater having two terminal circuits serving as input and output circuits, both of said circuits being connected to said common medium, switching devices, one in each of said terminal circuits normally in an open condition to prevent the transmission of energy between said repeater and said common medium, and automatic means effective during a brief interval in each of a succession of rapidly recurring cycles for causing the switching device in each one of a pair of lines comprising any one of said plurality of lines and any other one of said plurality of lines to assume a closed condition and for causing the switching device in each one of said terminal circuits to assume a closed condition to enable the transmission of energy from either one of the lines of said pair over said common medium into said repeater and from said repeater over said common medium and into the other line of said pair.

8. The combination in a signaling system of a pair of lines, a common medium to which said lines are connected, each of said lines having a transmission element connected in series therewith, each element having a normally open condition for preventing the passage of signals between the line and the common medium and a closed condition in which it permits the passage of said signals, a transmission mechanism having two terminal circuits connected to said com-

mon medium, a pair of transmission elements included respectively in said terminal circuits and serving in their normally open condition to disconnect said mechanism from the common medium and in their closed condition to connect it to said common medium, means effective during a brief portion of a rapid succession of cycles and in a given phase to close the transmission element in one of said lines and the element in one of said terminal circuits to permit the passage of signal energy into the transmission mechanism, means effective to sustain said energy in said transmission mechanism for an interval after each successive opening of said transmission elements, and means effective during a brief portion of each of said cycles and in a given phase to close the transmission element in the other of said lines and the element in the other of said terminal circuits to permit the sustained signal energy in said transmission mechanism to pass out of said mechanism and into said other line.

9. The combination in a signaling system of a pair of lines, a common medium to which said lines are connected, each of said lines having a transmission element connected in series therewith, each element having a normally open condition for preventing the passage of signal energy between the line and the common medium and a closed condition in which it permits the passage of signal energy, a repeater having two terminal circuits connected to said common medium, a pair of transmission elements included respectively in said terminal circuits and serving in their normally open condition to disconnect the repeater from the common medium and in their closed condition to connect it to said common medium, means effective for a brief portion of each of a rapid succession of cycles and in a given phase to close the transmission element in either one of said lines and the element in one of said terminal circuits to permit passage of signal energy from said one line by way of said common medium, means effective to sustain said signal energy in said repeater for a substantial interval after each successive opening of the transmission element in said one line and the transmission element in said one terminal circuit, and means effective for a brief portion of each of said cycles and in a different phase to close the transmission element in the other one of said lines and the element in the other one of said terminal circuits to permit the sustained signal energy in said repeater to pass into said other line by way of said common medium.

10. The combination in a signaling system of a plurality of lines, a medium common to all of said lines and serving to establish a communication connection between any one of said lines and any other one of said lines, means effective during a brief portion of each of a succession of rapidly recurring cycles and in a given phase for connecting any desired one of said lines to said common medium to permit signal energy in said line to flow into said common medium, means for sustaining the signal energy entering said common medium for a period at least as long as one of said cycles, and means effective during a brief portion of each of said cycles and in a different phase for connecting any other desired one of said lines to said common medium to permit the sustained signal energy to flow into said other desired line.

11. The combination in a signaling system of a pair of lines, a common medium to which said

lines are connected, each of said lines having a transmission element connected in series therewith, each element having a normal open condition for preventing the passage of signals between the line and common medium and a closed condition in which it permits the passage of signals in either direction, a transmission repeater having two terminal circuits, either one of which may serve as an input circuit to the repeater and the other as an output circuit from the repeater, both of said terminal circuits being connected to said common medium, a pair of transmission elements included respectively in said terminal circuits and serving in their normal open condition to disconnect said repeater from the common medium and in their closed condition to connect it to said common medium for the passage of signals in either direction between the common medium and the repeater, means effective during a brief portion of each of a rapid succession of cycles and in a given phase to close the transmission element in one of said lines and the element in one of said terminal circuits to permit the passage of signal energy between said one line and said repeater, means effective during a brief portion of each of said cycles and in a different phase to close the transmission element in the other of said lines and the element in the other of said terminal circuits to permit the passage of signal energy between said other line and said repeater, and means associated with said repeater for sustaining the signal energy entering the repeater from either of said lines until the other of said lines is connected to said repeater.

12. The combination in a communication system of a plurality of lines, a transmission medium serving in common for the transmission between

the lines of each of a plurality of pairs of said lines engaged concurrently in communication, switching means normally in an open condition to prevent transmission between each line and said common medium, means operative cyclically for effecting brief closures of said switching means to connect repeatedly to said common medium each line of all pairs engaged in communication, the connection of each line occurring in a phase which differs from that of every other line, and means associated with each communication pair for sustaining the transmission energy delivered from either line of said pair to the common medium until the other line of said pair is connected to the common medium.

13. The combination in a communication system of a plurality of lines, a common transmission medium for said lines, means dependent on the busy or idle condition of said lines for pairing any number of said lines selected at random with a corresponding number of said lines also selected at random to form a plurality of pairs for concurrent communication over said common medium, switching means normally in an open condition to prevent transmission between each line and said common medium, means operative cyclically for effecting brief closures of said switching means to connect repeatedly to said common medium each line of all pairs engaged in communication, the connection of each line occurring in a phase which differs from that of every other line, and means associated with each communication pair for sustaining the transmission energy delivered from either line of said pair to the common medium until the other line of said pair is connected to the common medium.

RALPH V. L. HARTLEY.