

Aug. 22, 1944.

F. A. HUBBARD

2,356,519

COMMUNICATION SYSTEM

Filed Oct. 9, 1942

7 Sheets-Sheet 1

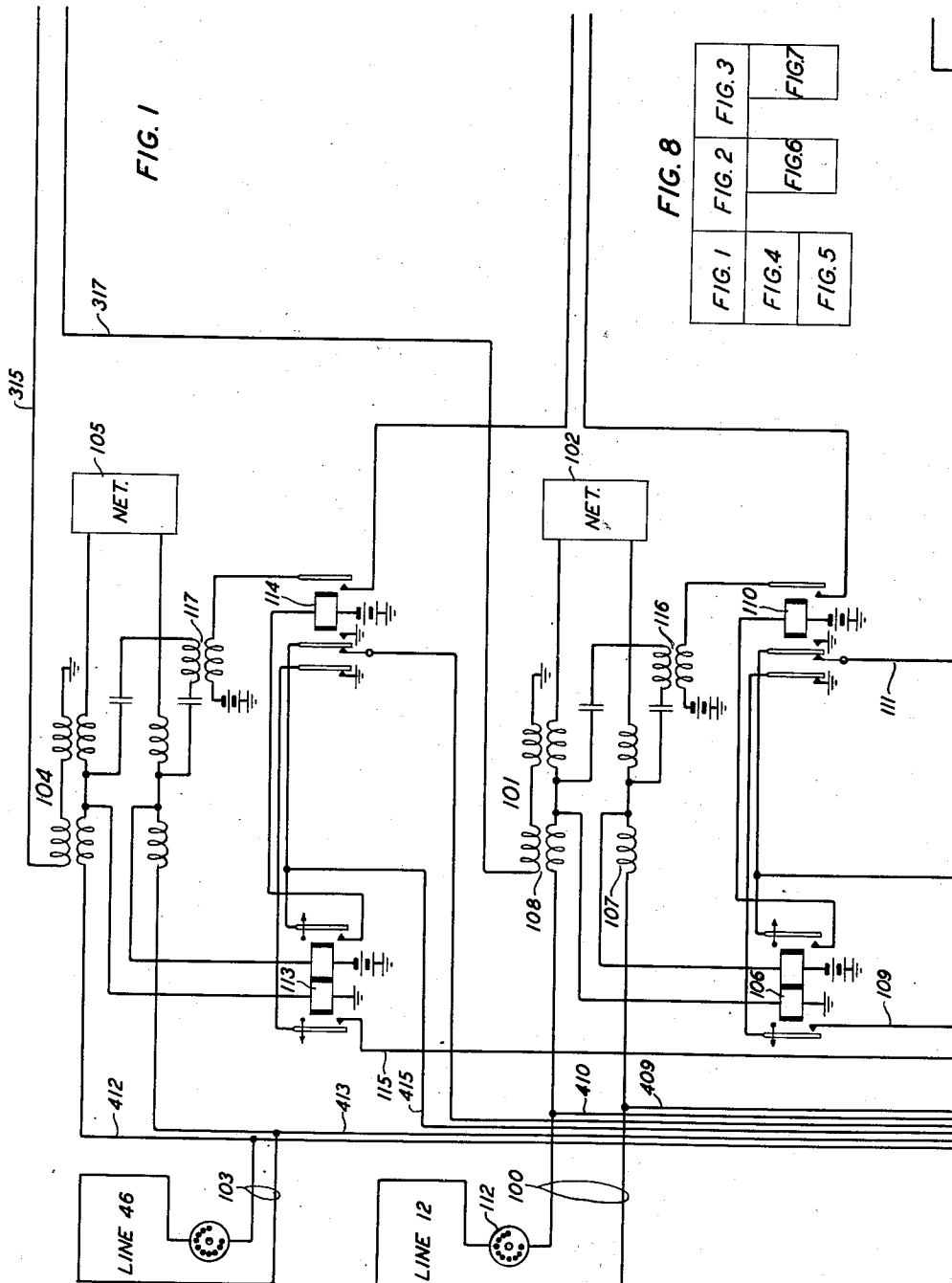


FIG. 8

FIG. 1	FIG. 2	FIG. 3
FIG. 4	FIG. 6	FIG. 7
FIG. 5		

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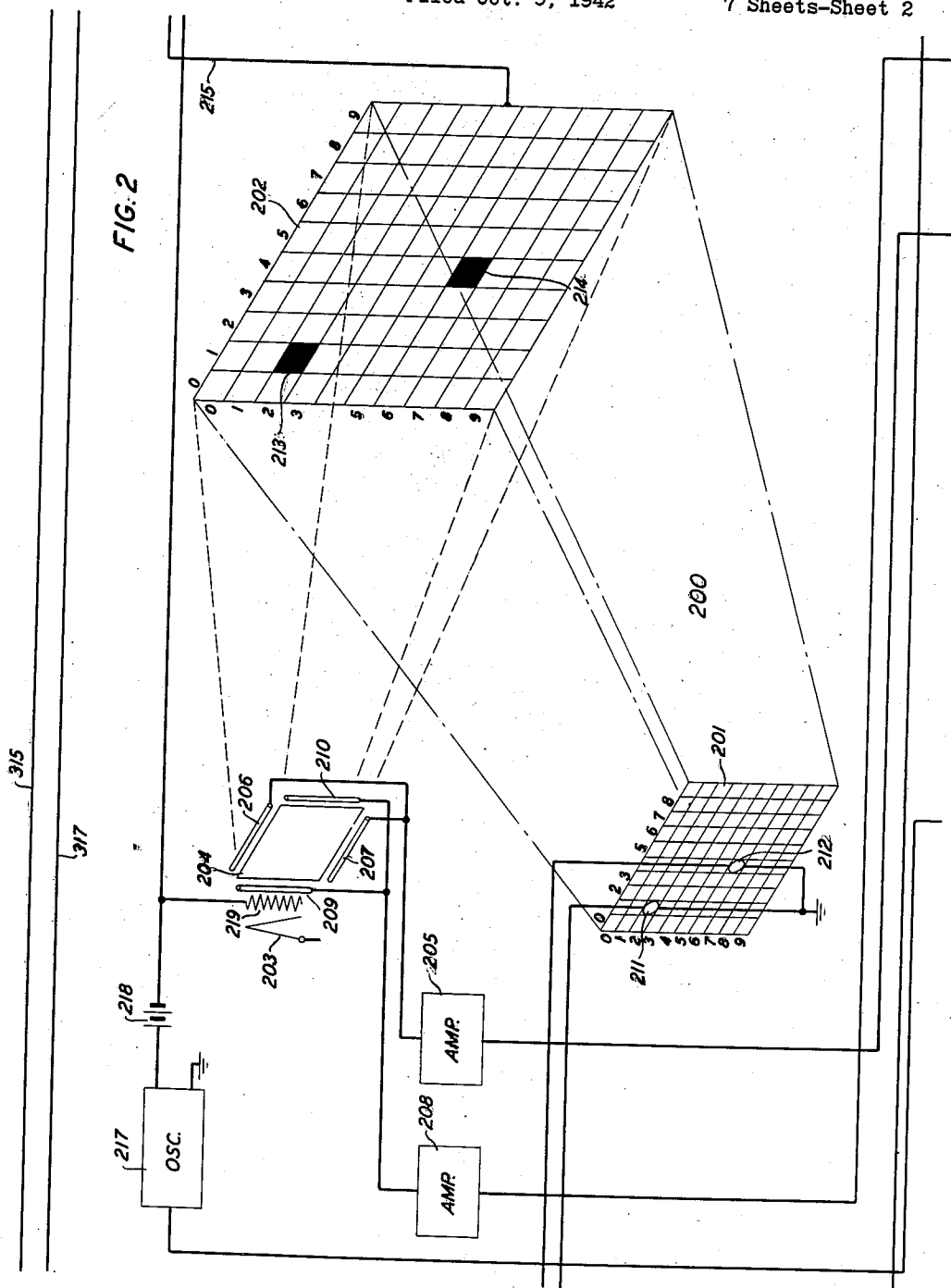
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COMMUNICATION SYSTEM

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7 Sheets-Sheet 2



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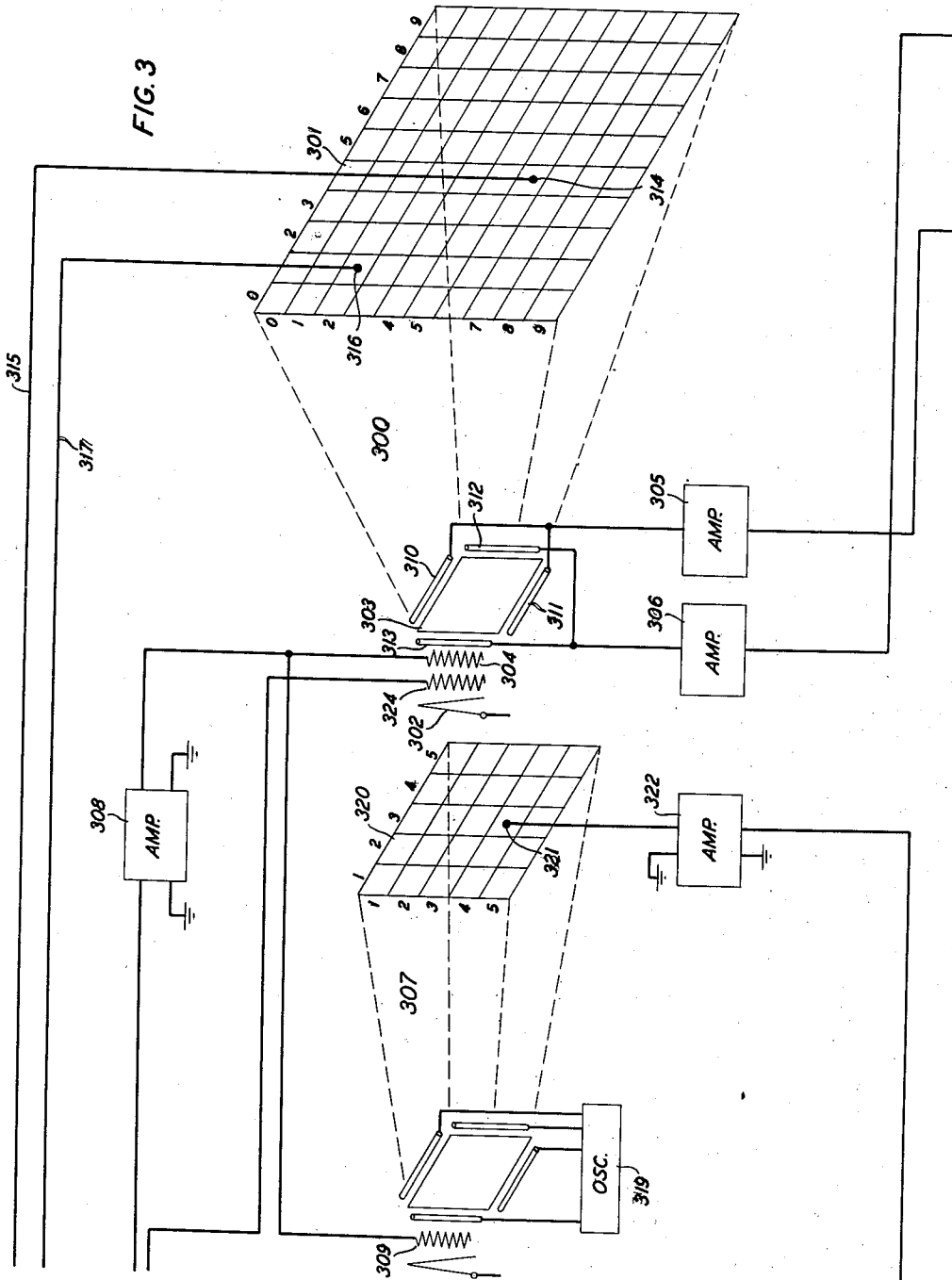
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2,356,519

Filed Oct. 9, 1942

7 Sheets-Sheet 3

FIG. 3



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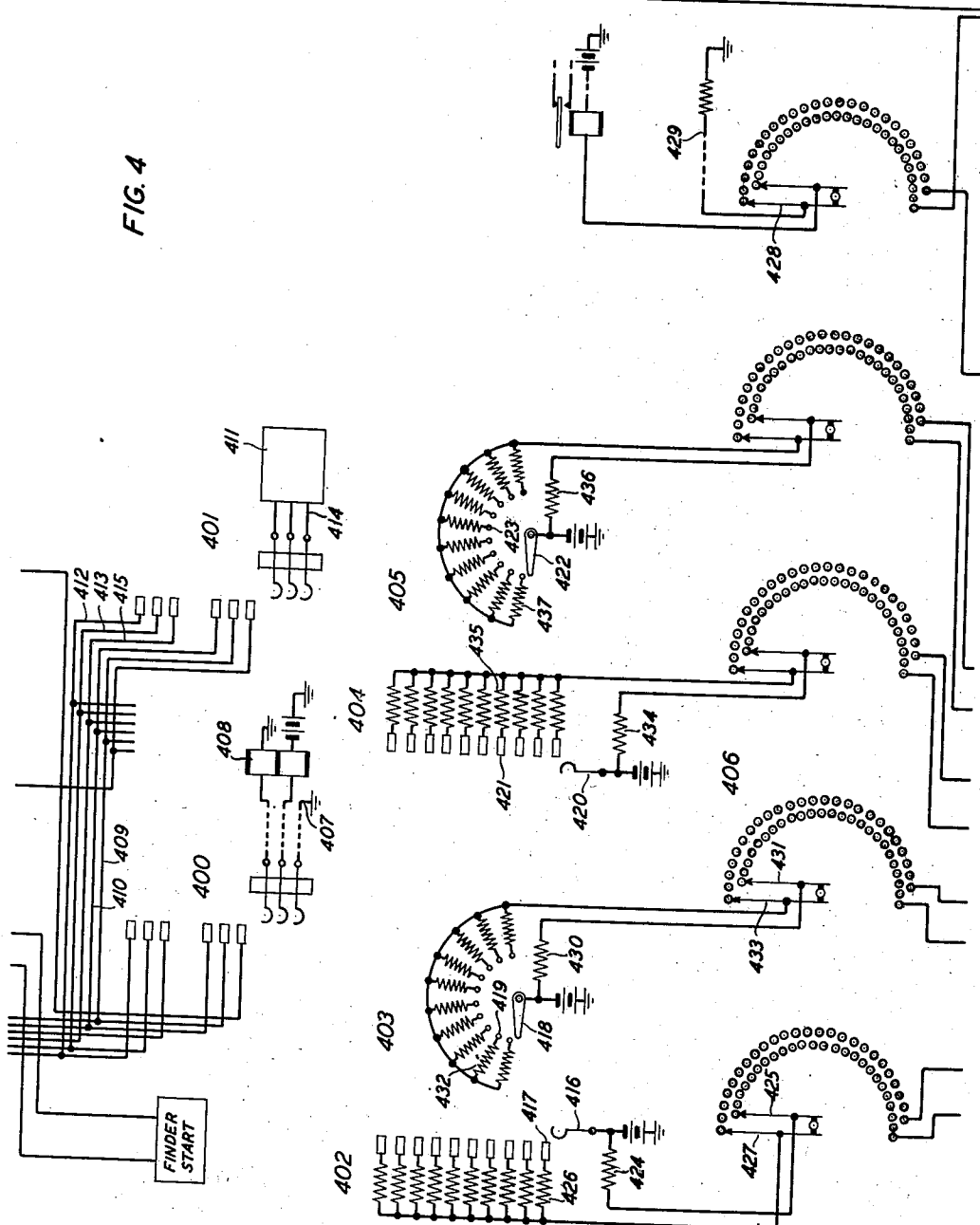
F. A. HUBBARD
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2,356,519

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7 Sheets-Sheet 4

FIG. 4



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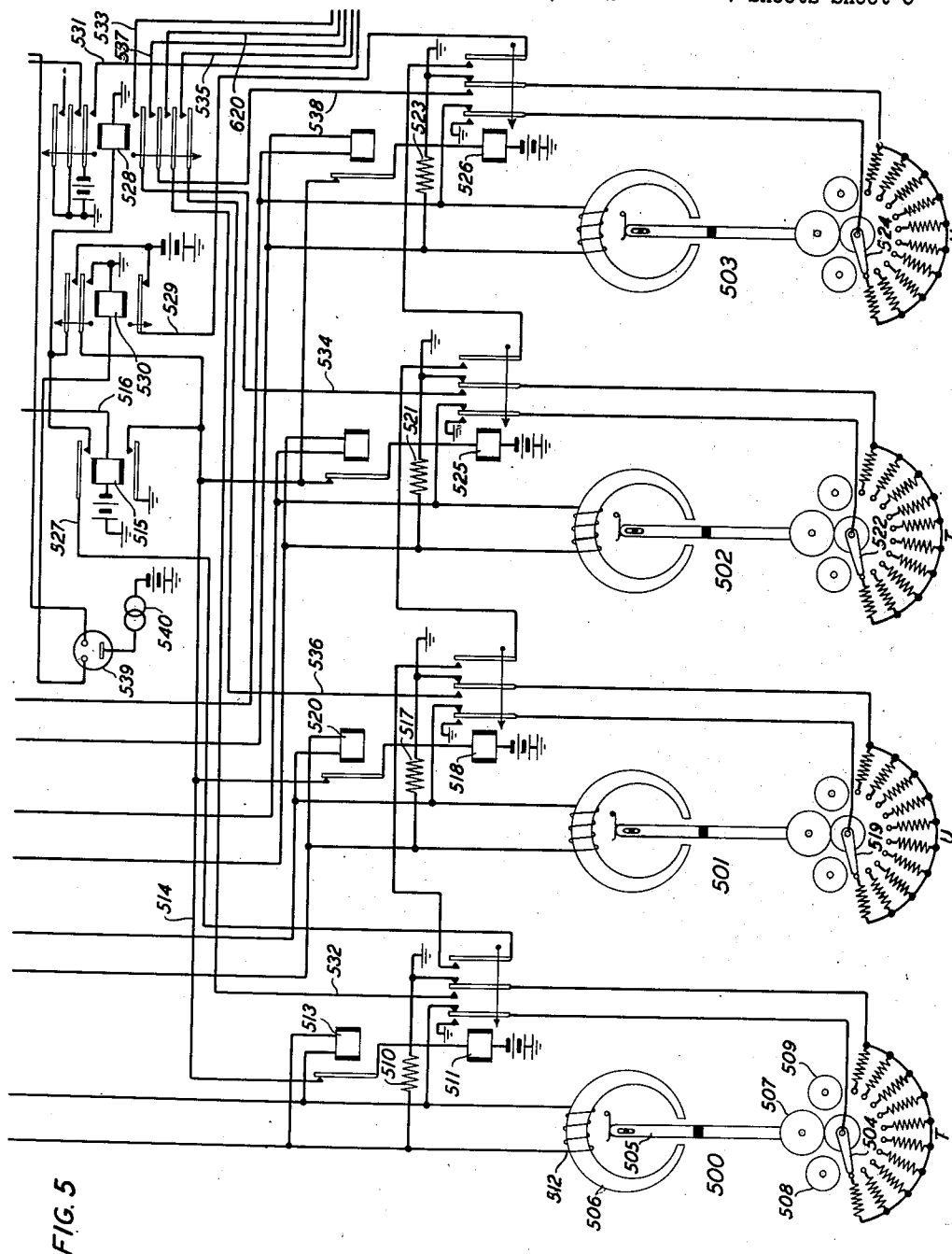
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COMMUNICATION SYSTEM

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7 Sheets-Sheet 5



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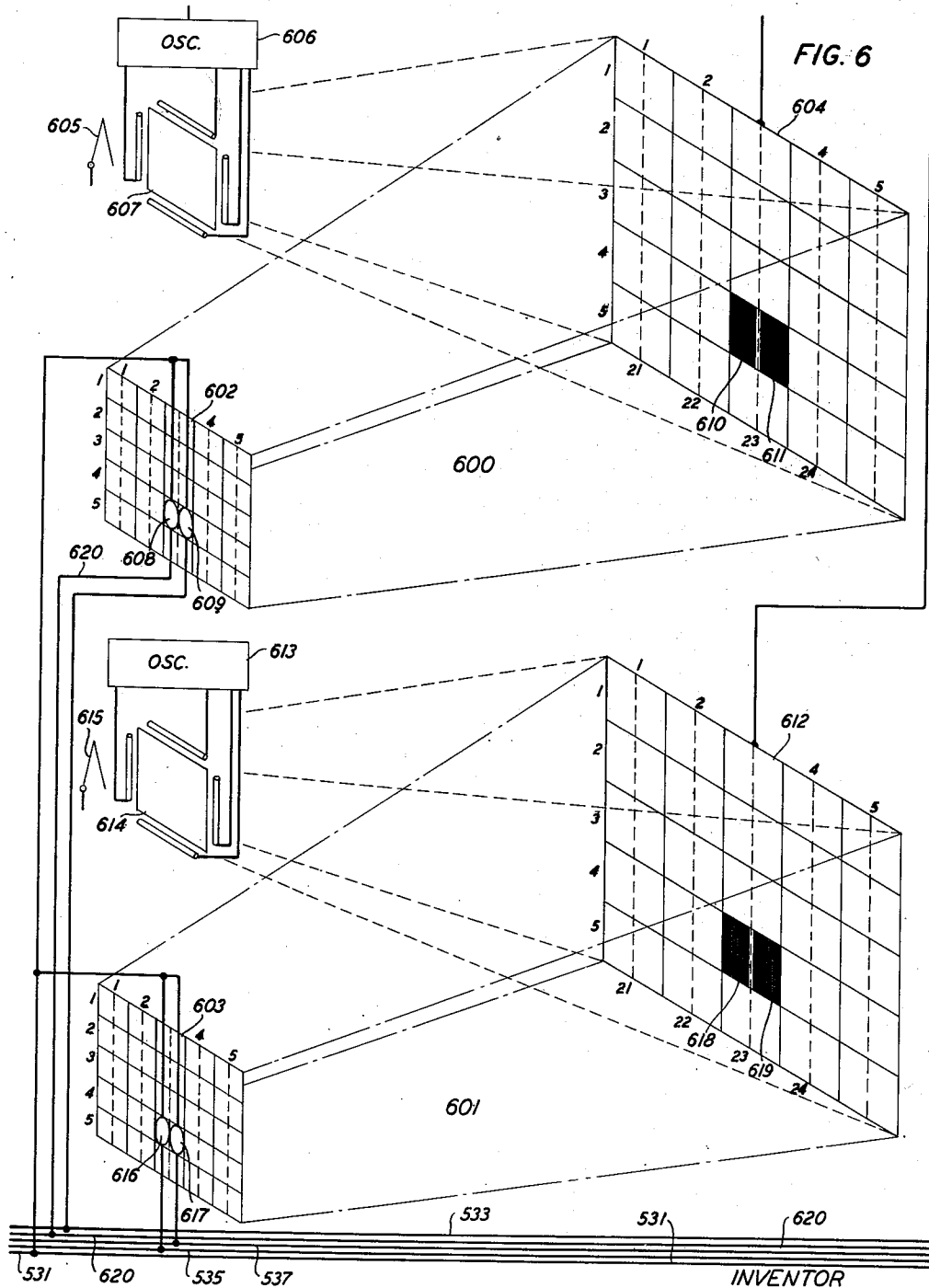
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COMMUNICATION SYSTEM

2,356,519

Filed Oct. 9, 1942

7 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

2,356,519

COMMUNICATION SYSTEM

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Application October 9, 1942, Serial No. 461,429

12 Claims. (Cl. 179—18)

This invention relates to electrical switching and particularly to switching devices for use in communication systems.

The objects of the invention are to simplify the devices used to perform the switching of communication lines or other electrical circuits; to eliminate to a large extent moving mechanisms heretofore used for this purpose; to increase the speed with which connections may be established; and in other respects to obtain improvements in switching systems.

Many varieties of automatic switching have been proposed in the past for interconnecting the lines of telephone, telegraph and other communication systems. Usually these switching mechanisms have depended largely upon electromechanical devices in which moving parts serve to perform the selective and connecting operations involved in the establishment of the desired connections. While some of these types have been developed to a high degree of reliability, it is true nevertheless that the presence of moving mechanical elements imposes limitations on the speed of operation and also introduces other problems. Some of these disadvantages are overcome in the system shown and claimed in my copending application, Serial No. 461,428, filed October 9, 1942, wherein electron beam scanning devices are utilized to establish connections between lines.

In accordance with the present invention further improvements and advantages are obtained over these prior systems, and particularly the one shown in the above-mentioned application, by means of a system in which any pair of lines of a plurality of lines may be interconnected for communication through the medium of a connecting circuit and a pair of energy beams, and in which one of said beams is caused to move directly into engagement with one line of the pair at the same time the other beam is caused to move directly into engagement with the other line of the pair. More specifically, the lines appear in the fields of two scanning or beam switching devices, the beams of which engage momentarily and repeatedly the lines of all pairs involved in communication. A plurality of controlling and registering mechanisms are provided, and these mechanisms are taken in use to register respectively the designations of the different pairs of lines engaged in communication. Thus, several communications may be going on concurrently, and each controlling mechanism serves in its turn to cause said scanning devices to direct their beams, one into engagement with

one line of the corresponding pair and the other into engagement with the other line of the pair. This operation is repeated in such rapid succession that the communication connection between each pair of lines has the same effect as if it were continuous.

A feature of the invention is a system in which the controlling mechanisms are scanned repeatedly to determine which ones are serving calls and in which the designation information registered in each controlling mechanism is effective at each scanning of said controlling mechanism to cause the scanning beams of the line connecting devices to move directly into communicative engagement with the respective lines of the pair being served by said controlling mechanism.

Another feature is a system in which a scanning device is provided for repeatedly scanning said controlling mechanisms to supervise the communications on the lines being served by said mechanisms. When communication ceases on any particular pair of lines, the supervisory scanning device detects this condition and causes the release of the control mechanism serving that pair of lines.

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 7, when arranged in the order illustrated in Fig. 8, disclose a telephone system incorporating the features of this invention.

Fig. 1 shows two of the subscribers' lines together with the line circuits and associated equipment;

Fig. 2 shows a transmitter or primary beam switch in which all of the lines appear and which serves to transmit the voice signals originating in all lines engaged in conversation;

Fig. 3 discloses a reproducer or secondary beam switch in which all of the lines appear and which serves to transmit the voice signals to all lines engaged in conversation. This figure also discloses an electron beam device which serves to scan the circuits for supervisory purposes;

Fig. 4 shows a pair of registers for registering the designations of the calling and called lines, together with means for selecting an idle one of a plurality of register links;

Fig. 5 discloses one of the register links;

Fig. 6 shows a pair of link scanners which serve to direct the movement of the beam of the transmitting switch of Fig. 2; and

Fig. 7 discloses a pair of link scanners which serve to direct the movement of the beam of the reproducer shown in Fig. 3.

The invention in its broader aspects contemplates a multiplex system in which a plurality of communication channels are established concurrently for voice communication, telegraph signaling, 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 telephone system, all of which may be subscribers' lines if desired, or a part of which may be trunks, such as those 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 the system.

Referring to the drawings, it will be noted that each of the lines in the system appears at the central office in a transmission transformer of the hybrid type whereby voice currents outgoing from the line and incoming thereto may be transmitted and received without mutual interference. For example, subscriber's line 100 appears in the hybrid transformer 101 and balancing network 102, and line 103 appears in the hybrid transformer 104 and balancing network 105, and the same is true of each of the remaining lines in the system.

Each of the one hundred lines in the system also has an individual appearance in the beam transmitter 200, and to this end the beam transmitter is provided with a field of lamps 201. There are one hundred of these lamps, each of which represents and is connected to one of the subscribers' lines, and they are arranged in a coordinate array of ten horizontal rows and ten vertical rows. The beam transmitter is also provided with an image screen 202 together with a suitable lens system for casting an image of the lamp array 201 on the screen 202. Accordingly, the screen 202 may be considered as comprising one hundred elemental areas arranged coordinately in ten horizontal and ten vertical rows, said elemental areas corresponding to the lamps in the field 201. Moreover, the beam transmitter 200 is provided with means, such as an emitting cathode 203, for producing a beam of electrons together with driving means 204 for causing the beam to scan the screen 202 repeatedly at a high rate of speed and in accordance with a desired pattern. The beam transmitter may be of any suitable type well known in the art in which the output voltage from the screen 202 created by the passage of the electron beam over the successive elemental areas is directly proportional to the amount of light focused on said individual areas.

Besides appearing in the beam transmitter 200, the group of one hundred subscribers' lines also appear in the beam switch or reproducer 300. The scanning field 301 of the reproducer 300 is divided into one hundred electrically separate elemental areas arranged coordinately in ten horizontal and ten vertical rows and the lines are connected respectively to these elemental areas. The reproducer 300 is also provided with an electron-emitting cathode 302 for producing a beam of electrons, a driving device 303 for directing the beam over the field 301 and a control electrode 304 for controlling the intensity of the beam. Like the transmitter 200 the reproducer 300 may be of any suitable well-known type. For example, any of the well-known cathode ray tubes may be employed, the general requirements being that

the screen is divided into a field of electrically separate elemental areas of light-sensitive material, that a beam of electrons is provided for scanning the field of elemental areas, and that a beam-directing means is provided for driving the beam over the areas in a desired pattern.

The horizontal and vertical location of the appearance of each line in the field 202 of the transmitter and in the field 301 of the reproducer is identical. Although any desired numbering system could be used, it will be assumed for the purpose of this disclosure that the line appearances in the fields 202 and 301 are numbered from left to right and from top to bottom beginning with the elemental area in the upper left corner of the field. For example, the first ten lines (lines No. 0 to No. 9) appear in the uppermost horizontal row of lamps in the field 201 of the transmitter, and in the images of these lamps in the corresponding row of elemental areas in the field 202, numbered from left to right in both cases. Furthermore, these first ten lines appear through electrical connections in the uppermost horizontal areas in the field 301 of the reproducer. The next ten lines (lines No. 10 to No. 19) appear in the second horizontal row from the top in lamp field 201 and correspondingly in the second horizontal row of image areas in field 202 of the transmitter and likewise in the second horizontal row of elemental areas of the field 301 of reproducer 300. The third group of ten lines (lines No. 20 to No. 29) appear in the third horizontal row of lamps in the field 201 and correspondingly in the third horizontal row of image areas in the field 202 of the transmitter and in the field 301 of the reproducer. Similarly, the remaining groups of ten lines appear in successive horizontal rows in the lamp field 201 and in the image fields 202 and 301.

The beams of the transmitter 200 and reproducer 300 are driven over their respective fields in complex patterns which depend at any given instant upon the designations of the subscribers' lines engaged in concurrent conversation and also upon the order in which the several pairs of conversing lines are served by the beam-controlling mechanisms. Briefly stated, if a given number of pairs of lines, appearing in a random pattern in the fields 202 and 301 according to the designations of these lines, are engaged concurrently in conversation, the beam of transmitter 200 will scan in succession the two lines of one conversational pair while the beam of reproducer 300 is scanning these same lines simultaneously in the reverse order, following which the transmitter and reproducer beams in a similar manner scan the two lines of a second conversational pair, following which these beams scan the lines of a third conversational pair, and so on until all pairs of lines in conversation have been scanned, whereupon the scanning process is repeated cyclically, following the same pattern. The scanning pattern, which is complex, depends not alone on the locations of the lines in the fields 202 and 301 but also on the beam-controlling mechanisms with which the lines are associated during conversation and which govern the movement of the beams from one pair of lines to the next.

The mechanism for controlling the beams of the transmitter 200 and reproducer 300 comprises registers for making a preliminary registration of the calling and called line designations of each conversational pair, a plurality of common register links to which the preliminary registrations of the conversational pairs are transferred, and a plurality of scanning devices which re-

peatedly scan these common register links to determine the designations of all pairs of lines involved in conversation and which in turn make use of this information to control the movement of the transmitter and reproducer beams in their complex patterns over the fields 202 and 301.

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 400 and 401, which may be of the well-known step-by-step line finder and connector types. The finder 400 and the connector 401, 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 line finder 400, in addition to its usual terminal banks and brushes, is provided with a vertical commutator 402 and with a rotary commutator 403. The ten segments of the vertical commutator 402 are connected to resistors of graduated values, the value of each resistance representing the corresponding level of the tens digit of all subscribers' lines appearing in that level. Similarly, the ten segments of the rotary commutator 403 are connected to ten resistors of graduated values, the value of each resistance representing the corresponding rotary positions of the switch and the units digit of all lines appearing in that rotary position. The connector switch 401 is also provided with a vertical commutator 404 and with a rotary commutator 405; and the ten graduated resistors associated with the vertical commutator represent the ten values of the tens digit of the called lines, while the graduated resistors associated with the rotary commutator 405 represent the different values of the units digits of the called lines. Briefly stated, therefore, the automatic vertical and rotary movements of the line finder 400 performed in the act of finding a calling subscriber's line serve to register the tens and units digits of the calling line number on the vertical and rotary commutators 402 and 403, respectively. And the vertical and rotary movements of the connector switch 401 in response to the calling subscriber when he dials the number of the called line serve to register the tens and units digits of the called line on the vertical and rotary commutators 404 and 405 respectively.

Each line finder-connector register is provided with a link selecting switch 406 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 link. The register link shown in Fig. 5, which is identical with the other links not shown in the drawings, comprises four registers 500, 501, 502, 503 and certain other controlling devices. The registers 500 and 501 serve to register the tens and units digits of the calling line, and the registers 502 and 503 serve to register the tens and units digits of the called line of a conversational pair. Each of these registers, such as the register 500, comprises a rotatable brush 504, a series of ten contacts connected respectively to graduated resistance elements, a polarized armature 505 and an operating magnet 506. When the magnet 506 is energized by current of one polarity, it moves the armature and the idler pulley 507 thereon into engagement with the driving pulley 508 to move the brush in one direction; and, when the magnet is energized by current of the opposite polarity, the armature 505 advances the idler pul-

ley 507 into engagement with the driving pulley 509 to move the brush 504 in the opposite direction. These registers are automatically positioned by means of bridge circuits including the graduated resistors associated with the commutators 402, 403, 404 and 405. These bridge circuits will be described more fully hereinafter.

The register links, including the one shown in Fig. 5, are scanned cyclically and in a definite order by two pairs of link scanners 600 and 601 and 700 and 701 to determine the designations of the lines being served by said links. Although any suitable number of links may be provided to serve the subscribers' lines, it is assumed herein that there are twenty-five of these register links. Accordingly the scanners 600, 601, 700, 701 are provided each with a pair of signal lamps for each register link, these pairs of lamps being arranged in a coordinate field of five horizontal and five vertical rows. In the scanner 600, for example, the lamp field 602 consists of twenty-five pairs of lamps, each pair representing a different one of the register links and the two lamps of each pair representing respectively the tens digits of the calling and called lines served by said link. In like manner, the lamp field 603 of scanner 601 comprises twenty-five pairs of lamps representing respectively the twenty-five register links, the two lamps of each pair representing respectively the units digits of the calling and called lines being served by the link. And the same is true of the lamp fields 702 and 703 of the scanners 700 and 701, except that the lamps of each pair are reversed, in comparison with the lamps of the scanners 600 and 601, such that any pair of lamps in the lamp field 702 represent respectively the tens digits of the called and calling lines and any pair of lamps in the field 703 represent respectively the units digits of the called and calling lines registered in the link circuit serving said lines.

Each of the scanners 600, 601, 700, 701 is provided with a lens system for focusing an image of the lamp field on the image field. In the scanner 600, for example, the twenty-five coordinately arranged pairs of lamps in the field 602 are focused in a coordinate arrangement on the image field 604. Thus the image 604 may be considered as divided into twenty-five pairs of elemental areas, each pair of areas receiving the images of the corresponding signal lamps. The image field 604 is scanned repeatedly and in a definite order by a beam of electrons emitted from the cathode 605 and driven by an oscillator 606 of suitable frequency through the driving device 607. Although any desired scanning pattern may be used, it will be assumed that the beam of scanner 600 moves from left to right over the uppermost horizontal row of image areas, then returning to the left and moving from left to right over the second horizontal row of areas, then returning to the left and repeating the same trace over the remaining horizontal rows of elements. After the beam has reached the last pair of elemental areas in the bottom horizontal row, it returns to the first horizontal row and repeats the cycle. If the pairs of lamps and elemental areas are numbered sequentially according to the trace followed by the beam, it will be seen that the register link represented by the pair of lamps 608, 609, for instance, and the corresponding pair of image areas 610, 611, is link No. 18 in the group of twenty-five links. In like manner, the scanner 601 is provided with an image field 612 on which the image of the lamp field 603 is focused

and with an oscillator 613 which operates through a driving device 614 to drive a beam of electrons emitted from the cathode 615 over the field 612 in synchronism with the beam of scanner 600 and following the same pattern. Also the scanners 700 and 701 are provided with image fields 704 and 705 and with oscillators 706 and 707 for driving the associated electron beams over these image fields in synchronism with and in accordance with the pattern followed by the beams of scanners 600 and 601. To this end the oscillators 606, 613, 706 and 707 are of the same frequency and are held in synchronism with each other, or if desired the beam-driving devices of all four scanners may be operated from a single source of oscillations.

The link scanners 600 and 601 control the two coordinate components of the motion of the beam of transmitter 200. Accordingly the output voltage from the image field 604 is applied through amplifier 205 to the plates 206 and 207 to determine the vertical or tens group selecting motion of the beam from cathode 203. Similarly the voltage output from the image field 612 is applied through amplifier 208 to the control plates 209 and 210 to determine the horizontal or units selecting movement of the beam of the transmitter 200. In like manner the output voltages from the image fields 704 and 705 are applied through amplifiers 305 and 306 to the controlling plates of the device 303 to determine the tens and units selecting movements respectively of the beam from the cathode 302 of the beam reproducer 300. Thus it will be seen that the output voltages from the image fields 604 and 612 determine the elemental area on which the beam of the transmitter 200 is caused to impinge and at the same instant the output voltages of the image fields 704 and 705 determine the elemental area on which the beam of the reproducer 300 is caused to impinge. If, therefore, the voltages of fields 604 and 612 are made to represent the tens and units digits of one line of a conversational pair at the same instant that the voltages of fields 704 and 705 represent the tens and units digits of the other line of said pair, and vice versa, it will be possible to connect any pair of lines for conversation, first in one direction and then in the other, during each scanning cycle of the link scanners. The manner in which these representative voltages are derived from the image fields of the link scanners will now be explained.

When the registers 500 and 501 assume their adjusted positions in accordance with the tens and units digits respectively of the calling line, they establish circuits for lighting the lamps 608 and 616 representing the calling line. As will be explained more in detail hereafter, the circuit for lighting the lamp 608 includes a resistor of the register 500 graduated to give the lamp an intensity which is a measure of the tens digit of the calling line. Likewise the circuit for lamp 616 includes a graduated resistor of the register 501 that gives the lamp an intensity corresponding to the units digit of the calling line. At the same time the lamps 708 and 709 are included in parallel circuits and are lighted therefore to intensities representing the tens and units digits of the calling line. In like manner, the setting of the registers 502 and 503 prepare circuits including their graduated resistors for lighting the lamps 609 and 710 to intensities representing the tens digit of the called line and for lighting the lamps 617 and 711 to intensities representing the

units digit of the called line. Therefore, when the link scanning beams reach the first image areas 610, 618, 712 and 713 representing link No. 18, the output voltages of fields 604 and 612 cause the transmitter 200 to direct its beam to the calling line, and the output voltages of fields 704 and 705 cause the reproducer 300 to direct its beam to the called line, whereupon any conversational signals in the calling subscriber's line are transmitted as will be explained hereinafter to the called line. An instant later the link scanning beams move to the image areas 611, 619, 714 and 715, whereupon the output voltages of fields 604 and 605 direct the transmitter beam into engagement with the called line, and the output voltages of field 704 and 705 direct the reproducer beam into engagement with the calling line, and any talking signals present in the called line are transmitted to the calling line. In this manner the group of twenty-five register links are scanned successively and repeatedly by the link scanners, and each time a link is encountered which is serving a pair of subscribers' lines in conversation, the link scanners determine the designations of the two lines and utilize this information to direct the beams of the transmitter 200 and reproducer 300 first into engagement with the calling and called lines respectively, and then into engagement with the called and calling lines respectively. And the rate at which the links are scanned is so rapid that the effect is the same as though each pair of subscribers' lines were permanently connected together while they are in conversation.

Since the register links are not included in the conversational connection between the subscribers' lines, it is necessary to provide some means for releasing these links as soon as the subscribers complete their conversation. For this purpose a scanning device 307 is provided for scanning the links continuously. As long as the subscribers' lines of a pair are held the link circuit serving said lines is also held under the control of the scanning device 307. As soon, however, as both subscribers of the pair replace their receivers, the scanning device 307 ceases to deliver energy to the link circuit which was serving said lines, and the link circuit thereupon restores to its normal condition.

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 right winding of line relay 106, transformer coil 107, thence over the loop of the subscriber's line and returning through transformer coil 108, left winding of relay 106 to ground. Relay 106, which is slow to release in character, attracts its armatures and applies ground potential to the usual line finder start conductor 109. The start condition on conductor 109 causes an idle line finder 400 to operate in its vertical and rotary movements to seize the calling line 100. When the finder reaches the calling line, a circuit is closed from battery through the winding of cut-off relay 110, contacts of relay 106, back contacts of relay 110, conductor 111, terminal and brush of the line finder 400 to the control conductor 407. The application of battery potential to conductor 407 serves in any well-known manner to terminate the hunting movement of the finder, whereupon ground potential is applied to conductor 407 in

the line finder to cause the operation of the cut-off relay 110. Before its operating circuit is opened, the cut-off relay 110 closes a locking circuit for itself traceable from battery through the winding of said relay, closed contacts of relay 106 to ground at the front contacts of relay 110. Relay 110 at its outer left armature opens the start conductor 109 to prevent the starting of another line finder and at its inner left armature removes the hunting condition from the conductor 111 extending to the line finder switches.

The calling subscriber now proceeds to manipulate his dial 112 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 408, brush and terminal of the line finder 400, conductor 409 over the loop of the subscriber's line and returning over conductor 410, terminal and brush of finder 400 to ground through the upper winding of impulse relay 408. In the well-known manner the impulse relay responds to these series of impulses to operate the connector switch 401 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 connector 401 positions its brushes on the terminals of the called line 103, the ringing and control mechanism 411 associated with the connector applies ringing current in the well-known manner over the conductors 412 and 413 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 414 through the brush and terminal of the connector, conductor 415, closed contact of line relay 113, which is operated when the called party answers, winding of cut-off relay 114 to battery. Relay 114 operates and locks in a circuit traceable from battery through its winding, closed contacts of relay 113 to ground at the inner left contact of relay 114. Relay 114 opens the start conductor 115 and applies ground potential to conductor 415 to render the line 103 busy in the banks of the connector switches.

The setting of the finder and connector switches 400 and 401 in their vertical and rotary positions as above explained, serves to register the tens and units digits of the calling and called lines respectively. The line finder 401 comes to rest with its vertical commutator brush 416 on the No. 1 terminal 417 and with its rotary commutator brush 418 on the No. 2 terminal 419; and the connector switch 401 comes to rest with its vertical commutator brush 420 on the No. 4 terminal 421 and with its rotary commutator brush 422 on the No. 6 terminal 423. Following the setting of the line finder and connector switches 400 and 401, the link selector switch 406 hunts for and seizes an idle one of the register links, such as the one shown in Fig. 5.

Next the registers 500, 501, 502 and 503 of the seized link are positioned in accordance with the tens and units digits registered on the finder 400 and on the connector 401. The setting of the link registers is performed by bridge circuits which are brought into balance when the registers assume their proper positions. One side of the bridge circuit for the register 500 may be traced from battery through the fixed resistor 424, brush 425 and associated terminal, fixed resistor 510 to ground. The other side of the bridge is traceable from battery through the commutator brush 416, terminal 417, graduated resistor 426, brush 75

427 and associated terminal, inner back contact of relay 511, brush 504 and the graduated resistor on which the brush happens to be standing at this time, outer right back contact of relay 511 to ground. If the bridge is unbalanced at this time, current flows in one direction or the other depending on the sense of the unbalance through the register operating coil 512 and through the winding of relay 513 in parallel. Relay 513 operates and opens the circuit of relay 511 to prevent this relay from operating. The magnet 506 is energized, and the brush 504 is driven in the direction necessary to bring the bridge into a balanced condition. As soon as a balance is established, namely, when the brush 504 reaches a graduated resistance of the same value as resistor 426, the brush 504 comes to rest and relay 513 releases. A circuit is now closed from battery through the winding of relay 511, contacts of relay 513, conductor 514 to ground at the front contacts of relay 515. It will be noted that relay 515 operated at the time the selector 406 seized the register link in a circuit from battery through its winding, conductor 516, brush 428 and the associated terminal, conductor 429 to ground. Relay 511 is made slow to operate in order that relay 513 may have time, following the seizure of the register link by the switch 406, to open the circuit of relay 511 which would otherwise be closed at this time by the operation of relay 515. The bridge circuit for setting register 501 may be traced on one side from battery through the fixed resistor 430, brush 431 and associated terminal, fixed resistor 517 to ground, and on the other side from battery, brush 418, terminal 419 and the associated graduated resistor 432, brush 433 and the associated terminals, normal contacts of relay 518, brush 519 through the graduated resistor and the normal contacts of relay 518 to ground. Relay 520 operates to open the circuit of relay 518, and the register 501 is driven until the bridge is balanced. When this occurs relay 520 releases and extends the grounded conductor 514 to operate the relay 518. Thus the register 500 is positioned to register in the link the tens digit of the calling line 100, and the register 501 is operated to register the units digit of the calling line. In like manner the register 502 is positioned under the control of the bridge circuit including fixed resistors 434 and 521, graduated resistor 435 and the graduated resistors associated with the register brush 522. Similarly the register 503 is positioned by a bridge circuit including the fixed resistors 436 and 523, graduated resistor 437 and the graduated resistor associated with the register brush 524. Thus the registers 502 and 503 are positioned to register the tens and units digits of the called line 103, and the associated relays 525 and 526 are operated.

As soon as all of the registers 500, 501, 502 and 503 are positioned, a series circuit is closed from ground through the winding of relay 528, front contact of relay 515, conductor 527, thence in series through the front contacts of relays 511, 518, 525 and 526, conductor 529, normal contacts of relay 530 to battery. Relay 528 operates in this circuit and prepares the circuits for lighting the lamps in the fields of scanners 600, 601, 700 and 701. The circuit for lamp 608 representing the calling line may be traced from battery through the contacts of relay 528, conductor 531, lamp 608, conductor 620, closed contacts of relay 528, conductor 532, front contact of relay 511 through the selected resistor and brush 504, front contact of relay 511 to ground. The circuit for lamp 708

representing the tens digit of the calling line is also closed from battery through the contacts of relay 528, conductor 531, lamp 708, conductor 620, contacts of relay 528 to ground as above traced over conductor 532. Lamps 608 and 708 burn at an intensity representing the value of the tens digit of the line 100, and images of these lamps are focused on the corresponding elemental areas 610 and 714. The circuits for the lamps 609 and 710 representing the tens digit of the called line are closed from battery through the contacts of relay 528, conductor 531 thence in parallel through these lamps to conductor 533 through the contacts of relay 528, conductor 534, front contacts of relay 525, resistor and brush 522, front contacts of relay 525 to ground. The value of the resistance in this circuit permits the lamps 609 and 710 to light at an intensity which is a measure of the tens digit "4" of the called line 103, and images of these lamps are focused on the corresponding elemental areas 611 and 712. Lamps 616 and 709 representing the units digit of the calling line are lighted in circuits traceable as above explained from battery over conductor 531 through these lamps in parallel to conductor 535, contacts of relay 528, conductor 536, contacts of relay 518 through the resistor and associated brush 519 to ground at the front contacts of relay 518. Also circuits are closed for the lamps 617 and 711 representing the units digits of the called line, and these circuits are traceable from battery over conductor 531 through the lamps in parallel, conductor 537, contacts of relay 528, conductor 538, front contacts of relay 526, brush 524 and the associated resistor, front contacts of relay 526 to ground. Lamps 616 and 709 light to intensities characteristic of the units digit "2" of the calling line 100, and images of these lamps are focused on the elemental areas 618 and 715; and lamps 617 and 711 are lighted to an intensity characteristic of the units digit "6" of the called line 103, and images of these lamps are focused on the elemental areas 619 and 713. The scanners 600, 601, 700 and 701 are now ready to control the beams of the transmitter 200 and reproducer 300 to establish conversational connections between the calling and called lines.

At the time the cut-off relays 110 and 114 of the calling and called lines operate, circuits are closed for lighting the signal lamps of these lines in the lamp field 201 of the transmitter 200. The circuit for lamp 211, which occupies position "12" in the coordinate field 201, may be traced from battery through the winding of transformer 116, contacts of relay 110, lamp 211 to ground. Similarly, the circuit of lamp 212, which occupies position "46" in the lamp field, is lighted in a circuit from battery through the winding of transformer 117, contacts of cut-off relay 114, lamp 212 to ground. Lamps 211 and 212 are illuminated to a given intensity, and their images are focused on the corresponding elemental areas 213 and 214.

As soon thereafter as the beams of the scanners 600 and 601 reach the elemental areas 610 and 618, the output voltages from the fields 604 and 612, which are proportional to the digits "1" and "2" of the calling line, are applied to the control plates 206, 207, and 209, 210, of the driving device 204 causing the beam of transmitter 200 to move immediately to the elemental area 213. Simultaneously therewith, the beams of scanners 700 and 701 reach the elemental areas 712 and 713, and the output voltages of fields 704 and 705, which are proportional to the digits "4" and "6" of the called line are applied respectively to the

deflection plates 310, 311 and 312, 313, causing the beam of reproducer 300 to move immediately into engagement with the elemental areas 314, individual to the called line 406. If at this instant the calling subscriber is speaking, the varying currents flowing in the line 100 are induced in the windings of transformer 116, causing the calling line lamp 211 to vary in intensity in accordance with the speech currents. This variation in the lamp intensity is reflected in the image 213, and a voltage variation likewise appears on conductor 215. This voltage is amplified by a suitable amplifier 308 and is applied to the control grid 304 of the reproducer 300, causing the intensity of the electron beam impinging on the elemental area 314 to vary in accordance with the calling subscriber's speech. Hence the output voltage from the elemental areas 314 varies in the same manner and is applied over conductor 315 through the transformer windings 104 to the called subscriber's line 103. Thus the calling subscriber's speech is transmitted through the transmitter 200 and the reproducer 300 to the called line during the brief instant that the beams are impinging on the elemental areas 213 and 314. An instant later the beams of scanners 600 and 601 move off the areas 610 and 618 and engage the areas 611 and 619, and simultaneously the beams of scanners 700 and 701 move off the areas 712 and 713 and engage the areas 714 and 715. The output voltages from the fields 604 and 612 now are proportional to the tens and units digits "4" and "6" of the called line, and the beam of transmitter 200 is moved from the elemental area 213 directly to the elemental area 214 which is individual to the called subscriber's line. Likewise the output voltages of fields 704 and 705 are proportional to the tens and units digits of the calling line, and the beam of reproducer 300 is moved directly from the elemental area 314 to the elemental area 316 which is individual to the calling subscriber's line. If at this instant the called subscriber is speaking, the varying currents in his line are induced in the transformer 117, causing the intensity of lamp 212 to vary accordingly. These variations in the lamp 212 are reflected in the image area 214, the output voltage in the circuit 215 varies accordingly, and these variations on the control grid 304 cause corresponding variations in the beam of transmitter 300 which is now impinging on the area 316 of the calling line. Therefore, the output voltage from the area 316 is applied over conductor 317 through the transformer 101 to the calling subscriber's line 100. During this brief interval any speech present in the called line 103 is transmitted through the transmitter 200 and the reproducer 300 to the calling subscriber's line.

An instant later the beams of the scanners 600, 601, 700 and 701 move to the elemental areas representing the next and successive link circuits. If any one of these links is serving a pair of lines, the output voltages from the controlling scanners cause the beams of the transmitter 200 and connector 300 to move directly to the elemental areas representing these lines. This scanning process is repeated cyclically, and each time the controlling scanners encounter a link serving a pair of lines, they cause the transmitter and reproducer beams to engage these lines in order that conversation may take place in both directions.

Since a plurality of pairs of lines may be engaged simultaneously in separate conversations and since beams of the switches 200 and 300

play over the fields 202 and 301 in an intricate pattern, varying from time to time as the combination of conversing lines changes, it is desirable to suppress these beams while they are moving from one elemental area to another and to render them effective only while they are dwelling on the areas to which they have been directed by the beam-controlling scanners. To this end an oscillator 217 is provided for controlling the suppressing grids 219 and 324, and a source of negative potential 218 is included in circuit with said grids. The negative potential of source 218 when unaffected by the oscillator 217 maintains the grids 219 and 324 at a potential sufficient to suppress the flow of electrons from the cathodes 203 and 302, respectively. The oscillator 217, however, which is maintained in a definite phase and frequency relation with oscillators 606, 613, 706 and 707, produces a positive voltage impulse for each of the lamp image areas over which the beams of scanners 600, 601, etc. pass. The phase relation between these oscillators is such that the positive impulses produced by the oscillator 217 and applied to the control grids 219 and 324 do not reach an amplitude sufficient to overcome the biasing battery 218 until the beams of scanners 600, 601, 700 and 701 have reached the selected image areas and until the output voltages from these scanners have been applied to the deflection plates of the switches 200 and 300. In other words, the virtual beams of switches 200 and 300 are driven over the fields 202 and 301 and come to rest on the desired elemental areas before the operating impulse is applied by the oscillator 217 to the grids 219 and 324. When the impulse is thus applied, it overcomes the negative battery 218, the positioned virtual beams assume their real character, and electrons flow from the cathodes 203 and 302 to the selected elemental areas as hereinbefore explained. The real beams of the switches 200 and 300 continue to impinge upon the selected areas representing the subscribers' lines of the pair and to transmit the talking signals from one line to the other until the beams of the scanners 600, 601, 700 and 701 are about to move from one image area to the next in their respective fields. Thereupon the positive impulse from the oscillator 217 ceases, and the beams of switches 200 and 300 are suppressed and remain in their virtual character until the beams of the scanners have moved to their next image areas. As soon as the scanner beams do arrive upon the next image areas, potentials are applied as above explained to the deflection plates of the switches 200 and 300, and the virtual beams of these switches are directed from the positions they last occupied to the elemental areas representing the lines characterized by the image areas upon which the scanning beams have just arrived. Shortly after the virtual beams of the switches 200 and 300 are driven to the new elemental areas, the oscillator 217 produces its next positive impulse, the cathodes 203 and 302 become effective, and the beams are transformed into their real state, permitting the flow of electrons to the selected elemental areas. Thus the beams of the switches 200 and 300 are in a virtual state during the brief intervals in which they are being driven by the scanners over the fields 202 and 301 to prevent them from interfering with other lines that may be involved in conversations.

As long as the cut-off relays 110 and 114 of the subscribers' lines are energized and the associated lamps 211 and 212 are lighted, the impinge-

ment of the beam of the transmitter 200 on the corresponding illuminated elemental areas 213 and 214, once per scanning cycle of the scanners 600 and 601, produces an output voltage in conductor 215 which, after amplification, is applied over conductor 318 to the control grid 309 of the supervisory scanning device 307. The beam of scanner 307 is driven by an oscillator 319 of the same phase and frequency as the oscillators 606, 613, etc.; therefore, the beam of scanner 307 scans the elemental areas in the field 320, representing respectively the register links, in synchronism with the movement of the beams of the scanners 600 and 601. While the beam of transmitter 200 is engaging first the elemental area 213 and then the elemental area 214, the beam of scanner 307 is engaging the elemental area 321 individual to the link circuit shown in Fig. 5. The output circuit from area 321 is amplified by a suitable amplifier 322 and is imposed across the control gap of a discharge tube 539. The tube ionizes in response to the successive voltage impulses applied thereto, and a circuit is closed from battery through the alternating current generator 540, anode and cathode of the tube 539, winding of slow-release relay 530 to ground. Relay 530 operates and remains operated in the circuit traced as long as ionizing impulses are applied to the control grid of the tube 539. And these ionizing impulses will be present as long as either the calling line 100 or the called line 103 is closed to maintain the associated cut-off relay in its operated condition. Relay 530 in operating opens the operating circuit of relay 528, but relay 528 being slow to release remains operated until it is locked in a circuit from battery through the front contact of relay 530 and the winding of relay 528 to ground. Relay 530 also closes a holding circuit over conductor 514 for holding the relays 511, 518, 525 and 526 operated.

As soon as relay 530 operates in the link, which occurs immediately that the registers 500, 501, 502 and 503 are positioned, the register circuit comprising the finder 400, the connector 401 and the selector 406 may be released for use by other lines. The restoration of the selector 406 causes the release of relay 515, but relay 528 is now held as explained at the contacts of relay 530.

After the subscribers have finished conversing, they replace their receivers on their switchhooks, and the line relays 106 and 113 release. The release of these relays causes the restoration of the cut-off relays 110 and 114, and the lamps 211 and 212 are extinguished. For a time the beam of transmitter 200 continues to engage the elemental areas 213 and 214 under the control of the scanners 600 and 601, but the output voltage in the conductor 215 is insufficient to sustain the beam of the supervisory scanner 307. Therefore, the tube 539 ceases to ionize its control gap, and the alternating voltage from the generator 540, opposing the battery on alternate cycles, extinguishes the main discharge gap of the tube and causes the release of relay 530. Relay 530 releases relay 528 to open the circuits of the lamps of the scanners 600, 601, etc., and also opens the holding circuits of relays 511, 518, 525 and 526. The link circuit is now fully restored and may be seized again in connection with the succeeding call.

As previously mentioned, the transmitter 200, the reproducer 300, and scanners 600, 601, 700 and 701 may be of any suitable and well-known type. Also the lamps in the fields 201, 602, 603, 702 and 703 may be chosen in accordance with the specific requirements. In particular they

should be capable of varying their luminosity in accordance with the intensity of the current supplied to them. If desired, light valves could be used instead of the lamps.

It will also be understood that the invention contemplates the use of virtual as well as real beams of electrons or other energy forms and that whenever the specification or claims speak of these beams, either in motion or in their instantaneous positions, these descriptions are intended to apply to the beams in their virtual nature as well as in their real form.

What is claimed is:

1. The combination with a plurality of lines of a connecting circuit, a controlling mechanism, means for registering in said mechanism the designations of any pair of said lines, means for repeatedly scanning said mechanism, and means controlled by said scanning means in accordance with said designations each time it scans said controlling mechanism for establishing a communicative connection between the lines of said pair over said connecting circuit.

2. The combination with a plurality of lines of a connecting circuit, a plurality of controlling mechanisms, means for registering in any one of said mechanisms the designations of any pair of said lines, means for repeatedly scanning said controlling mechanisms, and means controlled by said scanning means each time it scans the controlling mechanism having said designations registered therein for establishing a communicative connection between the lines of said pair over said connecting circuit.

3. The combination with a plurality of lines of means for establishing communicative connection between a pair of said lines comprising a device for producing a beam of energy, a device for producing a second beam of energy, said lines appearing in said devices, and means controlled in accordance with the designations of the lines of said pair for causing one of said beams to move directly into engagement with one of the lines of said pair and for causing the other of said beams to move simultaneously and directly into engagement with the other line of said pair.

4. In combination with a plurality of lines of means for establishing communicative connections between a plurality of pairs of said lines, each pair including a calling line and a called line, said means comprising a device for producing a beam of energy, a device for producing a second beam of energy, said calling lines appearing in said first device and said called lines appearing in said second device, and means controlled in accordance with the designations of the pairs of lines involved in concurrent communications for causing said first beam to engage the calling lines momentarily and successively and for causing said second beam of energy to engage successively and simultaneously the corresponding called lines.

5. The combination with a plurality of lines of means for establishing communicative connections between a plurality of pairs of said lines comprising a device for producing a beam of energy, a device for producing a second beam of energy, said lines appearing in said devices, and means controlled in accordance with the designations of the lines involved in communication for causing said first beam to engage repeatedly first one and then the other of the lines of each pair and for causing said second beam to engage repeatedly and simultaneously with said first beam first one and then the other of the lines of each of said pairs.

6. The combination with a plurality of lines of means for establishing communicative connections between a plurality of pairs of said lines, each pair including a calling line and a called line, said means comprising a device for producing a beam of energy, a device for producing a second beam of energy, said calling and called lines appearing in both of said devices, means for registering the designations of the lines involved in communication, and means controlled in accordance with the designations of said calling and called lines for causing said first beam to engage repeatedly and momentarily the calling line and the called line of each pair and for causing said second beam to engage repeatedly and momentarily the called line of each pair simultaneously with the engagement by said first beam of the calling line of such pair and to engage repeatedly and momentarily the calling line of each pair simultaneously with the engagement of the first beam with the called line of such pair.

7. The combination with a plurality of lines of a connecting circuit for establishing simultaneously connections between separate pairs of said lines, a plurality of controlling mechanisms, means for taking into use a controlling mechanism for each one of said pairs of lines involved in communication, means for registering in each mechanism the designations of the lines served thereby, means for repeatedly scanning said mechanisms, and means controlled by said scanning means in accordance with said designations each time it scans a controlling mechanism for establishing a communicative connection over said connecting circuit between the lines of the pair served by the particular controlling mechanism being scanned.

8. The combination with a plurality of lines of a connecting circuit for establishing coexisting connections between a plurality of pairs of said lines, a plurality of controlling mechanisms, means for taking into use a controlling mechanism for each one of said pairs of lines involved in communication, means for registering in each controlling mechanism the designations of the lines served thereby, means for scanning said controlling mechanisms repeatedly and in a definite order, and means controlled by said scanning means each time it scans a controlling mechanism serving a pair of lines for establishing a communicative connection between said pair of lines.

9. The combination with a plurality of lines of a connecting circuit for establishing coexisting connections between a plurality of pairs of said lines, a plurality of controlling mechanisms, means for taking into use a controlling mechanism for each pair of lines involved in communication, means for registering in each controlling mechanism the designations of the lines served thereby, a field of light sources representing said controlling mechanisms, means for determining the intensity of each light source in accordance with the designations registered in the corresponding control mechanism, means for scanning the light produced by said sources, and means controlled by said scanning means each time it scans the light corresponding to a control mechanism for establishing a communicative connection between the pair of lines served by said mechanism.

10. The combination with a plurality of lines of a scanning device in which said lines appear, a second scanning device in which said lines appear, a connecting circuit appearing in said scan-

ning devices for establishing a communicative connection between any pair of said lines, and means controlled in accordance with the designations of the lines of said pair for causing one of said scanning devices to establish connection with one line of said pair and for simultaneously causing the other scanning device to establish connection with the other line of said pair.

11. The combination with a plurality of lines of a connecting circuit for establishing connections between a pair of said lines, a scanning device in which one end of said connecting circuit appears, a second scanning device in which the other end of said connecting circuit appears, one line of said pair appearing in said first device and the other line of said pair appearing in said second device, means for registering the designations of the lines of said pair, and means controlled in accordance with the registered designations for causing said scanning devices to make

repeated and simultaneous connections with the respective lines of said pair to establish a communicative connection between them.

12. The combination with a plurality of lines of a connecting circuit for establishing coexisting connections between a plurality of pairs of said lines, controlling mechanisms, means for taking into use a controlling mechanism for each pair of lines involved in communication, means controlled by each of said controlling mechanisms for establishing communicative connection over said connecting circuit between the pair of lines served by said controlling mechanism, means for repeatedly scanning said controlling mechanisms, and means controlled by said scanning means for causing the release of a controlling mechanism when communication ceases between the lines of the pair served by said mechanism.

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