July 3, 1945. F. A. HUBBARD 2,379,715

COMMUNICATION SYSTEM

Filed Oct. 9, 1942 7 Sheets-Sheet 1

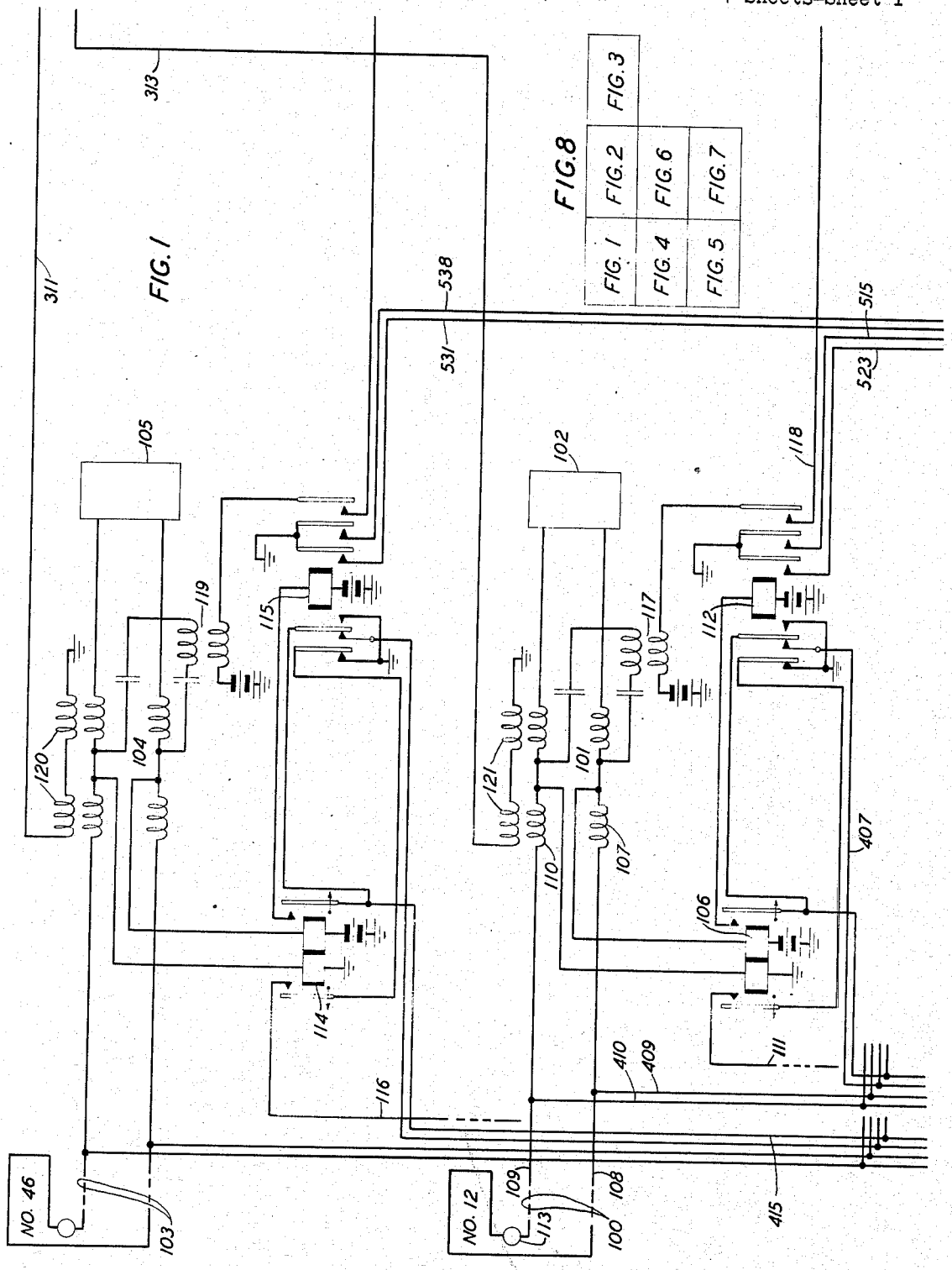


FIG. 1

FIG. 8

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

INVENTOR
FRANCIS A. HUBBARD
BY M. R. McKenney
ATTORNEY

July 3, 1945. F. A. HUBBARD 2,379,715

COMMUNICATION SYSTEM

Filed Oct. 9, 1942 7 Sheets-Sheet 2

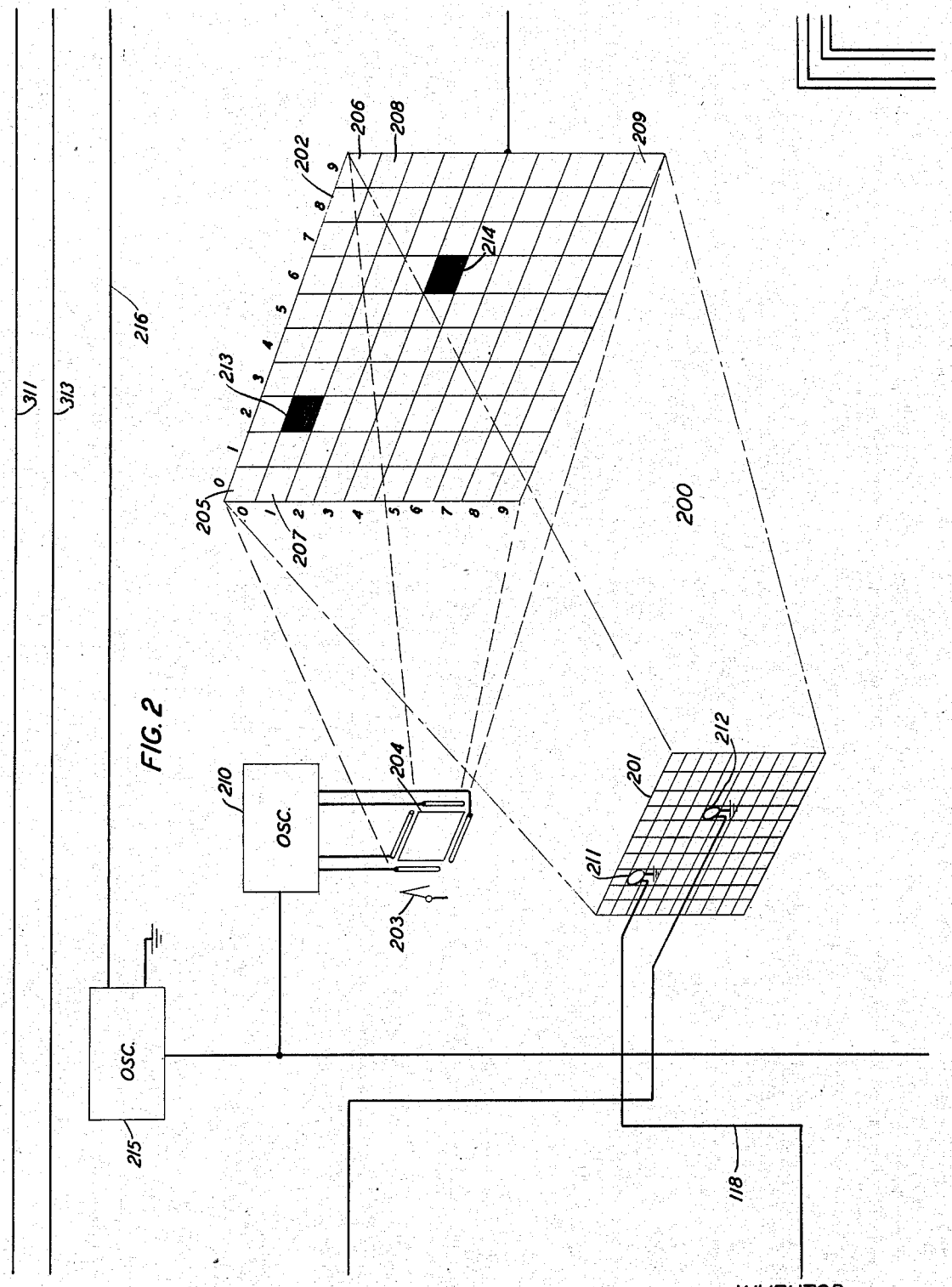


FIG. 2

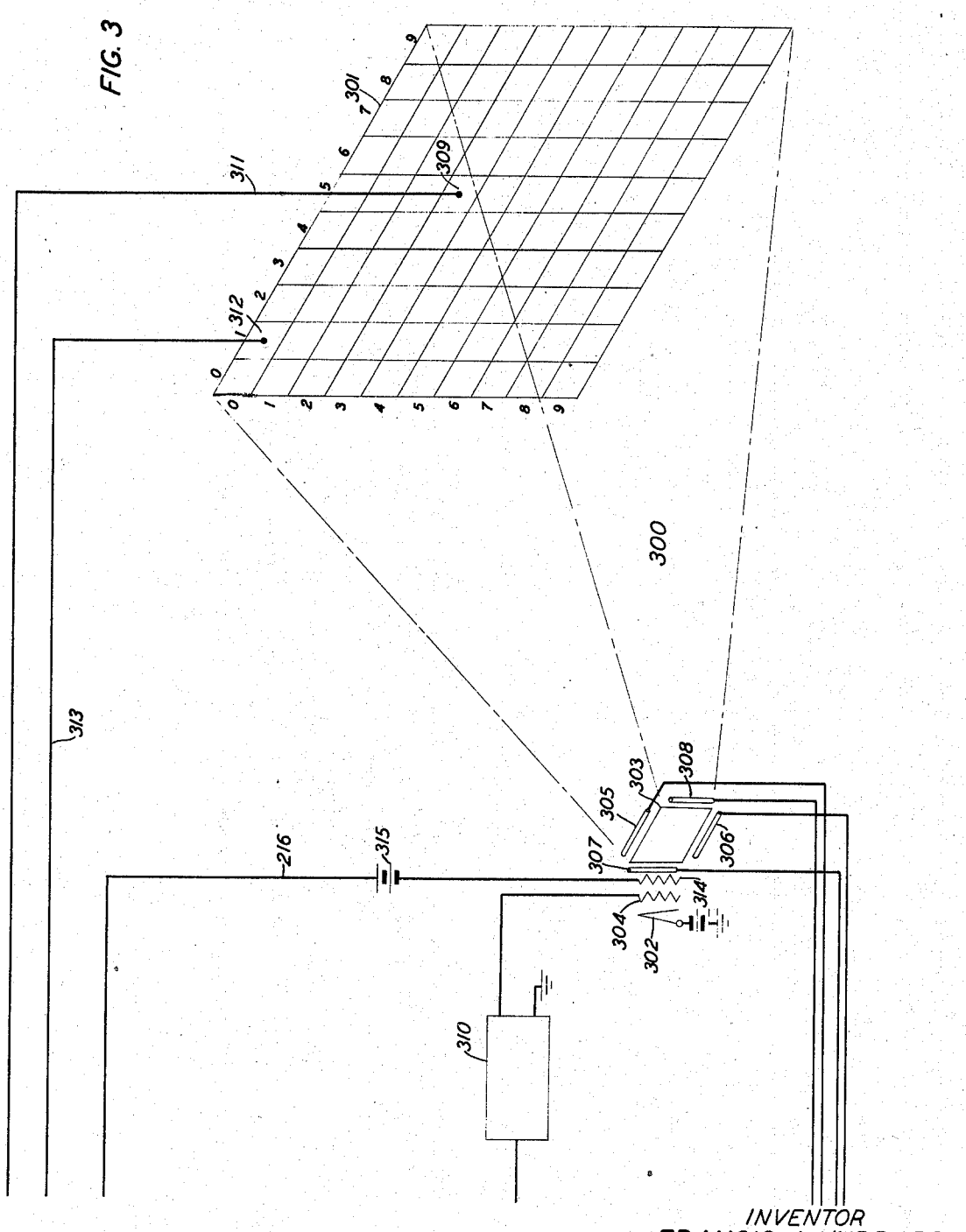
INVENTOR
FRANCIS A. HUBBARD
BY M. R. McKenney
ATTORNEY

July 3, 1945. F. A. HUBBARD 2,379,715

COMMUNICATION SYSTEM

Filed Oct. 9, 1942 7 Sheets-Sheet 3

FIG. 3



INVENTOR
FRANCIS A. HUBBARD
BY
ATTORNEY

July 3, 1945. F. A. HUBBARD 2,379,715

COMMUNICATION SYSTEM

Filed Oct. 9, 1942 7 Sheets-Sheet 4

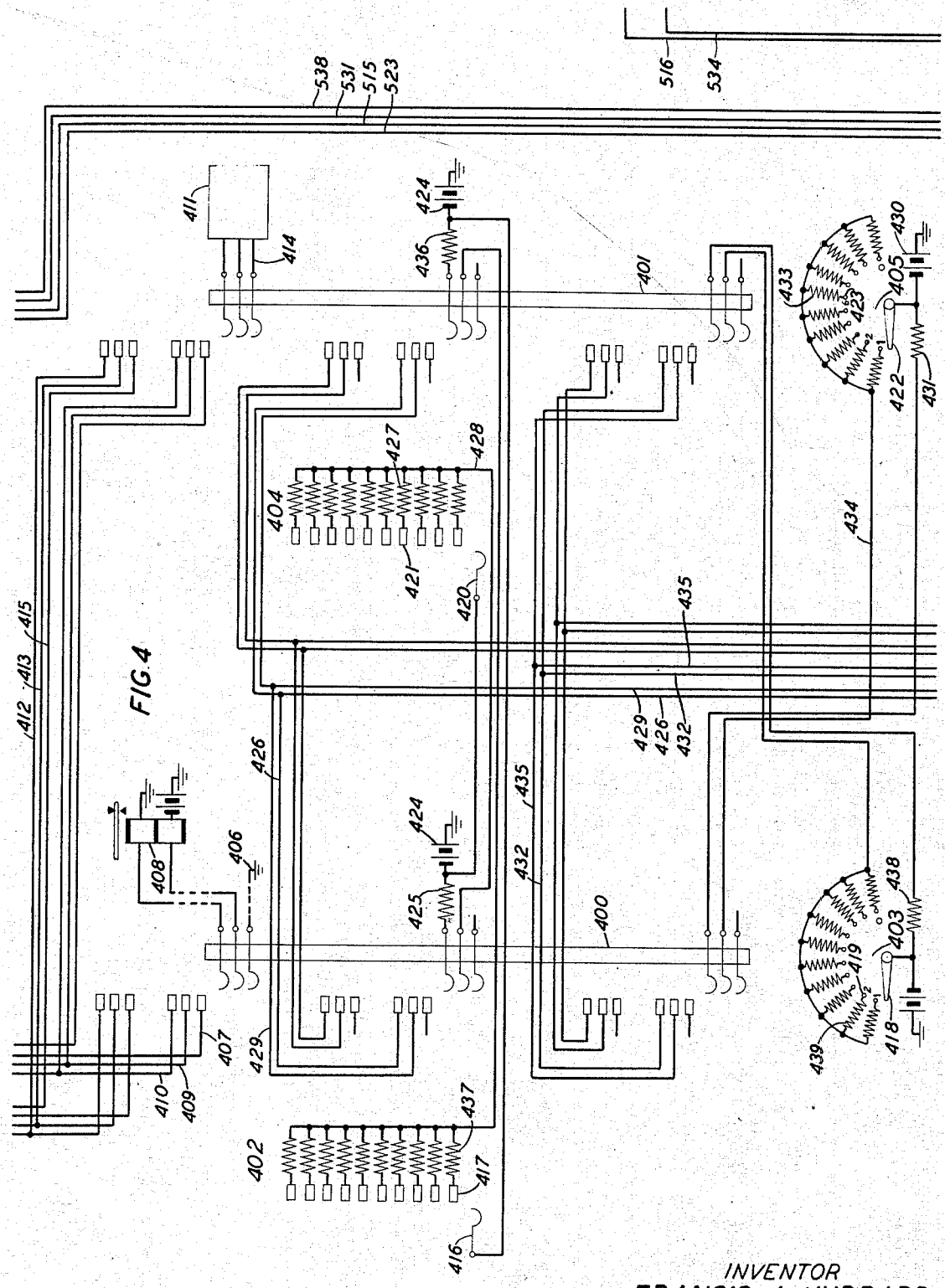


FIG. 4

INVENTOR
FRANCIS A. HUBBARD
BY M. F. McInerney
ATTORNEY

July 3, 1945. F. A. HUBBARD 2,379,715

COMMUNICATION SYSTEM

Filed Oct. 9, 1942 7 Sheets-Sheet 5

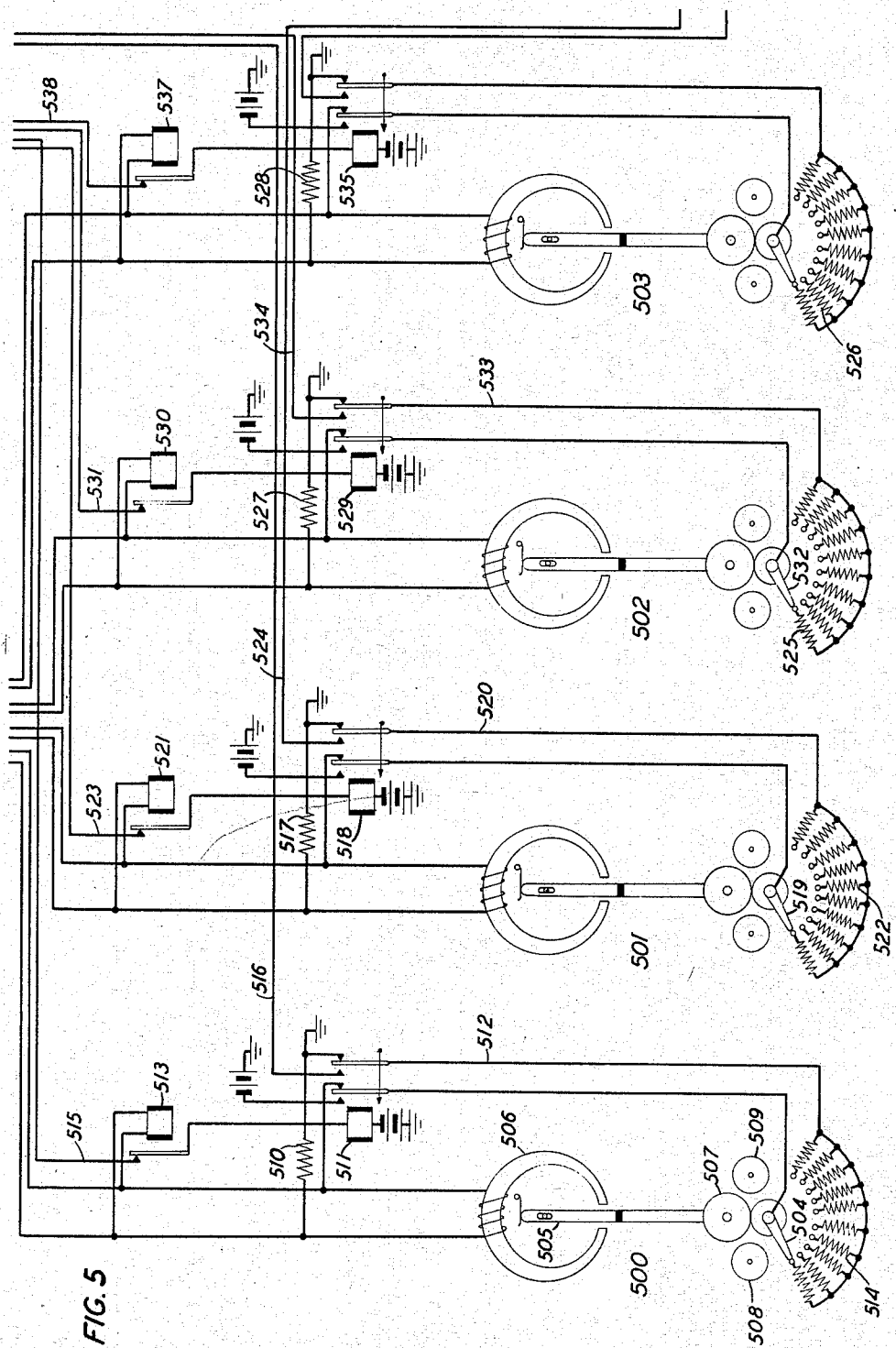


FIG. 5

INVENTOR
FRANCIS A. HUBBARD
BY M. R. McInerney
ATTORNEY

July 3, 1945. F. A. HUBBARD 2,379,715

COMMUNICATION SYSTEM

Filed Oct. 9, 1942 7 Sheets-Sheet 6

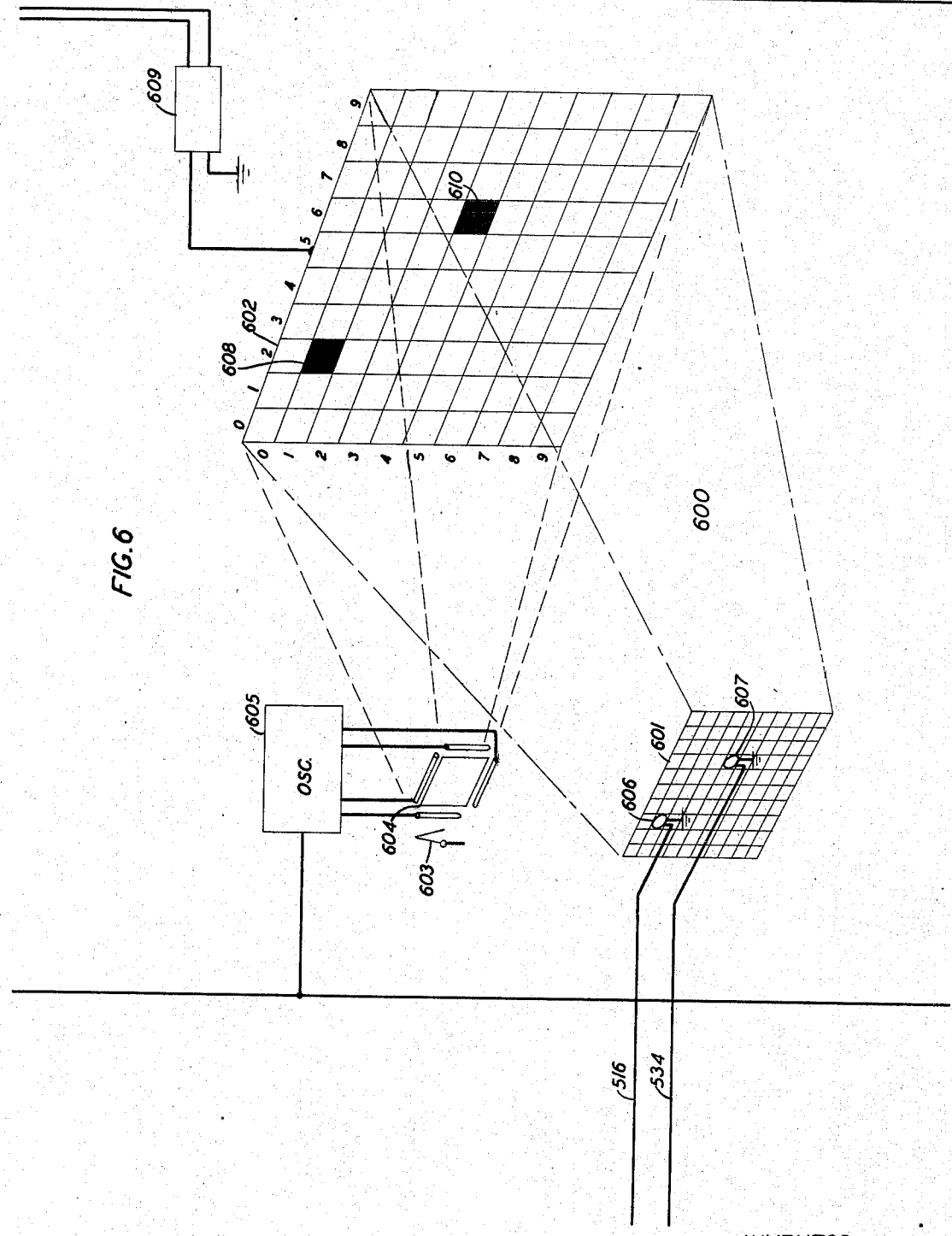


FIG. 6

INVENTOR
FRANCIS A. HUBBARD
BY M. F. McKenney
ATTORNEY

July 3, 1945. F. A. HUBBARD 2,379,715

COMMUNICATION SYSTEM

Filed Oct. 9, 1942 7 Sheets-Sheet 7

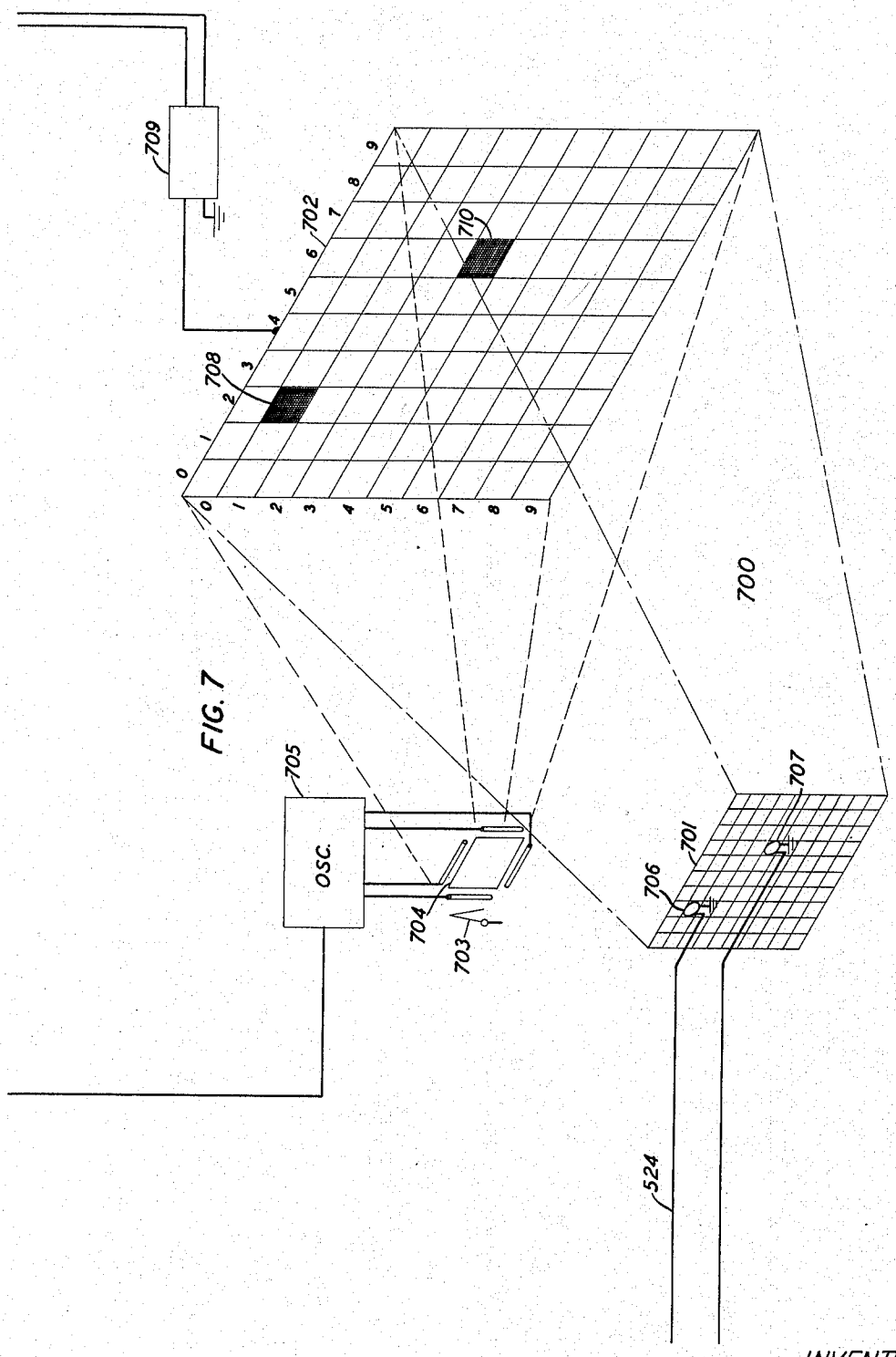


FIG. 7

INVENTOR
FRANCIS A. HUBBARD
BY W. R. McKenney
ATTORNEY

Patented July 3, 1945 2,379,715

UNITED STATES PATENT OFFICE

2,379,715

COMMUNICATION SYSTEM

Francis A. Hubbard, Maplewood, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application October 9, 1942 Serial No. 461,428

19 Claims. (Cl. 179—18)

This invention relates to electrical switching methods and switching devices and particularly to these methods and devices when applied to communication systems.

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

Many varieties of automatic switching have been proposed in the past for interconnecting the lines of telephone, telegraph and other communication systems. In almost all cases these mechanisms have depended largely upon the use of 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. Also there have been a number of suggestions heretofore for the use of electron beams for selecting telephone lines and other similar circuits. Furthermore, it has been previously suggested to use electron beams as distributors in systems of the usual multiplex distribution type.

In accordance with the present invention improvements and advantages are obtained over these prior methods and arrangements by means of a switching system in which electrical connection may be established between any two lines in a group of lines by means of energy beams which are capable of being directed automatically and repeatedly into engagement with the desired lines. More specifically a group of lines, having an appearance in a scanning field as calling or incoming lines, are scanned repeatedly at a high rate of speed by an energy beam, such as that produced by a cathode beam tube; and at the same time the said group of lines, having another appearance in a second scanning field as called or outgoing lines, are traversed by a second energy beam which is directed automatically into engagement with one line of a connecting pair whenever the first beam engages the other line of such pair. With this arrangement a pair of energy beams may serve to establish coexisting connections between a plurality of pairs of lines. To this end the first beam traverses the group of lines repeatedly and in a definite sequence, and each time it encounters one of the lines of a pair engaged in communication the second beam is directed automatically to the other line of the pair, and a momentary communication connection is established between the two lines. This operation is repeated in such rapid succession that the communication connection between each pair of lines is substantially continuous.

Another feature of the invention is a system in which the designations of the calling and called lines are registered and serve to control the scanning beams in such a way that one of these beams is automatically directed into engagement with one line of a pair each time the other beam encounters the other line of the pair.

Another feature of the invention is a system in which auxiliary scanning beams are provided for controlling one of the two connecting beams in accordance with the designations of the calling and called lines. When one of the connecting beams engages the calling line, the auxiliary beams are simultaneously in positions to direct the other connecting beam to the called line in accordance with the digits thereof. Similarly, when the first connecting beam reaches the called line, the auxiliary beams are simultaneously in positions to direct the second connecting beam into engagement with the calling line. Thus the calling and called lines are in communicative engagement with each other for two-way transmission once per cycle of the scanning beams.

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 discloses a transmitting 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 connecting beam switch in which all of the lines appear and which serves to transmit the voice signals to all lines engaged in conversation;

Fig. 4 discloses a pair of registers for registering the designations of the calling and called lines;

Fig. 5 shows a plurality of direction-controlling registers, the purpose of which is to control the scanning beam of the reproducer;

Fig. 6 shows a beam device which acts under the control of the registers of Fig. 5 to direct the horizontal movement of the reproducer beam; and

Fig. 7 shows a similar beam device, the func-

tion of which is to control the reproducer beam in its vertical movement.

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 100 lines in this telephone system, some or all of which may be subscribers' line, although it will be obvious that the invention is not so limited and that any desired number of lines may be included therein.

Referring to the drawings, it will be noted that each of the subscribers' 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 100 lines in the system also has an individual appearance in the transmitting beam switch **200**. To this end the beam switch is provided with a field of 100 lamps **201**, each of which represents and is connected to one of the subscribers' lines, these lamps being arranged in a coordinate array of ten horizontal rows and ten vertical rows. The beam switch 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 100 elemental areas arranged coordinately in ten horizontal and ten vertical rows, said elemental areas corresponding to the lamps in the lamp field **201**. Moreover, the switch **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 switch **200** is not shown in full structural detail; however, it 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 proportionate to the amount of light focussed on said individual areas.

Besides appearing in the transmitting switch **200** the group of one hundred lines also appears in a scanning reproducer or beam connector switch **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 scanning field **301**, a control electrode **304** for controlling the intensity of the beam, and a suppression electrode **314** for suppressing the beam while it is in transit from one elemental area to the next representing lines in conversation. Like the switch **200**, the reproducer **300** may be of any suitable 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 manner.

The horizontal and vertical location of the appearance of each line in the scanning field **202** of the transmitter and in the scanning field **301** of the reproducer is identical. Although any desired numbering system could be used, it will be assumed for the purpose of the present 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 row of elemental areas in the field **301** of the reproducer. The next ten lines (lines No. 10 to No. 19) appear in the second horizontal row of lamps **201** and correspondingly in the second horizontal row of image areas **202** of the transmitter and likewise in the second horizontal row of elemental areas in the field **301** of the reproducer. The third group of ten lines (lines No. 20 to No. 29) appear in the third horizontal row (from the top) of lamps in the field **201** and correspondingly in the third horizontal row of image areas in the field **202**. Likewise this group of lines appears in the third horizontal row (from the top) of elemental areas in the field **301**.

The pattern traced by the electron beam as it scans the image field **202** of the transmitter follows the numerical arrangement of the lines in the field. More specifically, if we consider the instant at which the beam impinges on the elemental area **205**, from this area it passes along the horizontal row until it reaches the last area **206** therein, from which it returns and scans the area **207** and the succeeding areas in the second horizontal row until it reaches the last area **208** therein, from whence it returns to the first area in the third horizontal row, and so on until it has reached elemental area **209** in the field. At this time the beam returns to the beginning of its cycle and repeats the pattern. The potential for operating the beam driving means **204** is supplied by the oscillator **210**. The frequency of the oscillator **210** determines the scanning frequency of the beam, which may be, for example, from 6,000 to 10,000 frames per second. Thus the electron beam of the transmitting switch **200** scan repeatedly, and in rapid succession, and in numerical order, the appearances of the group of one hundred lines in the image field **202**; and, as will be seen hereinafter, the electron beam of the connector **300** is caused to engage the elemental area of one line of a pair of lines in conversation each time the beam of the switch **200** engages the elemental area corresponding to the other line of the pair.

The mechanism for controlling the beam of the connector **300** comprises registers for registering the numbers of the calling and called lines and a pair of beam devices **600** and **700** which respond to these registrations for the purpose of controlling the horizontal and vertical motion compo-

nents of the connector beam. The designation registering mechanism comprises a plurality of pairs of line finders and connector switches and also a plurality of individual line registers. The finder and connector registers may be of any suitable type, such as the well-known two-movement step-by-step switches commonly used in telephone systems.

The line 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 resistor representing the corresponding level and the tens digit of all 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 resistor representing the corresponding rotary position 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 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.

It will be remembered that the beam of the connector **300** is directed to the called line appearance each time the beam of the transmitter **200** scans the calling line and is directed to the calling line appearance each time the transmitter beam scans the called line. Therefore, the registration of the calling line number on the finder switch **400** must be utilized thorugh the controlling beam devices **600** and **700** to direct the connector beam to the called line at the proper instant; and the registration of the called line on the connector switch **400** must be utilized through the controlling beam devices to direct the connector beam to the calling line appearance at the proper instant. To this end each subscriber's line is provided with a pair of beam-controlling registers. Four of these registers are shown in Fig. 5, registers **500** and **501** being individual to line **100**, and registers **502** and **503** being individual to line **103**. Each of these line registers, such as the register **500**, comprises a rotating brush **504** and a series of ten contacts connected respectively to graduated resistance elements. The register also includes 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 pulley **507** into engagement with the driving pulley **509** to move the brush **504** in the opposite direction. The operating windings of each pair of line register magnets are connected through the terminal banks of the line finder and connector switches **400** and **401** to the vertical and rotary commutators of these switches in such a manner that the pair of line registers individual to each line of a conversational pair of lines are positioned automatically in accordance with the tens and units digits respectively of the other line of said conversational pair. If, for example, lines **100** and **103** are to be connected for conversation, the line registers **500** and **501** individual to the line **100** are positioned automatically in accordance with the tens and units digits respectively of the line **103**; and likewise the registers **502** and **503** of the line **103** are positioned automatically in accordance with the tens and units digits respectively of the line **100**. As will be explained more fully hereinafter, the circuit means whereby each one of these line registers is positioned comprises a bridge including the resistors associated with the vertical and rotary commutators of the finder and connector switches and the resistors associated with the line registers themselves, the movement of the line register brushes serving to establish a balanced condition of the bridges when these registers have reached the proper positions.

The beam controllers **600** and **700** are substantially identical with the transmitting beam switch **200**. The controller **600** has a field of one hundred lamps **601** arranged in ten horizontal and ten verical rows and numbered in the same order as the lamps in the field **201** of switch **200**. Similarly, the image field **602** comprises one hundred image areas arranged in ten horizontal and ten vertical rows and numbered in correspondence with the numbering of the lamp field. The beam for the controller **600** is produced by an electron emitting cathode **603** and is driven by a driving mechanism **604** over the image field **602** in synchronism with and in acordance with the same pattern traced by the beam of switch **200**. To this end the oscillator **605** is driven in synchronism with oscillator **210**, or, if desired, a common source of driving voltage may be provided. Likewise, the controller **700** is provided with a coordinate field **701** of lamps and an image field **702** arranged in the same numerical order as the fields of beam devices **200** and **600**. The scanning beam of controller **700** is generated by the cathode **703** and is controlled in its scanning movement by the beam-directing mechanism **704**. The driving oscillator **705** is of the same frequency and synchronized with oscillators **210** and **605**, or, as above mentioned, all three devices **200**, **600** and **700** may be driven from a single source.

The function of the controller **600** is to control the vertical component of the movement of the beam of the reproducer **300**. Accordingly the output voltage from the image field **602** is applied to the deflection plates **305** and **306** which determine the position of the beam in a vertical direction; and the lamps in the field **601** are connected respectively to the line registers on which the tens digits of the line numbers are registered. For example, the No. 12 lamp **606** representing line **100** is connected to the resistance bank of register **500** on which is registered the tens digit of the line paired with line

100 for conversation. And the No. 46 lamp 607 representing line 103 is connected to the resistance bank of line register 502 on which is registered the tens digit of the subscriber's line paired with line 103 for conversation. Correspondingly the function of the controller 700 is to control the horizontal component of the movement of the beam of the reproducer 300; and the output voltage of the image field 702 is, therefore, applied to the deflection plates 307 and 308 which determine the position of the beam in the horizontal direction. The lamps in the field 701 are connected respectively to the line registers on which the units digits of the line numbers are registered. For instance, the No. 12 lamp 706 representing line 100 is connected to the resistance bank of register 501 on which is registered the units digit of the line paired with line 100 for conversation and the No. 46 lamp 707 representing line 103 is connected to the resistance bank of line register 503 on which is registered the units digit of the subscriber's line paired with line 103 for conversation.

Thus the beam devices 200, 600 and 700 are driven in synchronism over their image fields, all three of the beams engaging at the same instant the elemental areas representing the same line. The lamps in the field 201 of the transmitting switch 200 represent by their varying luminosity the speech currents flowing in the lines engaged in conversation. The varying luminosity of the lamps in the field 201 is reflected on the image areas in the field 202 which in turn causes corresponding variations in the voltage applied to the grid 304 of the connecting switch 300. And the switch 300 translates these varying grid potentials into varying voltages applied to the subscribers' lines engaged in conversation.

The intensity of illumination of the pair of lamps in the field 601 of controller 600 representing each pair of lines engaged in conversation is governed by the line registers to represent the tens digits of the lines. In other words, the intensity of the lamp representing one line of a pair is a measure of the tens digit of the other line of the pair: and the same is true of the lamp representing the other line of the pair. Therefore, at the instant the beam of controller 600 engages the elemental area representing either line of the pair, the output voltage from the image field 602 is such that the beam of the connector 300 is displaced in a vertical direction by the amount representing the tens digit of the other line of the pair. Similarly, when the beams of devices 200, 600 and 700 are scanning the elemental areas representing either line of a conversational pair, the output voltage of the image field 702 is a measure of the value of the units digits of the other line of the pair and serves to deflect the beam of connector 300 in a horizontal direction by an amount corresponding to the units digit of said other line of the pair. In short, therefore, the transmitting switch 200 scans the lines in succession and repeatedly, and each time the beam engages an elemental area representing a line in conversation the beam of connector 300 is directed automatically under control of controllers 600 and 700 to the elemental area representing the other line of the pair in conversation. Since all lines are represented in the field 202 and in the field 301, each calling line is connected to the associated called line and each called line with the associated calling line once per scanning cycle. While the beam of transmitter 200 is engaging the elemental area representing a line in conversation the talking currents flowing in the line are represented by the variations in the associated lamp in the field 201 and are translated through the switch 200 and the connector 300 into potentials that are applied to the other line of the pair. Two-way conversation is possible between each pair of lines, and the scanning rate of the transmitter 200 and connector 300 is so rapid with respect to the talking frequencies that the effect is the same as though each of the pairs of lines concurrently engaged in conversation were permanently connected together. Since a plurality of pairs of lines may be engaged simultaneously in separate conversations and since the beam of the switch 300 plays over the field of elements 301 in an intricate pattern, varying from time to time as the combination of conversing lines changes, it is desirable to suppress the beam while it is moving from one elemental area to another and to render the beam effective only while it is dwelling on an area to which it has been directed by the controllers 600 and 700. To this end an oscillator 215 is provided for controlling the suppressing grid 314, and a source of negative potential 315 is included in circuit with said grid. The negative potential of the source 315 when unaffected by the oscillator 215 maintains the grid 314 at a potential sufficient to suppress the flow of electrons from the cathode 302 to the field 301. The oscillator 215, however, which is maintained in a definite phase relation with oscillators 210, 605 and 705, produces a voltage wave having a frequency ten times that of the oscillators 210, 605 and 705. The phase relation between these oscillators is such that the positive impulses produced by the oscillator 215 and applied over conductor 216 to the grid 314 does not reach an amplitude sufficient to overcome the battery 315 until the beams of switches 200, 600 and 700 have reached the selected image areas and until the output voltages from the controllers 600 and 700 have been applied to the deflection plates of the switch 300. In other words, the virtual beam of the switch 300 is driven over the field 301 and comes to rest on the desired elemental area before the operating impulse is applied by the oscillator 215 to the grid 314. When the impulse is thus applied it overcomes the negative battery 315, the positioned virtual beam assumes its real character, and electrons flow from the cathode 302 to the selected elemental area under the control of the control grid 304 as above explained. The real beam of switch 300 continues to impinge upon the selected area and to transmit the talking signals to the corresponding line until the beam of switch 200 is about to move to the next elemental area in the field 202. Thereupon the positive impulse from the oscillator 215 ceases, and the beam of switch 300 is suppressed and assumes its virtual character. As soon thereafter as the beams of the switches 200, 600 and 700 reach the next elemental area representing a line in conversation, the virtual beam of switch 300 is driven from whatever position it occupies at the time to the elemental area in the field 301 corresponding to the other line involved in the conversation, the positive impulse is then applied by the oscillator 215, and the beam of switch 300 becomes real and transmits the conversational signals to said other line. Thus the beam of switch 300 assumes a virtual state during the brief intervals in which it is being driven by the controllers 600 and 700 over the field 301, to prevent interference

with other lines that may be involved in conversation and have their elemental areas in the path of the moving beam, and assumes a real state only after it has been fully positioned on the elemental area of the desired line.

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, conductor 108 thence over the substation loop and returning over conduetor 109, coil 110 through the 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 111. This start condition on conductor 111 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 112, closed contacts of line relay 106, normal contacts of relay 112, conductor 407, terminal and brush of the line finder 400 to conductor 406. The application of battery potential to conductor 406 serves in any well-known manner to terminate the hunting movement of the finder, whereupon ground potential is applied to conductor 406 in the line finder to cause the operation of the cut-off relay 112. Before its operating circuit is opened the cut-off relay 112 closes a locking circuit for itself traceable from battery through the winding of said relay, closed contacts of relay 106 to ground at the inner left armature and front contact of relay 112. Relay 112 at its outer left armature opens the start conductor 111 to prevent the starting of another line finder and at its inner left armature removes the hunting condition from conductor 407 extending to the line finder switches.

The calling subscriber now proceeds to manipulate his dial 113 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 line finder 400, conductor 409 conductor 108, thence over the loop of the calling substation and returning over conductor 109, conductor 410, terminal and brush of line finder 400 through the upper winding of relay 408 to ground. In the well-known manner the impulse relay 408 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 uppermost set of 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 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 114, which operated when the called party answered, winding of cut-off relay 115 to battery. Relay 115 operates and locks in a circuit traceable from battery through its winding, contact of relay 114 to ground at the inner left armature and front contact of relay 115. Relay 115 opens the start conductor 116 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. With these vertical and rotary commutator brushes in position, the line registers 500 and 501 of the calling line 100 are set respectively in accordance with the tens and units digits of the called line 103, and the registers 502 and 503 of the called line 103 are positioned in accordance with the tens and units digits of the calling line 100. One half of the electrical bridge circuit for setting the register 500 may be traced from battery 424, fixed resistor 425, brush and terminal of the finder 400, conductor 426, fixed resistor 510 to ground. The other half of the bridge may be traced from battery 424, connector brush 420, terminal 421, graduated resistor 427, conductor 428, brush and terminal of finder 400, conductor 429, inner back contact of relay 511, brush 504 in whatever position it may occupy at the time, through the associated graduated resistor, conductor 512, outer back contact of relay 511 to ground. Usually the bridge thus established is in an unbalanced condition and a voltage drop exists across conductors 426 and 429. Current therefore flows through the winding of relay 513 and in parallel therewith through the magnet coil of register 500. Relay 513 operates and remains operated as long as the bridge is in an unbalanced condition and in so doing opens the operating circuit of relay 511 before the latter relay, which is somewhat slow in action, can attract its armatures. Depending on the direction in which the bridge is unbalanced, the magnet 506 operates its armature 505 to engage the pulley 507 either with the driving pulley 508 or the driving pulley 509. In either case the brush 504 is driven over the bank of graduated resistors until it reaches the resistor 514, bringing the bridge into balance and terminating the movement of the brush 504. Since the bridge is now in balance, relay 513 releases and closes the following operating circuit for relay 511: battery through the winding of relay 511, normal contacts of relay 513, conductor 515 to ground at the closed contacts of the cut-off relay 112 of the calling line 100. Relay 511 attracts its armatures and establishes a circuit for lighting the lamp 606 representing the calling line 100 in the controller 600. This circuit may be traced from battery through the front contacts of relay 511, brush 504, resistor 514, conductor 512, front contacts of relay 511, conductor 516 through the lamp 606 to ground. Since the graduated resistor 514 has a value representative of the tens digit "4," the lamp 606 burns with a corresponding degree of luminosity.

The bridge circuit for setting the register 501 may be traced from battery 430 through fixed resistor 431, brush and terminal of line finder

400, conductor 432, fixed resistor 517 to ground; and from battery 430, brush 422, terminal 423, associated resistor 433, conductor 434, brush and terminal of finder 400, conductor 435, normal contacts of relay 518, brush 519 and the associated resistor, conductor 520, normal contacts of relay 518 to ground. If the bridge is in an unbalanced condition, relay 521 operates, and the coil of register 501 is energized in one direction or the other to cause the movement of the brush 519 to select the graduated resistor 522, thus bringing the bridge into balance. Thereupon relay 521 releases, and relay 518 operates in a circuit from battery through its winding, contacts of relay 521, conductor 523 to ground at the contacts of cut-off relay 112. Relay 518 operates and closes a circuit for lighting the lamp 706 representing the calling line 100 in the controller 700. This circuit may be traced from battery through the front contact of relay 518, brush 519, graduated resistor 522, conductor 520, conductor 524, lamp 706 to ground. Since the resistor 522 represents the No. 6 units digit the lamp 706 burns with a corresponding intensity.

From an inspection of the circuits it will be found that the registers 502 and 503 of the called line 103 are positioned to select the graduated resistors 525 and 526, under control of the commutators 402 and 403 of the finder switch 400, in accordance with the tens and units digits respectively of the calling line 100. The bridge circuit for setting the register 502 includes the fixed resistors 436 and 527 and the graduated resistor 437 as well as the resistor 525. The bridge circuit for setting the register 503 includes the fixed resistors 438 and 528 and the graduated resistor 439 as well as the resistor 526. After register 502 has been positioned, relay 529 operates in a circuit from battery through its winding, normal contacts of relay 530, conductor 531 to ground at the closed contacts of cut-off relay 115. Relay 529 closes a circuit for the lamp 607 representing the called line 103 in the controller 600. The lamp circuit may be traced from battery through the front contacts of relay 529, brush 532, resistor 525, conductor 533, front contacts of relay 529, conductor 534 through the lamp 607 to ground. The resistor 525 represents the tens digit "1," and the lamp 607 burns with a corresponding intensity. When the register 503 is fully positioned, relay 535 operates over a circuit traceable from battery through its winding, normal contacts of relay 537, conductor 538 to ground at the front contacts of relay 115 and closes an obvious operating circuit for the lamp 707 representing the called line 103 in the controller 700. Since the resistor 526 has a value representative of the No. 2 units digit, the lamp 707 is lighted to the corresponding intensity.

Thus, following the setting of the line finder 400 and the connector 401, the line registers 500, 501, 502, 503 are positioned in accordance with the values of the digits of the lines to be engaged in conversation. Having determined the setting of the line registers, the line finder 400 and associated connector 401 may be restored to their normal condition by any suitable controlling and releasing means. These switches may now be used to serve other calls. As above explained, the cut-off relays 112 and 115 are held in their operated condition under the control of the associated line relays, which in turn are held by the subscribers' lines; and the operated cut-off relays hold open the finder hunting circuits of lines 100 and 103 and also maintain these lines in a busy condition in the banks of the switches. Furthermore, the operated cut-off relays 112 and 115 maintain the relays 511, 518, 529 and 535 in their operated condition to hold the lamp circuits of the controllers 600 and 700.

The talking transmission circuits will now be explained. The calling line 100 is represented by the lamp 211 in the field 201 of the transmitter 200, and the circuit for this lamp may be traced from battery through the transformer winding 117, closed contacts of relay 112, conductor 118, lamp 211 to ground. Similarly the called subscriber's line 103 is represented in the field 201 by lamp 212, the circuit of which is closed from battery, through the transformer winding 119 and the front contacts of cut-off relay 115. While the calling subscriber is speaking, the varying talking currents flowing in the line 100 cause the induction in transformer winding 117 of voltages which in turn cause currents varying correspondingly to flow through lamp 211. And the same is true with respect to line 103 and its lamp 212. Therefore, the intensity with which lamps 211 and 212 are lighted varies in accordance with the speech currents flowing in the lines 100 and 103, from which it follows that the intensity of the light images on the elemental areas 213, 214 varies in accordance with said speech currents. As the beams of devices 200, 600 and 700 move in synchronism over the image fields, they first encounter the image areas representing the calling line 100. That is to say, the beam of switch 200 encounters the image area 213, the beam of controller 600 encounters the image area 608, and the beam of controller 700 encounters the image area 708, all at the same instant. Since the area 608 is illuminated by lamp 606 to an intensity equivalent to the digit "4" the output voltage from the image field 602, which is amplified by amplifier 609 and applied to the control elements 305 and 306, causes the beam of the connector 300 to move vertically until it is in line with the fourth horizontal row of elements, counting from the top of the field 301. Also since the elemental area 708 in controller 700 is illuminated by lamp 706 to an intensity equivalent to the digit "6" the output voltage from the field 702, which is amplified by the amplifier 709 and applied to the control elements 307 and 308, causes the connector beam 300 to move horizontally until it is in line with the sixth vertical row of elements in the field 301, counting from the left. Thus the joint action of controllers 600 and 700 brings the connector beam into engagement with the elemental area 309, representing the called line 103, at the instant the beam of transmitter 200 is engaging the elemental area 213 of the calling line 100, whereupon the oscillator 215 reacts on the grid 314 to transform the positioned virtual beam into a real beam of electrons. If at this instant the calling subscriber is speaking, the corresponding voltage variations produced by the image field 202 and amplified by the amplifier 310 are applied to the control grid 304 of the connector 300. The voltage variations on the grid 304 are reflected in the intensity of the electron beam impinging on the area 309, and this elemental area sets up a voltage in the conductor 311 which varies correspondingly. The varying voltage on conductor 311 causes a current of corresponding variations to flow through the transformer coils 120. These variations are in turn induced in the associated coils in the subscriber's line 300, and the speech currents flow over the conductors of said line.

Later in the scanning cycle the beams encounter the image areas **214**, **610** and **710** representing the called line **103**. In this case the image areas **610** and **710** are illuminated to intensities corresponding to digits "1" and "2," and the output voltages of the fields **602** and **702** cause the beam of reproducer **300** to impinge upon the elemental area **312** which is individual to the calling subscriber's line **100**. If at this instant the called subscriber is speaking, the output voltage of the tansmitter field **202**, which is varying in accordance with his speech, is impressed upon the control grid **304**, the beam of the connector **300** is varied accordingly, and the output voltage from the elemental area **312** causes a current of corresponding variation to flow over conductor **313** through the transformer coils **121**. The voltages across the coils **121** are induced into the subscriber's line **100** and cause the flow of speech currents therein.

Thus for each scanning cycle of the transmitting switch **200** a communication connection is established between the calling line **100** and the called line **103** and a separate communication connection between the called line and the calling line, and the scanning cycles are repeated at such high velocity that these communication connections for two-way conversation are to all intents and purposes permanent connections. And it will be obvious that any number of pairs of lines may be engaged in conversation concurrently.

When the subscribers have finished talking, they replace their receivers on the switchhooks, the line relays **106** and **114** release, and these relays in turn release the cut-off relays **112** and **115**. The cut-off relays release the register control relays **511**, **518**, **529** and **535** to open the lamp circuits of the controllers **600** and **700**. Thus the equipment used on this particular call is fully released and may be taken again for a subsequent call.

As previously mentioned, the beam devices **200**, **600** and **700** and the reproducer **300** may be of any suitable and well-known type. Also the lamps in the fields **201**, **601** and **701** 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 may be used instead of individual lamps for supplying the variable light intensity.

What is claimed is:

1. The combination with a group of lines of means for establishing communicative connection between a pair of said lines including any one of said lines and any other one of said lines, said means comprising a device for causing a beam of energy to scan repeatedly the lines of said group, a second beam of energy, and means effective each time said first beam encounters one of the lines of said pair for directing the second beam to the other line of said pair.

2. The combination with a group of lines of means for establishing communicative connection between any pair of said lines comprising a device for causing a beam of energy to scan repeatedly the lines of said group, a second beam of energy, and means depending on the designations of the lines of said pair and effective each time said first beam encounters one of the lines of said pair for automatically directing the second beam to the other line of said pair.

3. The combination with a group of lines of means for establishing communicative connection between any pair of said lines comprising means for causing a beam of energy to scan said group of lines repeatedly, a second beam of energy for making communicative engagement with the lines of said group, and means operative when said first beam scans one of the lines of said pair for moving the other of said beams to engage the other line of said pair.

4. In a communication system, a group of lines, means for enabling simultaneous communication between a plurality of pairs of said lines, each pair of which may comprise any line of the group and any other line of said group, means for establishing communicative connection between the lines of each of said pairs comprising a device for causing a beam of energy to scan repeatedly the lines of said group, a second beam of energy for engaging the lines of said group, and means effective each time the first one of said beams engages one of the lines of each pair for directing the second beam into engagement with the other line of such pair.

5. In a communication system, a group of lines, means for enabling simultaneous communication between a plurality of pairs of said lines, each pair of which may comprise any line of the group and any other line of said group, means for establishing communicative connection between the lines of each of said pairs comprising a device for causing a beam of energy to scan the lines of said group repeatedly and in a definite sequential order, a second beam of energy for selectively engaging the lines of said group, and means effective each time said first beam encounters one of the lines of any pair for moving said second beam automatically and directly to the other line of such pair.

6. In a communication system, a group of lines of which any line may be a calling line and any other line a called line, means for registering the designations of the calling and called lines, means for establishing a communicative connection between the calling and called lines comprising means for causing a beam of electrons to scan repeatedly the lines of said group, a second beam of electrons for selecting the lines of said group, and means controlled in accordance with the registered designations and effective each time one of said beams encounters the calling line for directing the other of said beams into engagement with the called line.

7. The combination with a group of lines, a field of sensitive elements representing respectively the lines of said group, means for establishing communicative connection between any pair of said lines comprising means for causing a beam of energy to move over the sensitive elements in said field, a second field of elements representing respectively the lines of said group, means for causing a second beam of energy to move over the elements of said second field, and means effective whenever said first beam encounters the element representing one of the lines of said pair in said first field for directing said second beam automatically into engagement with the element in the second field representing the other line of said pair.

8. The combination with a group of lines of means for establishing communicative connection between any pair of said lines comprising a common register device for registering the digits of the lines of said pair, individual registers for said digits, means for transferring the registered digits from said common register device to said

individual registers, means effective thereupon for releasing said common register device, means for causing a beam of energy to scan repeatedly the lines of said group, a second beam of energy, and means controlled by said individual registers and effective each time said first beam encounters one of the lines of said pair for directing said second beam to the other line of said pair.

9. The combination with a group of lines of means for establishing communicative connection between any pair of said lines comprising a common register device for registering the digits of the lines of said pair, individual registers for said digits, a balancing circuit for transferring the digits from said common register device to said individual registers, means for releasing said common register device, means for causing a beam of energy to scan repeatedly the lines of said group, a second beam of energy, and means controlled by said individual registers and effective each time said first beam encounters one of the lines of said pair for directing said second beam to the other line of said pair.

10. In combination, a group of lines, two fields of elements in which said lines appear respectively, a beam of energy for said first field, a beam of energy for said second field, means for causing said first beam to traverse in repeated cycles the elements in said first field to establish a communicative connection with any desired line at each cycle, and means effective each time the first beam encounters the element representing the said desired line for causing said second beam to engage the element in said second field representing any other desired line to establish communicative connection between said first and second desired lines.

11. In combination, two fields of elements, a group of lines, each line being represented by one of the elements in each of said fields, means for establishing coexisting connections between a plurality of pairs of said lines comprising a device for scanning one of said fields with an electron beam, a second device for selecting the elements in the other of said fields with an electron beam, and means effective when the first one of said beams engages the element representing one line of a pair involved in a connection for directing the other beam to the element representing the other line of the pair.

12. In combination, two fields of elements, a group of lines, each line being represented by one of the elements in each of said fields, means for establishing coexisting connections between a plurality of pairs of said lines comprising a device for causing a beam of electrons to move repeatedly and rapidly over the elements of said first field which represent lines in a condition of communication, a second device for causing a beam to move over the second field of elements, and means effective when one of said beams engages the element representing one line of a pair involved in a communicative connection for causing the other beam to move directly to the element representing the other line of the pair.

13. In combination, a group of lines of which any pair may be engaged in communication, a field of lights in which said lines appear respectively, means for varying the intensity of the lights representing said pair of lines in accordance with the communication signals flowing in said lines, a field of sensitive elements, means for producing an image of said light field on said field of sensitive elements, means for causing a beam of energy to scan said field of sensitive elements, and means effective when said beam encounters the element corresponding to one line of said pair for establishing a communicative connection with the other line of said pair.

14. The method of establishing a communicative connection between the lines of a group of lines which comprises repeatedly scanning the lines of said group in rapid succession with a beam of energy and auomatically directing a second beam of energy into selective engagement with one of the lines of any pair of lines when said first beam engages the other line of said pair.

15. The method of establishing communicative connections between the lines of a group which comprises repeatedly scanning the lines of said group in a definite sequential order and an rapid succession with a beam of energy and directing a second beam of energy selectively into communicative connection with one of the lines of any pair of the lines when said first beam of energy engages the other line of said pair.

16. The method of establishing coexisting connections between a plurality of pairs of lines of a group of lines which comprises scanning the lines of said group in sequential order and in rapid succession with a beam of energy and directing a second beam of energy selectively into communicative engagement with one of the lines of each of said pairs when said first beam of energy engages the other line of such pair.

17. In combination, a plurality of lines, means for establishing a communicative connection between a pair of said lines comprising means for causing a connecting beam of energy to scan said lines repeatedly, means for causing a second connecting beam of energy to engage said lines, an auxiliary beam of energy, and means controlled by said auxiliary beam each time one of said connecting beams makes communicative engagement with one of the lines of said pair for directing the other of said connecting beams into communicative engagement with the other line of said pair.

18. In combination, a plurality of lines, means for establishing a communicative connection between a pair of said lines comprising means for causing a connecting beam of electrons to scan said lines repeatedly, means for causing a second connecting beam of electrons to engage said lines, an auxiliary beam of electrons movable in synchronism with said first connecting beam, and means controlled by said auxiliary beam each time said first connecting beam makes communicative engagement with either one of the lines of said pair for directing said second connecting beam into communicative engagement with the other line of said pair.

19. In combination, a plurality of lines, means for establishing a communicative connection between any pair of said lines comprising means for causing a beam of electrons to scan said lines repeatedly, means for causing a second beam of electrons to engage said lines, a plurality of auxiliary beams of electrons movable in synchronism with said first connecting beam, and means controlled by said auxiliary beams and effective each time said first connecting beam makes communicative engagement with either one of the lines of said pair for directing said second connecting beam into communicative engagement with the other line of said pair.

FRANCIS A. HUBBARD.