April 8, 1941. A. A. LUNDSTROM 2,237,742

TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 1

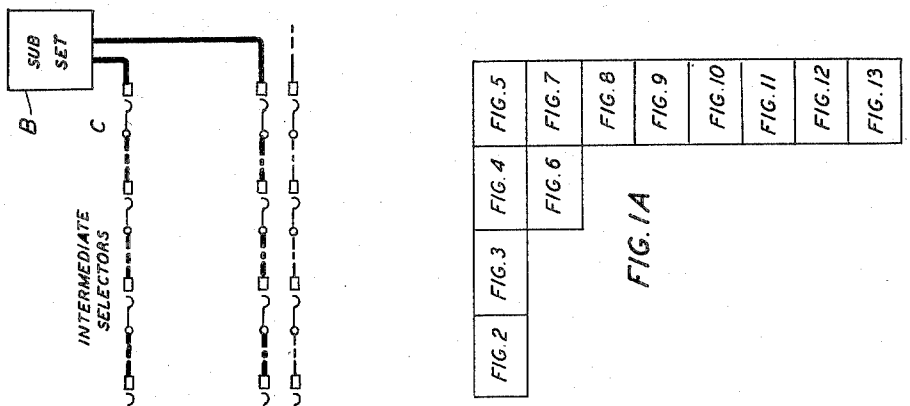

FIG. 1A

FIG. 1

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TELEPHONE SYSTEM

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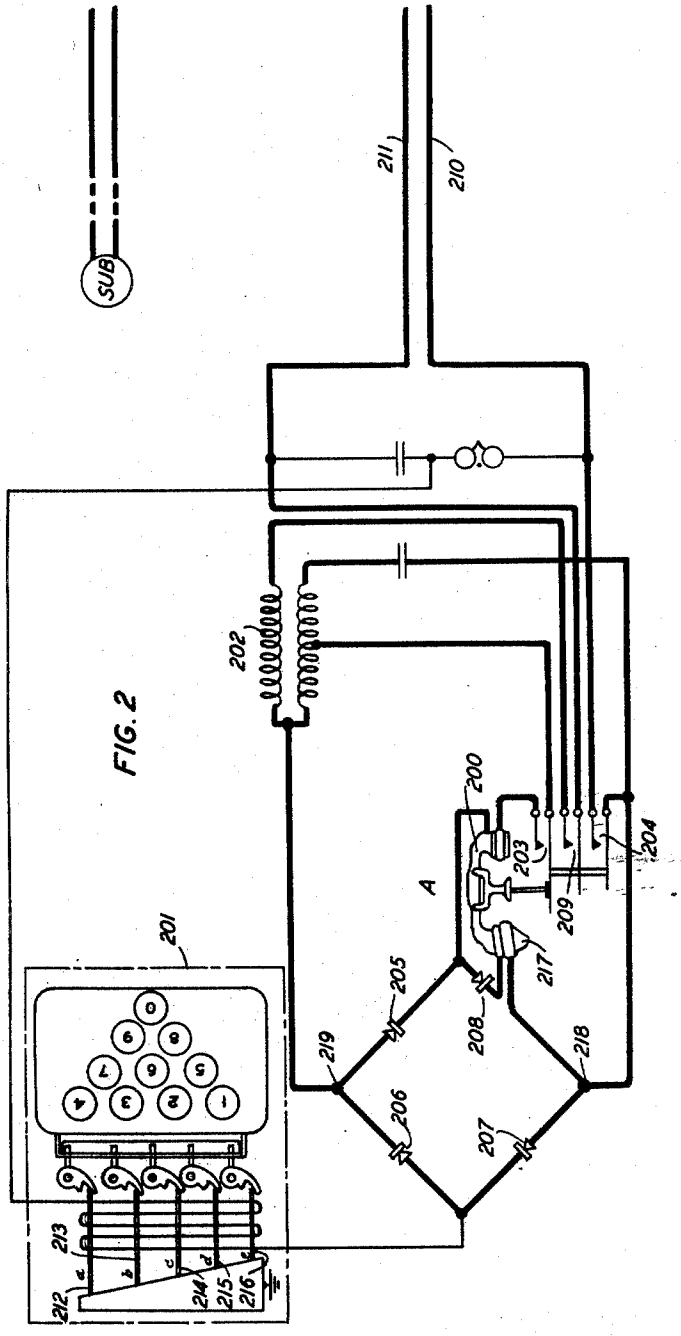

FIG. 2

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April 8, 1941. A. A. LUNDSTROM 2,237,742

TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 3

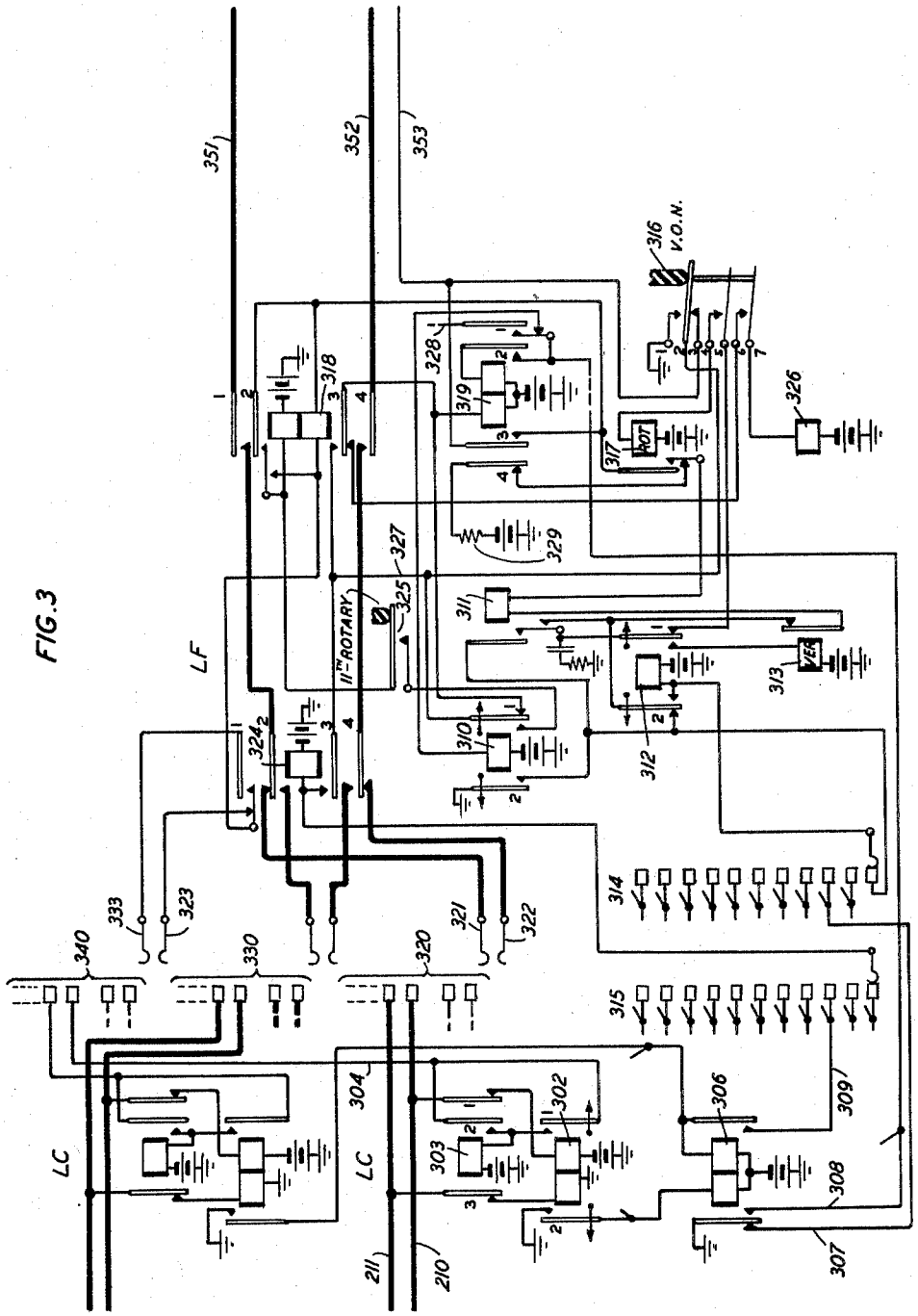

FIG. 3

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TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 4

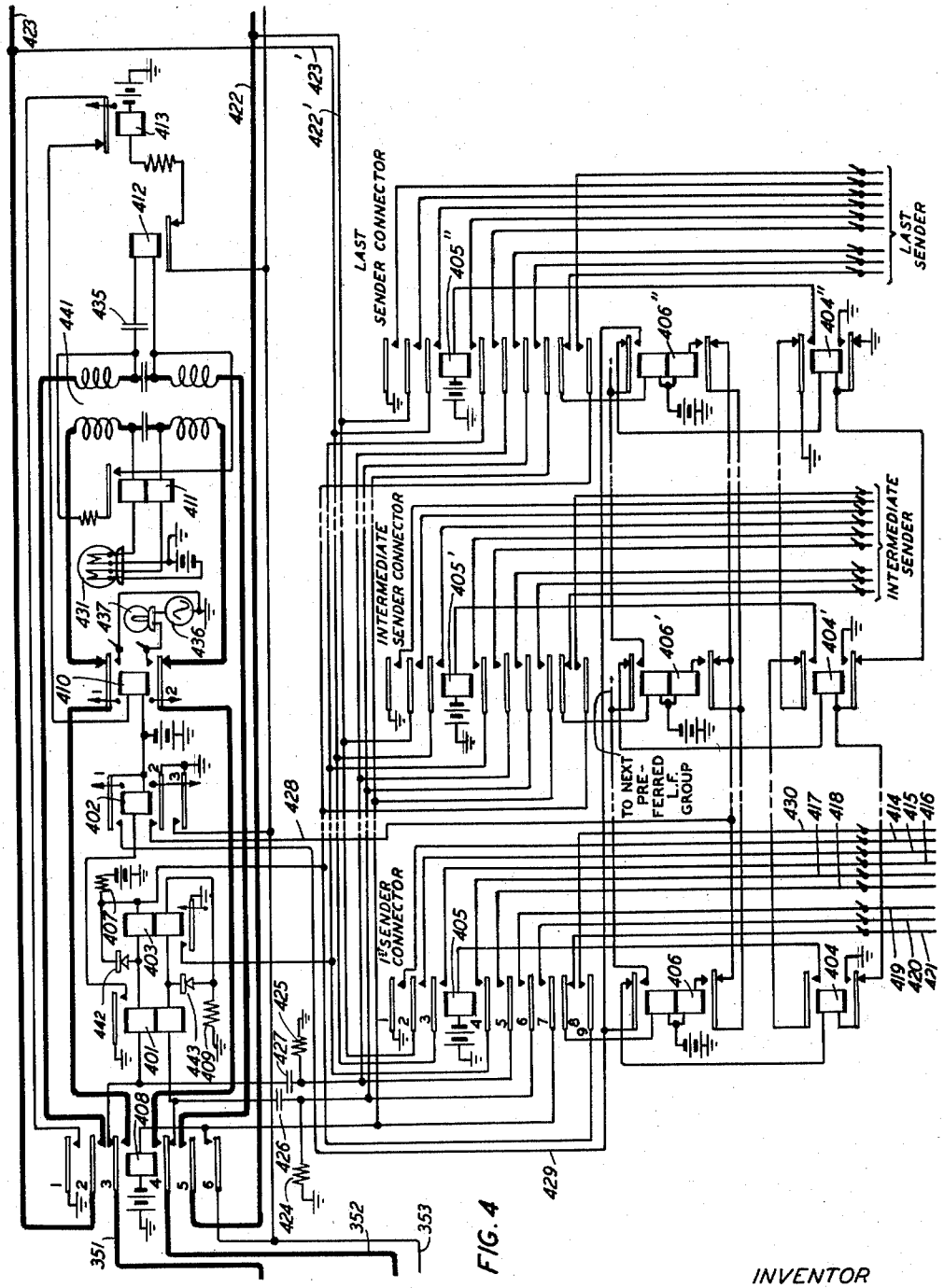

FIG. 4

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TELEPHONE SYSTEM

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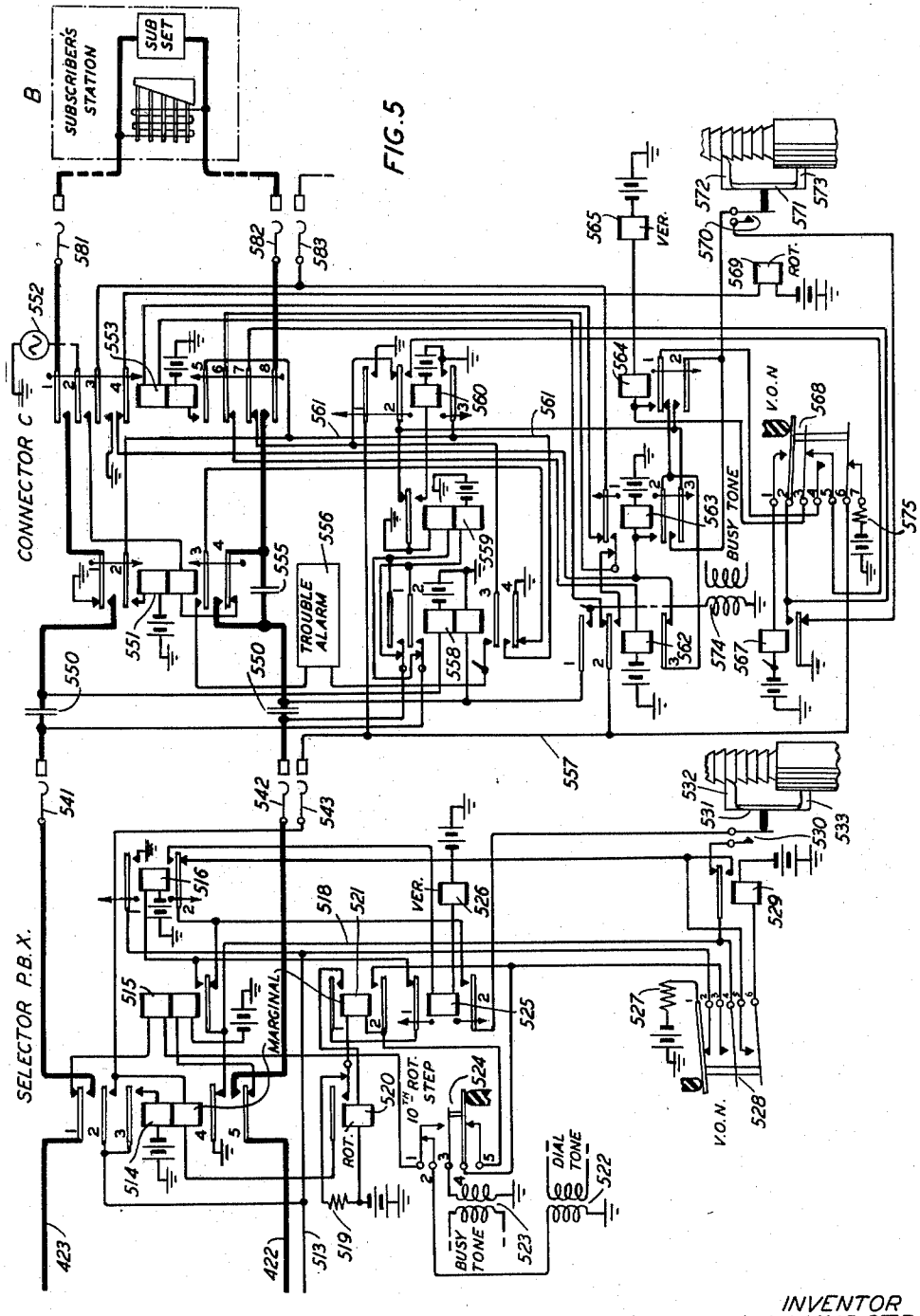
FIG. 5



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TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 6

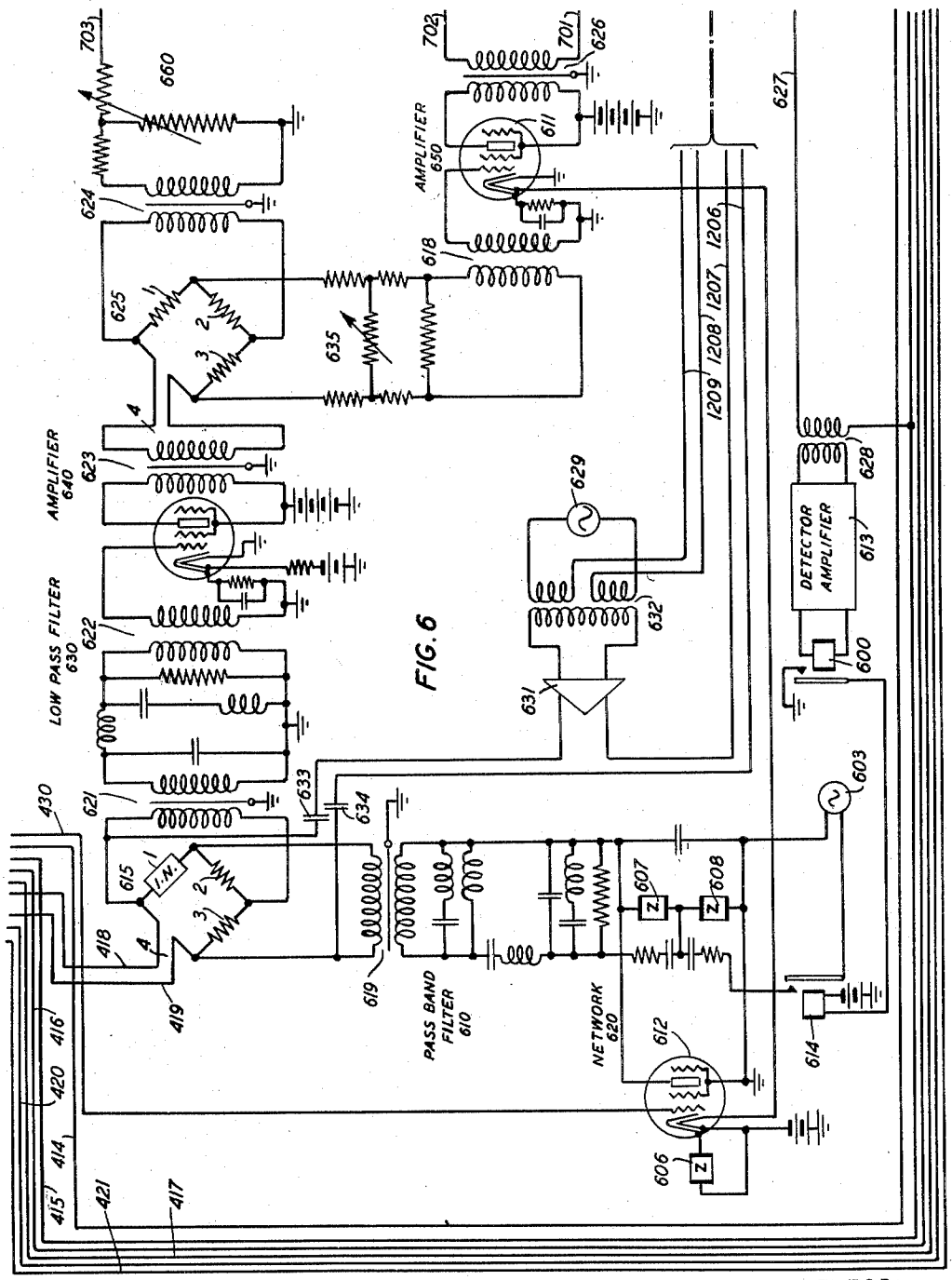

FIG. 6

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TELEPHONE SYSTEM

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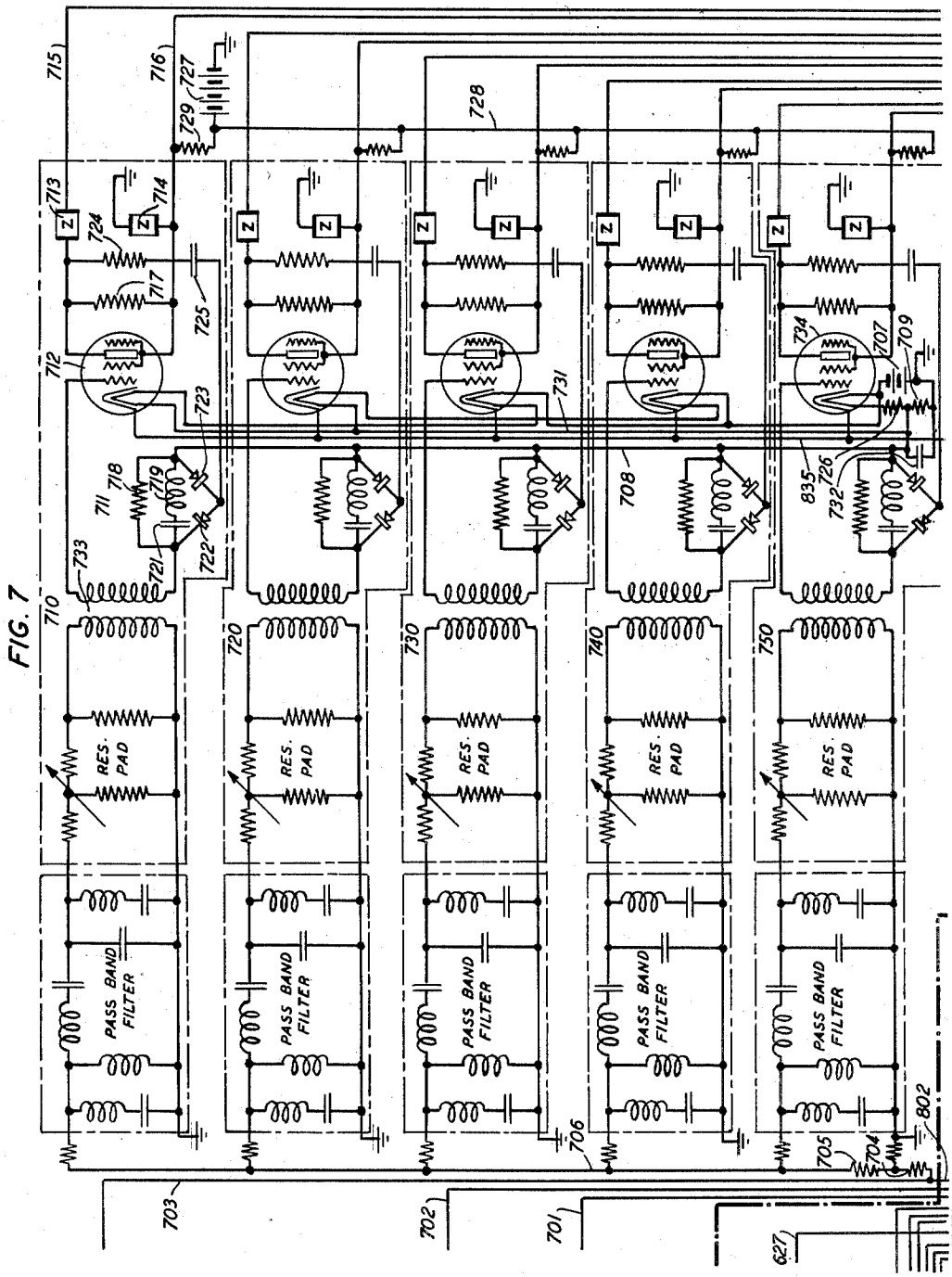

FIG. 7

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TELEPHONE SYSTEM

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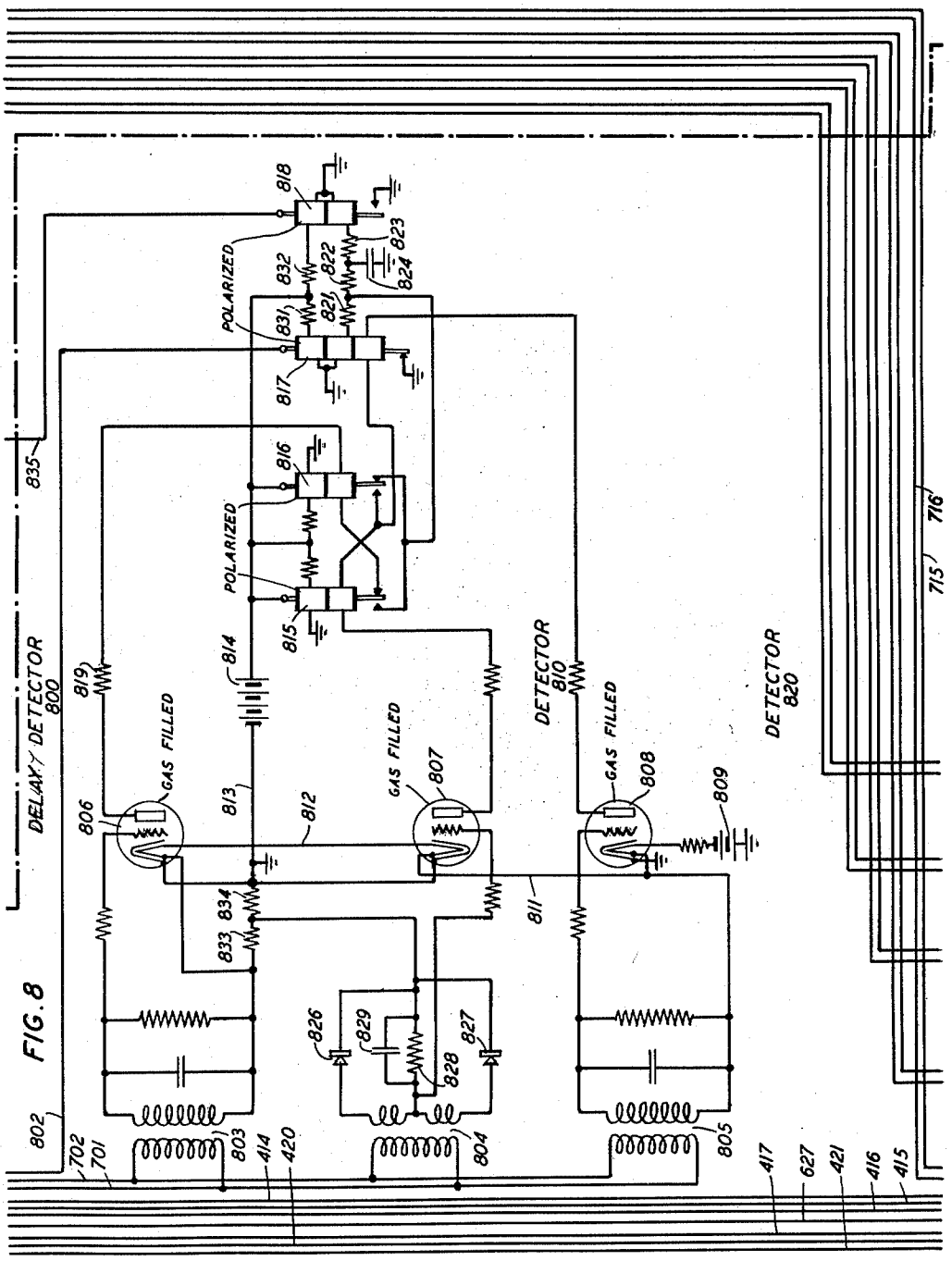

FIG. 8

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TELEPHONE SYSTEM

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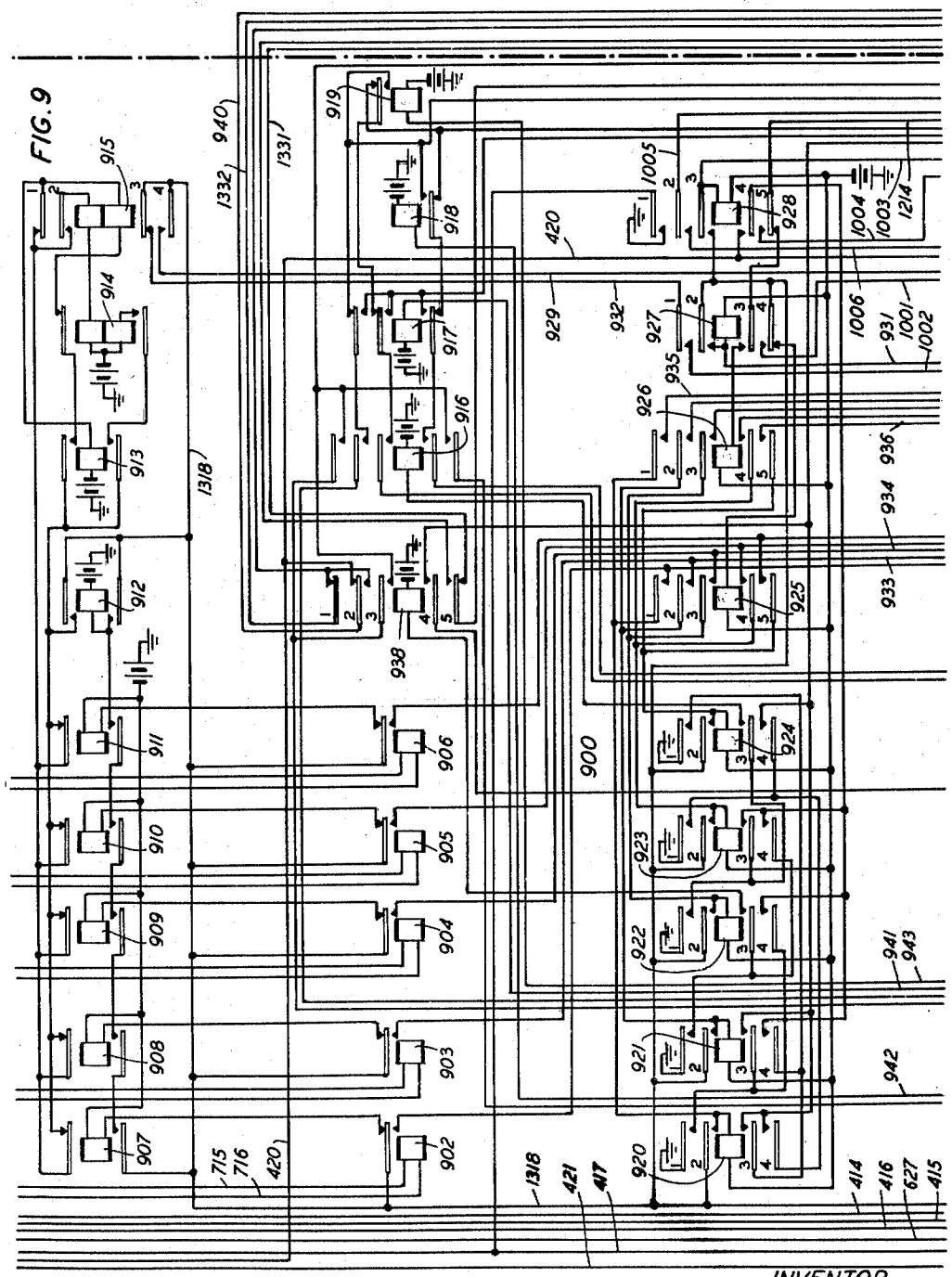
FIG. 9



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TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 10

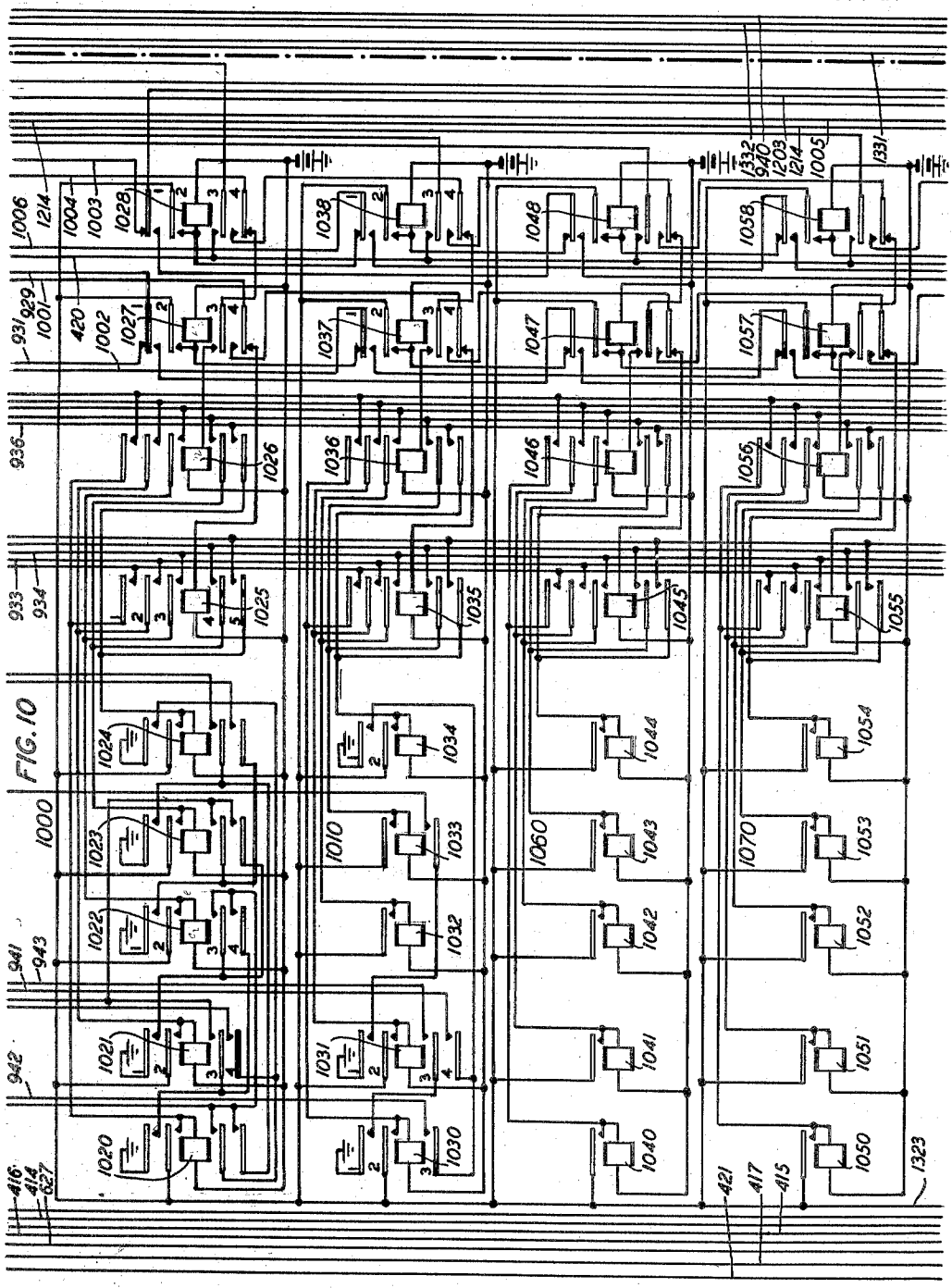

FIG. 10

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TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 11

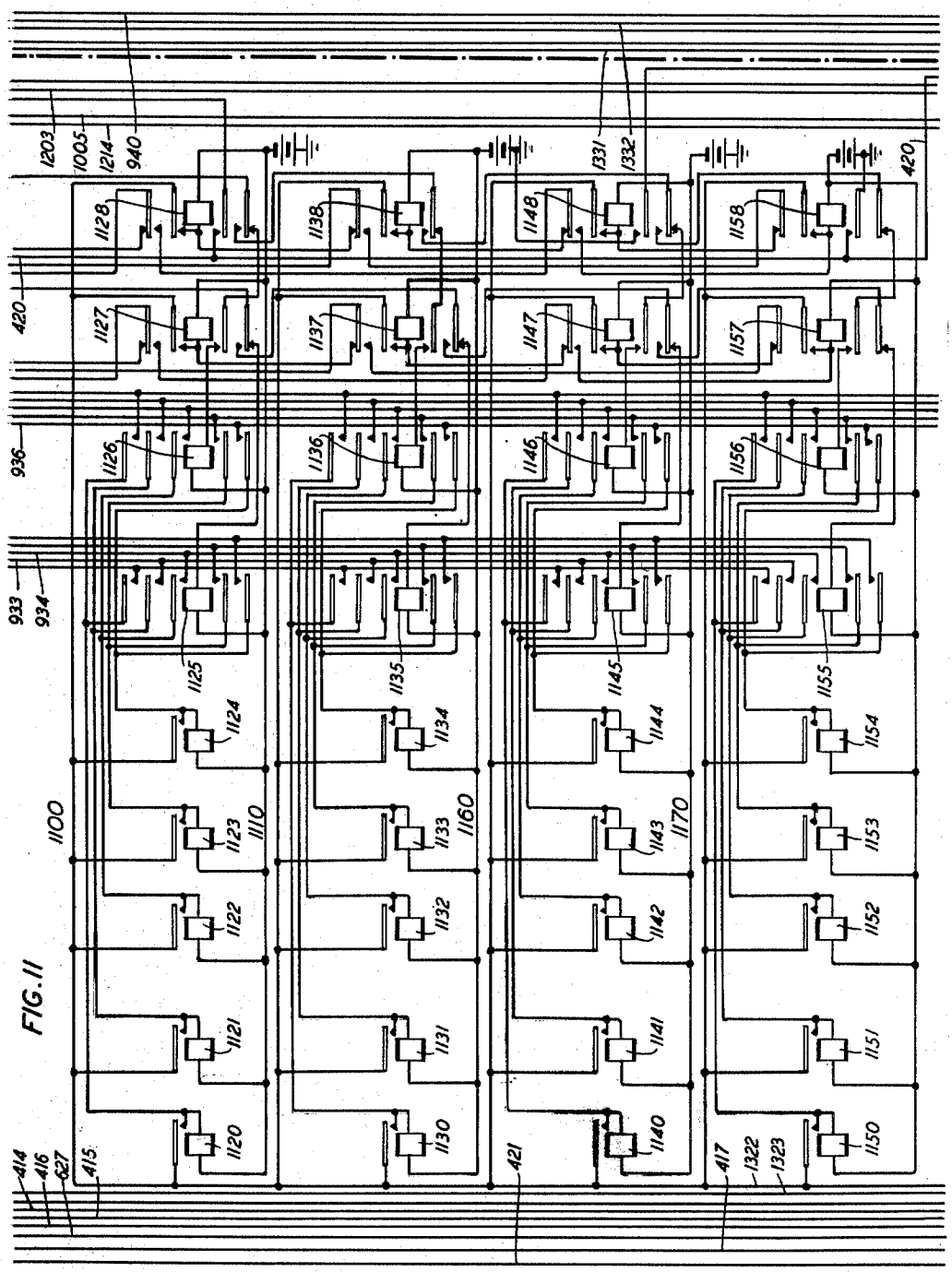

FIG. 11

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TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 12

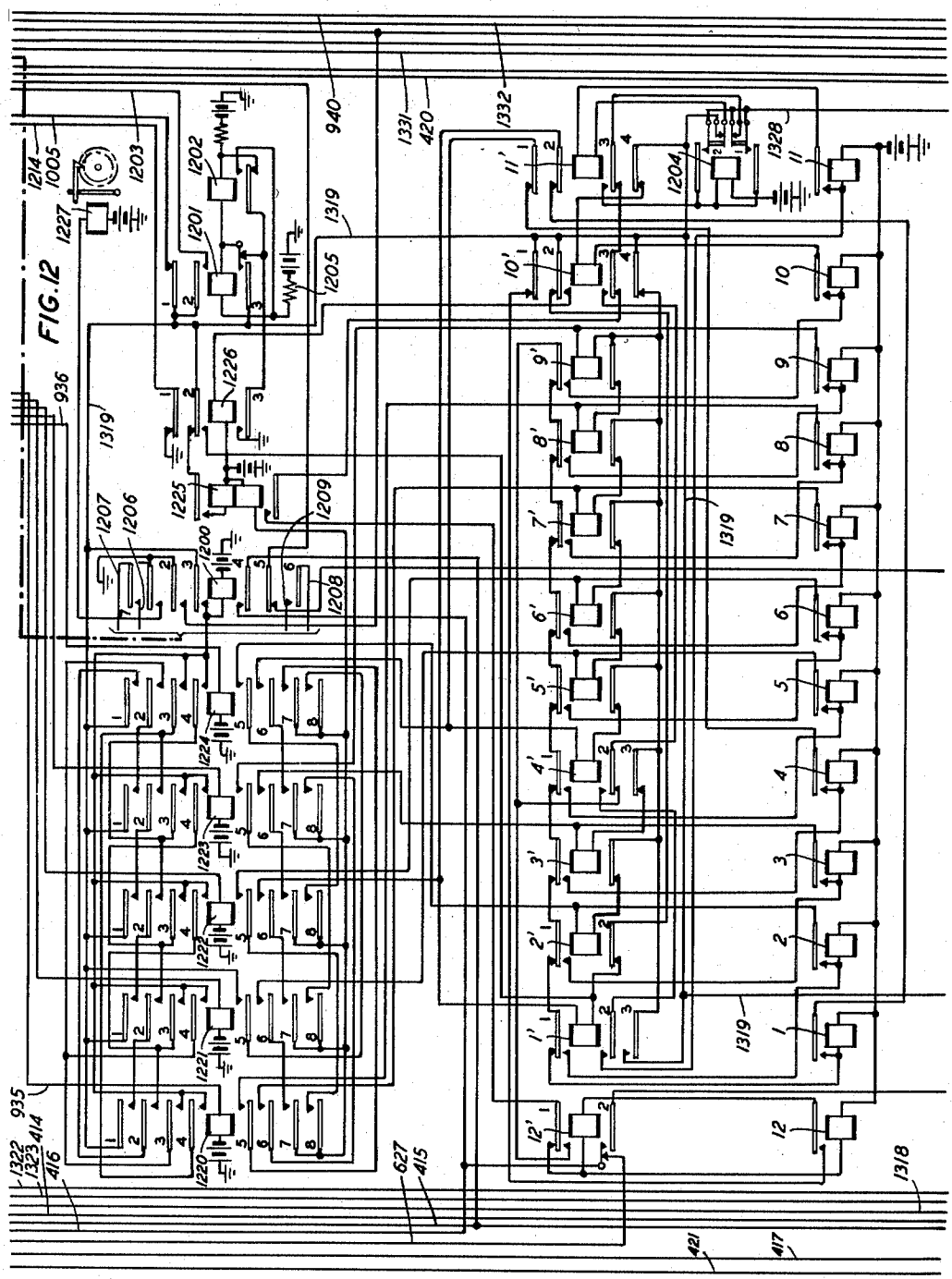

FIG. 12

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TELEPHONE SYSTEM

Filed Nov. 28, 1939 13 Sheets-Sheet 13

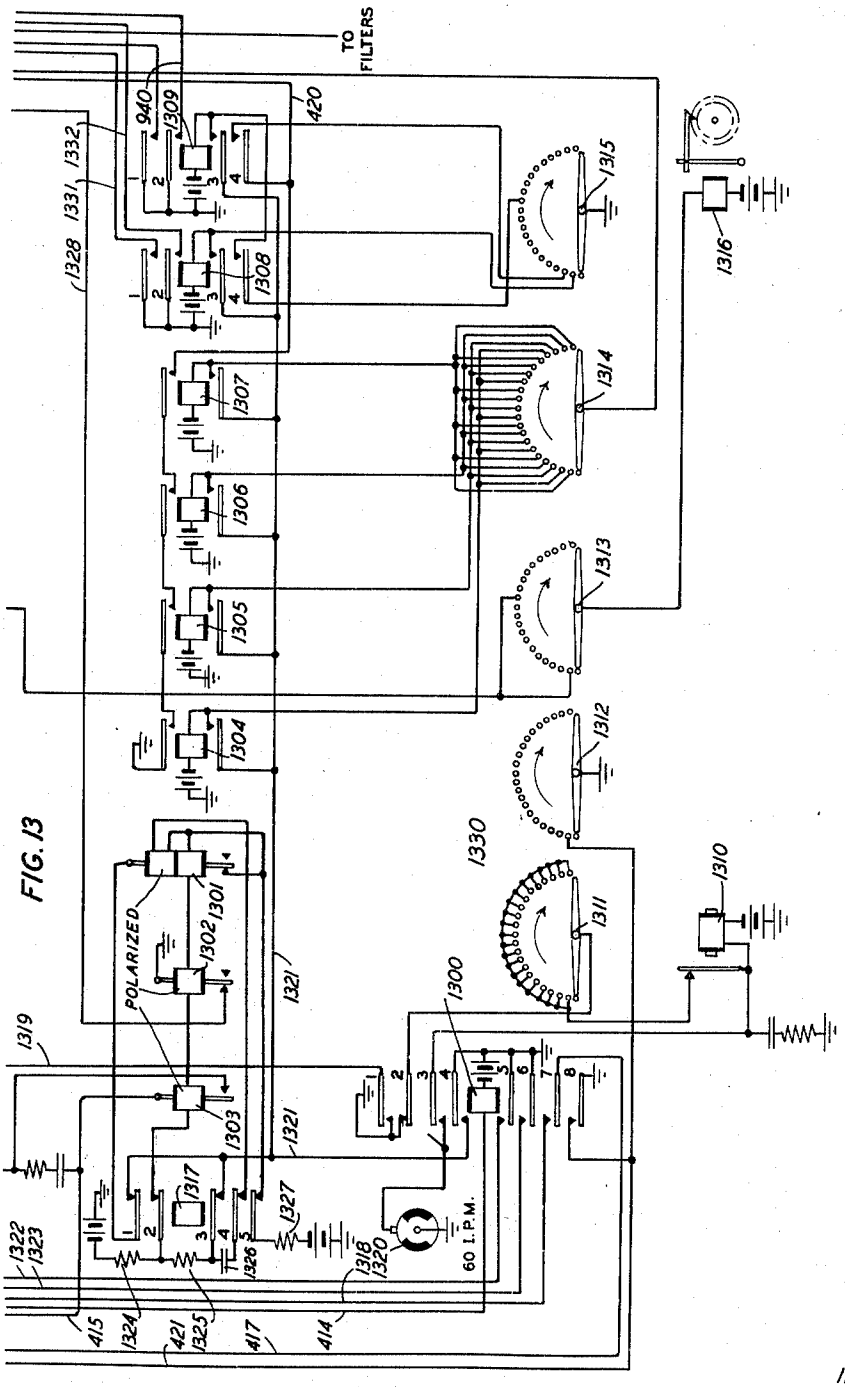

FIG. 13

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Patented Apr. 8, 1941 2,237,742

UNITED STATES PATENT OFFICE

2,237,742

TELEPHONE SYSTEM

Alexis A. Lundstrom, East Orange, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application November 28, 1939, Serial No. 306,466

25 Claims. (Cl. 179—18)

My invention relates to telephone systems and more particularly to one in which the designation of a wanted subscriber is transmitted by currents of different frequencies generated at the calling station by a device operatively responsive to the manipulation of a key-set. In certain automatic telephone systems the subscriber station is provided with a rotary dial, and when the establishment of a connection is desired, this dial is operated a number of times to produce trains of impulses which are transmitted to the exchange over the line wires and there received either on a succession of step-by-step selectors which are directively operated in response to the impulses to reach the called subscriber's line or upon so-called "senders" which function to directively set the selectors under the control of its own pulses, produced in response to those produced at the calling station but recorded in the sender.

Both of these methods of establishing automatic connections, while satisfactory from an operating standpoint, are, nevertheless, susceptible of distinct improvements, on the one hand from the calling subscriber's viewpoint who, in dialing as many as nine different trains of impulses for certain types of connections, may, in waiting for the dial to return home during the production of each train of impulses, forget how many digits have already been dialled and, therefore, make it necessary for him to start the establishment of the connection all over again thus incurring loss of time; and on the other hand also from the operating company's viewpoint which, in dial-operated systems and because the quantity of central office equipment is, among other things, a function of the time taken to dial a number, must provide more equipment than would otherwise be necessary if the time taken to transmit a wanted designation could be appreciably reduced below that required by the use of the dial.

According to my invention a calling subscriber communicates the office and number of a wanted subscriber by means which control the production of alternating or pulsating currents of various frequencies, said means preferably comprising a set of depressible keys any one of which, when depressed, causes alternating currents of particular frequency or frequencies to be produced for transmission over the line wires. These alternating current may be generated at the caller's instrument as, for example, by means of a number of reeds which, in response to the depression of a key, are set into vibration within a magnetic field in the combination required to produce the frequencies corresponding to the key depressed.

According to one feature of my invention the subscriber's station is arranged, with respect to the receiving equipment at the central office to which the line extends, to avoid the production of currents other than the signal frequencies produced by the current generating instrument at the subscriber's station. In operating with signal frequency transmission it has been found desirable to use alternating currents having frequencies lying within the voice range, and in the embodiment of the present invention in which the current generating device is located at the subscriber's station and is equipped with reeds that have natural periods within this range, the equipment at the central office which responds to the currents produced by these reeds cannot distinguish between these currents and, say, other currents within the voice range which may be produced by sounds that impinge upon the telephone transmitter during the act of operating the caller's sending instrument. To avoid the production of these false currents it is necessary to so dispose the reed generator across the line during the transmission of the signals that practically no line current passes through the transmitter during the generation of the signal frequencies. According to this feature of my invention a rectifier network is provided for the transmitter and the reed generator whereby, on signaling, the network presents a high loss to any line current that would flow to or from the transmitter but little or no impedance to the flow of the alternating line current through the coil of the instrument that produces the signal frequencies. On the other hand, when the connection has been set up, the direction of the line current is reversed so that, in this case, the rectifier network presents little or no impedance to the flow of direct or alternating line current through the transmitter and a high impedance to the flow of alternating current through the coil of the sending instrument.

According to another feature of my invention a sender is provided at the central office in which the alternating currents produced by the reed generator and transmitted over the line wires control the operation of as many channel detectors as there are signal frequencies, each detector being responsive substantially to a single frequency, to cause the operation of a relay. The combination of two relays operated for a single digit is then employed to record on settable regis-

ters the digit represented by the relays operated. The setting of the registers is then utilized in the known manner to cause the operation of switches for selectively reaching the wanted line.

Yet according to another feature of my invention the intensity of the dial tone transmitted to the calling station is controlled by the distance of the station from the home office in order that the intensity of the tone to the several stations at different distances from the office shall be uniform.

According to another feature of my invention a delay circuit is provided whereby the channel detectors are not made responsive to the incoming signals for a short interval subsequent to their arrival, in order that a portion of the energy delivered to them may be dissipated before the detectors are made available for responsive operations. The reason for this is to make sure that relays which will be operated by the activation of the individual detectors will not be so by a false response of any detector to the transient disturbance set up in all the channel filters by any sudden arrival of the signals at their inputs due to the depression of a key at the calling instrument. In this way the relays will not be subject to false operations from transients of durations shorter than a predetermined interval.

Yet according to another feature of my invention this delay circuit is adapted to paralyze or otherwise render inactive any of the detector channels if the input signal is of greater intensity than a predetermined value, and, also, to keep the detectors paralyzed until the disturbance has passed below the just operate level of the delay circuits for a predetermined interval of time. If the disturbance then goes above this level it must, of course, persist for longer than another predetermined interval to render the detector channel effective.

Yet another feature of my invention is the use of a special tuned feedback arrangement in the detector channel which renders the operation of the relay controlled thereby more sensitive to the incoming frequency and renders the release of the relay more quickly than otherwise when the signal current is removed. This makes for positive relay action which expedites and renders reliable those functions of the sender that depend upon the operation and release of the channel relays.

These and other features of my invention will be readily ascertained from the following detailed description of the invention, appended claims and attached drawings in which:

Fig. 1 is a schematic representation of the invention as embodied in a connection between the calling subscriber's station A and the called subscriber's station B over a train of switches selectively positioned by a sender responsive to the signaling frequencies generated at the calling station;

Fig. 1A shows the arrangement of Figs. 2 to 13, inclusive to disclose the complete invention;

Fig. 2 shows a subscriber's station circuit equipped with a reed current generating device and rectifier network for controlling current through the station transmitter and effectively switching from talking to reed generator circuit and vice-versa for conversation or signaling respectively;

Fig. 3 is a combined line circuit and the line connecting side of a line-finder switch of a private branch exchange;

Fig. 4 is the outgoing part of the line-finder switch including the sender connector;

Fig. 5 shows the private branch exchange selector PBX, a final connector C and wanted station B; while

Figs. 6 to 13, inclusive disclose the sender.

Considering first Fig. 1, it will be seen that the subscriber's station A is equipped with a reed plucking current generating device 201. A typical instrumentality of this kind is that shown in Patent 2,147,710, issued to R. F. Mallina on February 21, 1939. Briefly, this instrument comprises five reeds, tuned, respectively, to as many different frequencies and mounted to modulate the field of a permanent magnet which, in turn, causes a voltage to be induced in a common pick-up winding connect to the line. Any two of the reeds are plucked simultaneously by the depression of one of the ten key buttons and are thus caused to vibrate at their natural period to produce alternating currents determined by their different and respective periodicities. It is understood, however, that the alternating current generating device located at the subscriber's premises is not limited to the one above-mentioned and briefly described but may be any suitable instrument for producing signal frequencies either singly or combined with means responsive to the operation of a key or similar device.

In order to disclose the invention in its broadest aspects and thus bring out its flexibility with respect to its adaptation to telephone systems employing different types of equipment and used for establishing different kinds of connections, said invention is applied by way of illustration to the establishment of telephone connections over a system involving a calling subscriber's line located in a private branch exchange which is provided with mechanical switching facilities that are selectively operated to connect with trunks radiating in the several directions through which desired connections may be established in accordance with the number transmitted from the calling station. The switching structures herein used for illustrating the operation of the invention are of the well known step-by-step or Strowger type and reference may be had to pages 53 to 67, inclusive, of the second edition of "Automatic Telephony" by Smith and Campbell for a detailed description of the operation of the circuits associated with these switches. Only those portions of the circuits of the selector and connector switches are shown as are required for a clear and complete description of this invention, the omitted portions of these circuits being indicated by broken lines. It should be understood, however, and the description of the operation of the invention will amply show, that the invention may just as readily be applied to any other type of switching structure as, for instance, the so-called panel or cross-bar type, and the modification of the controlling circuits for adapting the invention to these or any other type of switches may be easily made by anyone skilled in the art.

Referring now more particularly to Fig. 1, there are shown a calling subscriber's station A equipped, as said before, with a reed current generating device 201, the associated line finder LF which includes the line circuit LC, omitted from Fig. 1 but shown in detail in Fig. 3, a sender connector SC, a private branch exchange selector switch PBX, intermediate selector switches, indicated but not shown, a connector switch C

and a called subscriber's station B. Directly below the sender connector are a plurality of senders designated by the first sender and last sender. In brief, the invention functions as follows:

When the subscriber A lifts the receiver from the cradle, the line finder LF is operated to move its brushes to the terminals of the line, after which an idle sender is connected to the line finder by the operation of a relay **405** of whatever sender happens to be free, the senders being disposed in a preferred order for distributive connections among the several groups of line finders serving the different groups of lines. The line-finder switch LF, however, is one connecting element of a switch structure which comprises the line-finder switch proper having access to calling line terminals, the sender connector element **405** by which an idle sender is connected to the calling line via the brushes of the line-finder switch and a selector switch structure that has access, through its brushes, to the different trunk groups leading to the several points of destination.

Now when the sender becomes connected to the line, the private branch exchange switch becomes operatively associated with the sender and it transmits "dial tone" thereto just as it would transmit it to the calling subscriber to notify him that he may proceed to dial if it were connected directly to the subscriber's line. In my invention, however, the switch PBX, instead of being selectively positioned by impulses produced at the calling station as it would be in a dial operated system, will be selectively positioned by impulses produced by the sender, and since the sender can produce these switch-stepping impulses only in response to the call designation as keyed by the subscriber and recorded in the sender, dial tone cannot be transmitted from the selector directly to the calling station, but from the sender to the station after the sender has become operatively connected to the selector. The tone which is transmitted by the selector PBX to the sender operates equipment therein which produces another tone that is then transmitted over the line to the calling station.

In response to this tone, the subscriber operates device **201** to transmit the wanted designation by depressing a key for each letter or digit representing the wanted number, and the depression of each of the keys will cause two of the reeds to vibrate at a definite frequency, each thereby producing a current of that frequency. These currents are transmitted over the line into the sender which is provided with a frequency detector channel for each signal frequency. The particular channels tuned to the transmitted frequencies are operated, after a small time interval to allow for the dissipation of transients, and cause the operation of a relay in each of the responding channels. Obviously the successive depression of different keys will produce a successive combination of different frequencies which will cause the operation of a different combination of detector channels and relays operated in response thereto.

In combination with the five detector channels there is affiliated a special delay system network. This system has the function of connecting the channel filters to the input side of the line after a part of the signal energy has dissipated itself and, some time later, to sensitize the channel detector units. The purpose of this is, as said before, to avoid in the signal frequency the effect of components of other frequencies present which, unless kept out of a particular signal band, will tend to decrease the frequency discriminating qualities of the channel filters by setting up an additional frequency spectrum. The additional delay thereafter, before the channel detectors are sensitized, is necessary in order to allow the spectrum resulting from suddenly applying the signals to the filters at the end of the first delay to subside. This permits the filters to realize a good portion of their steady state frequency discriminating characteristics and thus enable the detectors to respond to larger variations in loss due to loop differences and other causes without obtaining false operations in adjoining channels.

The delay circuit serves three other functions in addition to those mentioned. The first is to block any signal of less than a predetermined duration; the second is to block any signal which has an intensity of a certain predetermined value above the just operate level of the channels and the third is to block the operation of the channels until the signal passes below the just operate level of the delay network to a predetermined lower level. If the signal then goes above the just operate level after dropping below the predetermined lower level, it must persist for a period longer than the interval of time controlling the second function mentioned above before the channels will be activated.

The combination of relays operated in response to the incoming combination of two frequencies that corresponds to the depression of a key is recorded in a group of register relays which are locked to preserve the record, and every time the channel relays operate in response to succeeding combinations of frequencies, a corresponding record is locked in another and succeeding register, each digit of the called line designation thus being recorded on a separate register, there being provided in the sender as many registers as the maximum number of digits that may be required to set up a connection to any part of the telephone area.

Once the called number is recorded on the several registers, the sender proceeds to use the registrations successively to produce the number of impulse trains required to directively position all the selectors necessary to reach the wanted line. According to Fig. 1 the subscriber will have to key one digit for setting the private branch exchange selector PBX, and the number of levels to which the brushes of this selector will be caused to step by the sender will depend upon the direction of the call; the destination from the private branch exchange outlet controlling, in any case, the number of additional digits required. If, for instance, the call is to terminate before the manual board of another private branch exchange, one digit will suffice to directively set the private branch exchange switch PBX on the bank level containing the trunks that lead to this board. On the other hand, if the connection is for a called subscriber B, reached through an automatic central office, a maximum of nine digits may be required, that is, one digit for directively setting the private branch exchange switch PBX to the outlet level for reaching the office selectors, three digits for the designation of the wanted office in order that the office selectors may be positioned for connection, to a trunk extending to the wanted office, four digits for the directive setting of the selectors in the office for reaching the terminals

of the wanted line and an additional digit for a possible party line or ten thousand digit designation for the wanted line. When the appropriate number of selectors has been positioned by the corresponding number of pulse trains produced by the sender, the sender provides a suitable signal, in the form of a circuit for operating relay 408, for closing the connection through, after which the called line B is rung in the known manner and the sender is disconnected from the line by the release of relay 405, in readiness to set up another call.

Referring now more particularly to Figs. 2 to 13, the complete understanding of the invention may be obtained from a consideration of the circuit operations which follow the initiation of a call and the transmission from the subscriber's station of the wanted subscriber's number.

Assuming that line A is located in the second level of terminals in the lower bank 320 of the two banks of terminals 320 and 330 accessible to the brushes of line finder LF and that a call is initiated from said line by the removal of the handset 200 from its cradle. As a result, off-normal switchhook contacts 203, 204 and 209 are closed and a circuit is completed for the subscriber's line relay 302 which extends from battery through the right winding of said relay, No. 1 contacts of cut-off relay 303, line conductor 210, switchhook contacts 204, one arm of the rectifier bridge consisting of rectifiers 207 and 206, primary winding of the induction coil 202, switchhook contacts 209, line conductor 211, No. 3 contacts of cut-off relay 303, left winding of line relay 302 to battery. Relay 302 operates and through its No. 2 contacts closes a circuit for operating group relay 306 while through its No. 1 contacts and conductor 304 it connects the winding of cut-off relay 303 to the sleeve terminal of the line in bank 340. Relay 306 operates and disconnects ground from conductor 307 so as to mark the second commutator segment of all of the line-finders having access to the group of lines containing line A, and connects ground to start conductor 308. Assuming the line finder LF to be the first idle finder in the group, the ground on conductor 308 is extended through the normal No. 1 contacts of relay 319 to the winding of relay 310. Relay 310 operates, thereby closing a circuit for energizing relays 311 and 312, the circuit for the latter relay being traced from battery through its winding, through the brush and normal segment of commutator 314, to ground at the No. 2 contacts of relay 310 and the circuit for the former being traced from battery through resistance 329, No. 4 contacts of relay 319, through the normally closed contacts of rotary magnet 317, winding of relay 311, back contact of the vertical magnet 313, and through the No. 2 back contacts of relay 312, to ground at the No. 2 contacts of relay 310. When relay 312 operates, the circuit for operating relay 311 may be traced through the No. 2 front contact of relay 312 (instead of through the No. 2 back contact) and thence through the brush and normal segment of commutator 314, to ground at the left front contact of relay 310. Relay 311 is locked operated through its front contacts to ground on the No. 2 contact of relay 310, independent of relay 312 and independent of the commutator 314, while relay 312 is locked operated through its No. 2 front contact and the front contacts of relay 311 to the ground at the No. 2 contacts of relay 310.

With both relays 311 and 312 operated, a circuit is closed for operating the vertical magnet 313, said circuit being traced from battery through its winding, the No. 1 front contacts of relay 312, the outer set of contacts of relay 311, to ground at the No. 2 contacts of relay 310. The operation of vertical magnet 313 raises the shaft and all multiple and commutator brushes up to the first level of line terminals and opens the circuit through the winding of relay 311 in consequence of which said relay releases and opens the circuit through the winding of magnet 313, which releases. Now if the terminals of the calling line were located in the first level of the terminal bank, relay 312 would release when its locking circuit is opened by the release of relay 311 since its own operating circuit, opened when the brush of commutator 314 was advanced from its normal position, would not be closed on the first segment of commutator due to the disconnection of ground from this segment by the operation of relay 306. It has been assumed, however, that the terminals of the calling line are not located in the first level. Therefore relay 312 will be held operated through the brush and first segment of commutator 314, to ground at the back contact of the group relay associated with the lines which do connect to terminals in the first level. Relay 311 is then reoperated through the No. 2 contacts of relay 312, to ground on the first off-normal segment of commutator 314. When relay 311 reoperates, the circuit for energizing the vertical magnet 313 is closed once more and the reoperation of the magnet accordingly steps the shaft and brushes up to the second level. With magnet 313 operated, however, relay 311 again releases, whereupon the circuit through the winding of the magnet is again opened and relay 312 is unlocked. Since the ground normally connected to the second segment of commutator 314 has been disconnected therefrom by the operation of relay 306, relay 312 releases to prevent the further operation of magnet 313. The calling line being connected to bank 320 to which brushes 321 and 322 have access, it is not necessary to operate the brush switching relay 324; and since relay 306 was operated through its left-hand winding, no ground is connected to conductor 309 to cause the operation of relay 326 over the circuit that would be completed through its right contacts and the brush accessible to the segments of commutator 315 reserved for the lines located in the upper terminal bank 330.

As soon as the shaft was moved upward from its normal position, the vertical off-normal springs 316 were operated to connect ground to conductor 327 and to prepare for the operation of the rotary magnet 317. The release of relay 312, after the brushes have been advanced to the calling level, again closes a circuit to ground on the No. 2 contacts for operating relay 311, and the reoperation of this relay closes a circuit for operating the rotary magnet 317, said circuit extending from battery through the winding of the magnet, the No. 4 and No. 5 contacts of the vertical off-normal springs 316, the No. 1 back contact of relay 312, the front contacts of relay 311 to ground at the No. 2 contacts of relay 310. Magnet 317 operates and advances the lower brushes 321 and 322 to the first set of terminals in the selected level, opens the circuit for operating relay 311 and connects the winding of this relay through the front contacts of magnet 317, the lower winding of relay 318, and the No. 1 normal contacts of relay 324 to the test brush 323. If the calling line is connected to the first set of terminals in the selected level, the circuit through the winding of relay 311 is extended over

brush 323, over the sleeve conductor 304 of the calling line, through the No. 1 contacts of the operated line relay 302, through the winding of the cut-off relay 303 to battery, thereby holding relay 311 operated to prevent the further advance of the brushes. If the calling line is connected to some other set of terminals in the selected level, then relay 311 is not held operated and its release will cause the release of magnet 317. When this magnet releases, relay 311 reoperates, causing thereby the reoperation of magnet 317. Relay 311 and magnet 317 are, in this manner, alternately operated and released until the test brush 323 engages the sleeve terminal to which conductor 304 is connected, at which time relay 311 is held operated in series with the winding of cut-off relay 303 over the path previously traced. The cut-off relay 303 operates and relay 318 is sufficiently energized by the current through its lower winding to close a locking circuit from battery through its upper winding and No. 2 front contacts, through the front contacts of magnet 317, the winding of relay 311, the back contact of magnet 313, and through the front contacts of relay 311 to ground at the No. 2 contacts of relay 310. Relay 318, with the aid of the current flowing through its locking winding is now completely operated to extend a connection from line A through brushes 321 and 322, the No. 2 and No. 4 back contacts of relay 324, and the No. 1 and No. 4 contacts of relay 318, over conductors 351 and 352, No. 3 and No. 4 back contacts of relay 408, both windings of relay 401, both windings of relay 403, the upper windings and the lower windings of both relays being serially connected, respectively, with the upper winding of relay 403 bridged by rectifier 442 and lower winding bridged by rectifier 443, resistance 407 to battery, and resistance 409 to ground. Relays 401 and 403 operate to perform functions which will be shortly described except to note at this time that relay 401 closes an obvious circuit for relay 402 which, in operating, applies ground over its No. 3 contacts to the holding conductor 353 which functions to hold relay 318 in an operated condition over a locking circuit through the No. 3 contacts of relay 319, No. 2 contacts of relay 318, upper winding of said relay to battery and, further, to hold operated the brush transfer relay 324, if operated, over a locking circuit extending from ground on said conductor, No. 2 and 3 contacts of vertical off-normal springs 316, No. 3 contacts of relay 324, winding of said relay to battery. It further closes a circuit for relay 413 over the contacts of relay 412 which operates but performs no function at this time. Relay 319 operates in a circuit through its left winding, the No. 3 front contacts of relay 318 and the No. 1 and 2 contacts of vertical off-normal springs 316, locks to ground on conductor 308 should there be another calling line in the same level in either bank to keep the group relay 306 operated from the contacts of the line relay of said other line, extends this ground over its No. 1 contacts to conductor 328 which is the start conductor in the next line-finder switch of the group that will be taken into use and, at its No. 4 contacts, disconnects battery through resistance 329 from the winding of relay 311, and opens the circuit of relay 310 which releases and closes a circuit path for the left winding of relay 319 through its No. 1 back contacts to off-normal ground on conductor 327. The purpose of this circuit is, of course, to insure that if another call is initiated in the group during the interval when the line finder LF is releasing and, therefore, when its brushes have not been completely reset, the releasing line finder will not be reseized by the reclosure of the circuit for relay 310 and the consequent operation of vertical magnet 313; for, in such an event, the brushes may be arrested from returning to normal and restarted in their upward movement from some position other than normal. Therefore by holding relay 319 operated to ground on the vertical off-normal contacts 316 until the brushes reach normal, any call initiated prior to this time will have the start ground on conductor 308 extended to conductor 328 and thence to relay 310 of whatever line-finder switch in the group is normal and selectable.

When relay 401 operates, it closes an obvious circuit for relay 402 which operates as already described. Relay 402 is made slow-release so that any momentary accidental depression of the switchhook which may cause the release of relay 401, said last mentioned relay being held over the line loop will not, at the same time, cause the release of relay 402 and thereby disturb the circuits established through its contacts. Relay 402, on operating, connects battery through its No. 1 contacts to the winding of a relay in the group of relays 404 to 404'' of the first idle sender available to the group of line finders serving line A, characterized by the normal position of the sender busy relay 406 to 406''.

Each line finder, depending upon the traffic density of the sender group, has a number of sender connectors as an integral part of its circuit organization, each sender connector comprising a relay 405, sender busy relay 406 and a sender selecting relay 404, each connector giving accessibility to one sender. The designations of the relays just mentioned refer to the first connector in Fig. 4 which is also first in the order of selection, while all intermediate connectors have similarly designated relays that are primed (those of the last connector being double primed) to indicate identity of function in the different connectors.

Now when a sender is made busy through operative association with a line finder in any group or through the removal of the sender from service, a circuit is closed for the upper winding of relay 406 in every sender connector through which the busy sender may be available. Postponing for the moment the tracing of the current path involved for this relay, it will be observed that if relay 406 operates as a result of the sender connectable to the first sender connector being made busy, said relay will lock in a path extending from battery through its lower winding and lower front contacts, lower back contacts of all intermediate sender busy relays 406' to 406'' which are normal because their associated senders are free, conductor 428 to ground on the No. 2 contacts of relay 402. Similar locking circuits will, of course, be available to the other sender busy relays in the event that the associated senders are not free.

If the senders available to the sender connectors forming an integral part of the line finder LF are all free, then, when ground is connected to the No. 1 contacts of relay 402, the sender accessible through the first sender connector will be selected for operative association with said line finder and this is accomplished by operating relay 404 over a circuit path which extends from battery on the No. 1 contacts of relay 402,

conductor 429, upper back contacts of relay 406, winding of relay 404, lower back contacts of said relay, through the back contacts of other relays 404', intermediate the first sender-connector and the last, to ground on relay 404'' of the last sender-connector. On the other hand, if all senders available to these connectors are busy except the intermediate sender and, therefore, all relays 406 to 406'' are operated and locked except the intermediate relay 406', then the sender accessible through the intermediate sender-connector will be selected by the operation of relay 404' over a circuit which extends from battery on conductor 429, upper front contacts of relay 406, upper front contacts of relays 406' of all sender-connectors between the first and the intermediate connector, upper back contacts of relay 406', winding of relay 404', bottom back contacts of relays 404', bottom back contacts of relays 404' of all sender-connectors between the intermediate connectors and the last connector to ground on the bottom back contact of relay 404''. In the same manner if all senders are busy except the one accessible through the last sender-connector, the above circuit will be traced through the top front contacts of all relays 406 to 406', top back contacts of the last relay 406'', winding of relay 404'' to ground on the bottom back contacts of said relay. Thus it is seen that a chain preference lock-out circuit is provided whereby the line finder LF is caused to be connected to the idle sender available through the first sender-connector which is not busy, a condition which is denoted by the non-operated condition of the sender busy relay 406 of the sender available through that channel.

For the purpose of continuing with the description of the operation of the system, however, it may be assumed that the sender connectable to the line finder LF through the first sender-connector is idle and that, therefore, as a result, relay 404 operates in the manner above described.

Upon the operation of relay 404 a circuit is completed for relay 405 which extends from ground on the top back contact of relay 404'', serially through the top back contacts of all other relays 404' in each of the connectors, which relays are non-operated by the opening of their respective circuit paths through the top contacts of their corresponding sender-busy relays 406 as soon as these relays operate in response to the non-availability of their respective senders, top front contacts of relay 404, winding of relay 405 to battery. Relay 405 operates to perform functions noted hereinafter.

With relay 405 operated, ground is connected over its No. 1 contacts to conductor 414 and thereby completes a circuit for relay 1300 which operates to perform a number of functions to be noted hereinafter. Relay 405 over its No. 2 contacts connects the ring conductor 422 to conductor 415 (via conductor 422') which, in turn, joins conductor 416 through the No. 4 contacts of relay 1200 when operated; over its No. 3 contacts relay 405 extends the tip conductor 423 to conductor 416 (via conductor 423'); over its No. 4 contacts, it extends ground to conductor 417 applied thereto by the contacts of relay 403 which, through the No. 7 contacts of relay 1300, applies locking ground to certain control relays in the sender and also to the armatures of the detector responsive relays 902 to 906; over its No. 5 contacts it extends the line conductor 351 to conductor 418 and thence to one arm of the resistance bridge 615 while through its No. 6 contacts it extends the other line conductor 352 over conductor 419 to the other side of said resistance bridge to form the fourth arm thereof; over its No. 7 contacts it connects the winding of relay 408 to conductor 420 and thence to conductor 901 via the No. 2 contacts of relay 938 and conductor, thence to the No. 2 contacts of relay 1309 which, when operated, cause relay 408 to operate as described hereinafter; over its No. 8 contacts it opens the operating circuit of its associated sender busy relay 406 which, however, will not release at this time since it is locked over its lower winding and contacts to ground on the No. 2 contacts of relay 402 as already described; while over its No. 9 contacts it connects battery through resistance 407 to conductor 430 which extends to the grid of vacuum tube 612.

In the present embodiment of the invention, it is assumed that the connection is to be completed to subscriber's line B located in an automatic office equipped with step-by-step switches of the Strowger type, the A or first digit office selector of which can be reached from the terminal banks of the PBX selector shown at the left of Fig. 5 to the windings of whose line relay 515 the tip and ring conductors 423 and 422 are respectively extended. Now when relay 405 operates and these two conductors are joined to conductors 416 and 415, respectively, as above described, a current path is completed for relay 515 which extends from battery, lower winding of relay 515, No. 5 back contacts of relay 514, conductor 422, conductor 422', No. 2 contacts of relay 405, conductor 415, primary winding of transformer 628, conductor 627, No. 2 normally made contacts of relay 12', conductor 416, No. 3 contacts of relay 405, conductor 423', conductor 423, No. 1 back contacts of relay 514, upper winding of relay 515, Nos. 1 and 2 contacts of "10th Rot. step" rotary off-normal springs 524, secondary winding of transformer 522 to ground. Relay 515 operates and closes an obvious circuit for relay 516 which also operates and, in doing so, applies ground to hold conductor 513.

Inasmuch as the primary winding of transformer 522 is connected to a source of dial tone, said tone is induced over the operating circuit of relay 515, above traced, including the primary winding of transformer 628. This tone, therefore, is further induced into the secondary winding of said transformer, resulting in the operation of detector-amplifier 613. This detector-amplifier may be of any suitable type wherein an energy supply is activated to operate relay 600 upon the induction of the tone current in the secondary winding of transformer 628, and the operation of relay 600 closes an obvious circuit for relay 614 which operates and connects generator 603 to the network 620. The current produced by the generator 603 is transmitted through the network 620, and through the filter 610, but the quantity of energy that gets through will depend upon thyrite resistance elements 607 and 608 bridged across the network, the shunting effect of which is controlled by the quantity of current flowing through the anode circuit of vacuum tube 612 of which said elements form a part.

It will be remembered that the operation of the sender-connector relay 405 extended the line conductors 351 and 352 to conductors 418 and 419, respectively, and that these, in turn, are connected to the fourth arm of the resistance bridge 615. Now the two vertical terminals of this bridge are connected to the primary winding of transformer 621 while its two horizontal points

are connected to the primary winding of transformer **619**.

Referring again to relay **403** which, it will be recalled, operated over the line loop, the flow of current through resistance **407** causes a potential drop measured by this resistance, and the current flowing therethrough, that is applied to conductor **430** which, as said before, is connected to the grid or control element of vacuum tube **612**. This tube is of the "heater" type having a thyrite resistance element **606** in series with its cathode. Prior to the application of the potential drop through resistance **407** to the grid of the tube, there is a slight current flowing through its anode circuit which extends from battery, thyrite **606**, the cathode (the filament of the tube being heated through a series battery connection with the filament of vacuum tube **611**), anode of tube **612**, the two thyrite elements **607** and **608** to ground. Thyrite is selected to supply the fixed negative bias on tube **612** because it has the electrical characteristic that potential drop across itself increases very slowly with increase in current through itself. Therefore, variation in anode current of tube **612** will not materially affect the negative potential drop across thyrite **606** and it will remain almost fixed. If there is no potential drop or a very slight potential drop in resistance **407** due to the fact that, for instance, the line loop is long, the grid bias is strongly negative because of the application to the cathode of the negative potential drop through the thyrite element **606**. The current flowing through the anode circuit is, under these circumstances, very small. Conversely, if the potential drop from resistance **407** applied to the grid is large as would be the case, for instance, when the loop is small, the resulting grid bias due to the sum of the positive potential drop across resistance **407** and the negative potential drop across thyrite **606** would be less negative. In consequence, the anode current would be large. In other words, the voltage drop across thyrite element **606** works in opposition to the voltage applied to the grid from the loop so that, on long loops, the total grid bias will be highly negative to permit very little current to flow through the anode circuit of the tube while on a short loops the total negative grid bias will be small to permit a very large current to flow through the anode circuit. Consequently the potential drop applied to the grid of tube **612** and the quantity of current which then flows through its anode circuit, above traced, depends upon the length of the loop, including the resistance of conductors **210** and **211** that extend between the subscriber's station A and the terminals on the line-finder bank **320** at the telephone office. Whence it follows that the current flowing through the anode circuit of vacuum tube **612**, being dependent upon the value of the positive potential on the grid of the tube, is a maximum for zero line loop and a minimum for the longest line loop. The anode current, however, circulates through the thyrite elements **607** and **608**, which have the property of decreasing in resistance with an increase in current flowing therethrough. For the small current through the anode circuit produced by a long line loop, the current through the thyrite elements is slight, the resistance thereof remains comparatively high and the shunting effect of these elements, bridged across the network **620** is very small. Hence for a long line loop, by which is meant the ohmic distance of the calling subscriber's station A from the office in which the line terminates, most of the energy from the generator **603** will be transmitted directly into the filter **610**, without any appreciable quantity of it passing through the shunting thyrite bridge. On the other hand, when the loop is small or of negligible resistance, the current through the anode circuit is large, the thyrite elements decrease their resistance in response to the passage of the current and the effect is to produce a shunt path across the network **620** that will cause most of the energy from the generator **603** to flow through the shunt circuit with little of it passing into the filter **610**.

The reason for the above arrangement is to regulate the quantity of dial or keying tone current transmitted back to the calling station in accordance with the length of the loop so that the intensity of the tone will be practically uniform for all stations regardless of their distance from the office. In dial telephone systems in which the designation of the wanted line is transmitted by means of direct current impulses, no such case need be exercised about the tone intensity at the station because the tone used is usually of low frequency, preferably within the voice range, say around 500 to 600 cycles. Since the line loss increases with the frequency used, the loss in the intensity of the tone at this frequency (500 to 600 cycles per second) is small for different loops and the same energy level, therefore, may be applied to all lines regardless of their distance from the office. But in the present telephone system in which the designation of the wanted line is transmitted by means of combination of frequencies within the voice range, the frequency of the dial or keying tone used cannot be within the same range as the signal frequencies because the keying tone transmission network is coupled to the channel detectors responsive to these signal frequencies and such detectors therefore, may be falsely operated in response to the dial current. To avoid any such false operations, the keying tone frequency is chosen well above the range used for signaling from the calling station. Since the line loss is greater with the higher frequency than it is with the frequency used in dial systems, it is evident that if the tone level is suitable for the most remote station it will be too loud for the nearest station which fact makes it necessary to make the quantity of tone transmitted over the line depend upon the length of the loop as above described. Thus when the line is long the quantity of keying tone current transmitted thereover will have to be sufficient to provide for ohmic and attenuation losses over it whereas, when the line is short and the electrical constants making for such losses are not present, the quantity of tone current is reduced in proportion to allow for the production of the same intensity of sound at the station receiver.

The keying tone is produced by the generator **603** which generates the odd harmonics of some base frequency say, for example, 20 cycles, and the pass-band filter **610** has an upper and lower frequency cut-off which defines the harmonics to be produced by the generator **603**. Thus if the filter is designed to pass all frequencies between an upper limit of 1480 cycles and a lower limit of 1400 cycles, the generator should be adapted to produce the 71st or 73rd harmonic of the 20 cycles and either or both of these harmonics would be transmitted through the filter and transformer **619** to the horizontal terminals

of the resistance bridge 615, whence they will flow through the line loop as described below.

Arms 2 and 3 of the bridge 615 are of equal resistance while arm 1 is a network "in" whose impedance is equal approximately to that of the line loop which comprises the fourth arm of the bridge. Inasmuch as the loop will vary in accordance with the remoteness of the station from the central office, the impedance network "in" may be composed of elements that will give an average impedance for all lines. Now when keying tone voltage is induced in the secondary winding of transformer 619, the voltage is impressed upon the horizontal terminals of the bridge 615 and the current will circulate through the four arms of the bridge including the line loop and the station A at the extremity thereof, causing a tone to be heard by the subscriber who will understand it as a signal to transmit the designation of the wanted station by manipulating the key-set 201. For the average loop in which the impedance "in" of the fourth arm of the bridge equals that of the loop, the potential drops across the resistance of arm 2 and impedance "in" of arm 1 will equal that across resistance of arm 3 and the impedance of the loop making up arm 4. As a result, there will be no difference of potential across the vertical terminals of bridge 615 and no keying tone current will flow through the primary winding of transformer 621. For other cases besides the average loop, however, the bridge will, of course, be unbalanced and some keying tone current will flow through the primary winding of transformer 621 to cause a voltage to be induced in the secondary thereof included in the network of filter 630. This filter 630, however, is a low-pass filter whose constants are designed to block the passage therethrough of any of the keying tone frequencies so that the amplifier 640 and the receiving detector channels connected thereto via the bridge 625 will be immune to operation from keying tone current.

Upon hearing keying tone the subscriber is thus informed that the circuit is ready for him to transmit the wanted designation. However, before considering the operation of device 201 for this purpose, it should be observed, first that the frequencies of the transmitted signals to be produced by device 201 are all within the voice frequency range and second, that the production of currents of the same frequencies or within the same frequency range by sounds impinging upon the transmitter during the sending of the wanted designation, must be prevented in order to avoid false operation of the detector channels in Fig. 7 which are normally responsive to the currents produced by the device 201. In order to provide the channels with practical immunity from noise currents, advantage is taken of the well-known relationship in a telephone transmitter, between its efficiency in producing variable currents consequent to the impingement of sound waves upon it and the quantity direct current flowing through it at the time. According to the feature of my invention, practically no current flows through the transmitter 217 during the time when the subscriber manipulates the key-set 201 but current will flow through it during talking. This is accomplished by the use of a rectifier bridge 205—206—207—208 and by reversing the direction of current flow through the line when the called subscriber B answers the call. Further, the rectifier bridge above mentioned places an alternating current loss on the transmitter 217 to attenuate any speech currents that may be set up due to the incomplete removal of direct current through the transmitter by the bridge during the first condition and further acts to switch out of circuit the reed set itself during talking inasmuch as talking current, flowing through rectifiers 205 and 208, cannot flow through rectifiers 206 or 207 and, therefore, through the coil of the generator set. This avoids a transmission loss which otherwise would be present if talking current were allowed to flow through the generator coil.

It will be recalled that when the calling station A is cut through to the sender-connector by the operation of relay 318 a line current is established by battery fed through relays 403 and 401, no circuit being established into the sender because of blocking condensers 426 and 427. The direction of current flow is from ground (the positive pole of the battery), resistance 409, lower winding of relay 403, paralleled rectifier 443, lower winding of relay 401, No. 4 back contacts of relay 408, thence as traced to conductor 210, switchhook contacts 204, to the lower vertical terminal 218 of the rectifier bridge. Since rectifier 208 is in series with transmitter 217 and is disposed so as to be in the high resistance direction for currents flowing into the transmitter via terminal 218, most of the current from this terminal will flow through rectifier 207, rectifier 206, upper (primary) winding of transformer 202, switchhook contacts 209, conductor 211, thence as traced to the No. 3 back contacts of relay 408, upper winding of relay 401, upper winding of relay 403, paralleled rectifier 442, resistance 407 to the negative pole of the battery. Thus practically no current flows through the transmitter 217 so long as the current is in the direction indicated. Since the efficiency of the telephone transmitter is very low when a small direct current flows through it, any sounds impinging thereupon will produce very little pulsating current that will be of an order to affect the detectors in Fig. 7. On the other hand, when the connection to station B is established and the receiver is removed from its cradle thereat it will be shown that under these circumstances relay 408 will be operated and talking battery for the calling station will then be supplied from ground through the right filament of ballast lamp 431, upper winding of relay 411, upper left winding of repeat coil 441, No. 1 back contacts of relay 410, No. 3 front contacts of relay 408, thence as traced to line conductor 211. The negative pole of the battery will be applied through the left filament of ballast lamp 431, lower winding of relay 411, left lower winding of repeat coil 441, No. 2 back contacts of relay 410, No. 4 front contacts of relay 408 thence as traced to line conductor 210, whereupon the current will then flow via conductor 211, switchhook contacts 209, primary winding of transformer 202, to terminal 219 of the rectifier bridge, thence through rectifier 205, rectifier 208, transmitter 217, terminal 218 of the bridge, switchhook contacts 204, to negative battery on conductor 210. Current now flowing through the transmitter will cause it to operate at high efficiency to produce pulsating currents in response to sound waves impinging upon the diaphragm, thereby permitting conversation to flow over the established connection.

Going back, now, to the transmission of the wanted designation, the subscriber manipulates the key device 201 to depress in succession each of the keys corresponding to the character or num-

ber of the wanted line. The depression of a key in the key-set **201** causes any two of the five reeds **212**, **213**, **214**, **215**, and **216**, to be plucked in the appropriate combination required to generate, by their respective vibration in the magnetic field of the permanent magnet of the key-set, an alternating current having a frequency characteristic determined by the natural periods of each of the reeds. Thus the longest reed **212** will, when plucked, vibrate with a natural period that will produce a current having a frequency of *a* cycles per second while the shortest reed **216** will vibrate with a period that will produce a current having a frequency of *e* cycles per second. Each of the other three reeds are proportioned to produce frequencies intermediate these two limiting frequencies; that is, reed **213** will produce a current having frequency *b*, reed **214** will produce current having a frequency *c* and reed **215** will produce a current having a frequency *d*. In actual practice, the frequencies thus designated by letters will be represented by frequencies within the voice range. Thus one such range may be as follows: *a*=**500** cycles; *b*=615 cycles; *c*=775 cycles; *d*=995 cycles; and *e*=1225 cycles. Other ranges are possible and these may be fixed by the physical constants of the reeds used in the key-set.

The code combination of two frequencies for each of the digits designated by the several keys will be discussed further on in connection with the registration of the various digits transmitted. For the present, however, it will suffice to note that the depression of any key in the key-set will cause the plucking of the two reeds required to produce the two frequencies individual to the digit designated by the key depressed, and these two frequencies are transmitted over the line loop as already traced down to conductors **418** and **419**, the circuit being completed through the primary winding of transformer **621** which is connected to the two vertical terminals of resistance bridge **615**.

The signal frequencies passing through the primary winding of transformer **621** cause the induction of currents of identical frequencies in its secondary winding, thence they pass through the low-pass filter **630** into the amplifier **640** coupled to the filter **630** by transformer **622**. The secondary winding of transformer **623** forms the fourth arm **4** of the resistance bridge **625** and the amplified signals repeated into it from amplifier **640** are applied to the four cross-points of the bridge whence the energy divides, part of it circulating through the primary winding of transformer **624** connected to the vertical terminals of the bridge and part of it entering the resistance pad **635** to circulate through the circuit completed by the primary winding of coupling transformer **618**.

The portion of the energy which passes through transformer **624** into the resistance pad **660** is short-circuited to ground, on the one side through the resistance pad and on the other side through the normally closed contacts of polarized relay **817** the armature of which is connected to conductor **703** via conductor **802**. The circuit of relay **817** is normally completed from ground through its middle winding, resistance **821**, back contacts of relay **816** to positive battery **814**. Relay **817** also has a biasing circuit through its upper winding extending from ground therethrough, resistance **931** to battery **814** so that, if the circuit through its middle winding is opened, the relay will be immediately forced to its unoperated position and thereby break the ground connection to conductor **802**. Further, it may be noted at this point that relay **818** also has a biasing circuit through its upper winding, extending from ground therethrough, resistance **832** to battery **814**. In the case of this relay, however, it is held in a non-operated position so long as the circuit through its lower winding is effective, which circuit extends from ground through its lower winding, resistances **823** and **822** to battery **814** via the back contacts of relay **816**. But when this circuit is opened in the manner hereinafter described, the circuit through its upper winding will immediately force the relay to its operated position and thereby apply ground to conductor **831** which extends to the cathodes of the tubes in the several detector channels **710** to **750**. This means that any signaling energy which is transmitted over the line loop and gets through the resistance pad **660** will have no effect in actuating any of the five signal detectors **710** to **750** so long as relay **817** remains operated to maintain ground on conductor **703**, thus preventing any of the energy from getting into the filter elements of the detector channels. Even after relay **817** has released, in the manner to be described hereinafter, and the signal energy does get through, it will be ineffective to actuate any of the detectors until ground is placed on conductor **831** by the operation of relay **818**. Hence by properly timing the release of relay **817** and the operation of relay **818** in relation to each other, the detector channels may be made to respond to any part of the signal energy spectrum.

Considering that portion of the signal energy which passes through the resistance pad **635**, the signal is amplified through amplifier **650** and transmitted via the secondary winding of transformer **626** and conductors **701** and **702** into the three detector circuits **800**, **810** and **820** connected to said conductors **701** and **702** by coupling transformers **803**, **804** and **805**, respectively. These three detectors with their respective networks constitute the delay circuit.

The delay circuit contains gas-filled detector tubes **806**, **807** and **808** which have as their duty the quick conversion of any alternating current signals to a relay operation and, further, the quick release of the relay upon the removal of the signal. Tubes **806** and **807** and their respective relays **816** and **815** are wired so as to accomplish this requirement with but a few milliseconds delay either in operation or release. As is well known, a gas-filled tube is adapted to start a space current discharge between its cathode and anode whenever the grid control element has a sufficiently small negative potential with respect to the cathode. The grids of the above tubes have a normal negative bias supplied by negative battery **809** which also supplies filament current to each of the tube filaments via conductors **811** and **812** and resistances **833** and **834** to ground on conductor **813**. The sensitivities of the detector tubes **806** and **808** to operation are determined by the magnitude of the fixed negative potential between the grid and the cathode. A higher bias causes a lower sensitivity thus requiring more signal potential from the transformer to operate the particular tube. Tube **806** is the most sensitive with a negative grid to cathode bias constituted by the sum of the potential drop across resistances **833** and **834**. Tube **808** is the least sensitive, it having a grid to cathode bias determined by the potential from resistances **833**, **834** and the filament of tubes **806** and **807**.

Tube 807 derives its negative bias from the potential drop across resistance 834 only, which is so selected that said bias is not sufficient to hold the tube inoperative if the anode battery should be applied to it when no signal is present. Thus, as will be explained hereinafter, tube 807 will conduct from anode to cathode when no other voltage is applied to its grid. The anode of tube 806 is further connected to positive battery 814 through a path which extends from the positive pole of said battery, armature and normal contact of relay 815, lower winding of relay 816, protective resistance 819 to the anode of the tube. Consequently if the incoming portion of the signal which passes through transformer 803 and is further applied to the grid of tube 806 is sufficiently high, the tube will be rendered conducting on the positive half cycle of the potential, which sufficiently reduces the negative grid to cathode fixed potential bias whereupon a space current discharge will occur in tube 806 that will complete a current flow from ground on the cathode, conducting space between cathode and anode, resistance 819, lower winding of relay 816, normal contact and armature of relay 815 to the positive pole of the battery 814. Relay 816 operates in this circuit and, in doing so, performs three functions; first, it breaks its back contact to remove battery 814 from the middle winding of relay 817 via resistance 821, and, second, from battery the lower winding of relay 818 via resistances 822 and 823. Relay 817, however, is normally operated over a circuit previously traced while relay 818 is normally in its unoperated position, it being held away from its front contact by the circuit through its lower winding. But when relay 816 operates and removes battery from its back contact, relay 817 will be driven to its unoperated position by the circuit through its upper winding while relay 818 will be driven to its operated position by the circuit through its own upper winding. However, due to the fact that condenser 824 is connected between resistances 822 and 823 and is charged by the circuit above traced through the middle winding of relay 817 and the lower winding of relay 818, then, when battery is removed from this circuit, the condenser discharges to ground through the windings of these relays, thereby delaying the release of relay 817 and the operation of relay 818. The quantity of the delay in both cases is determined, of course, by the electrical constants of condenser 824 and the value of the resistances 821, 822 and 823, which may be fixed, if desired, to values such that relay 817 will release in about 5 milliseconds after relay 816 has broken its back contact and relay 818 will operate in about 25 milliseconds after relay 817 has released. Other values may be selected if different release and operate intervals for these relays are desired. Third, relay 816, by closing its front contacts, connects positive battery 814 to the anode of detector tube 807 by way of the lower winding of relay 815 and further applies the same battery to the anode of detector tube 808 by way of the lower winding of relay 817.

That portion of the signal energy which passes through the coupling transformer 804 into the detector 810 is rectified by the rectifiers 826 and 827, bridged around the secondary winding of said transformer. This rectified energy sets up a direct current voltage through the combination of resistance 828 and condenser 829 which is applied negatively to the grid of detector tube 807. Now, resistance 834 is so selected that the negative potential set up across itself from battery 809 is not sufficient to keep tube 807 inoperative when battery 814 is connected to its anode through the contact of relay 816. However, the added negative rectified voltage on the grid of tube 807 due to the signal which is set up by the rectifiers 826 and 827 across resistance 828 and condenser 829 is sufficient to keep tube 807 inoperative after battery 814 is connected to its anode. Resistance 833 is therefore selected to produce a negative potential drop with current from battery 809 which, when added to the potential drop of resistance 834, will hold tube 806 inoperative until an alternating current signal of sufficient positive intensity is present on conductors 701 and 702, which signal will, at the same time, hold tube 807 inoperative when battery 814 is connected to its anode as the result of operation of tube 806 and relay 816 when this signal is applied. The detector tube 807 is rendered operative only upon the removal of the negative voltage produced by the rectification which will cause the tube to operate. Therefore the application of a signal will not cause tube 807 to operate but the removal of signal will when battery has been applied to its anode. It will be observed, however, that this negative bias is applied to the grid of the tube before positive battery is applied to its anode by the operation of relay 816. This is necessary since the tube 807 is normally insufficiently negatively biased from the potential drop on resistance 834, and the connection of battery 814 to its anode before the negative rectified voltage is applied would cause the premature operation of this tube.

That portion of the energy which gets through the coupling transformer 805 is applied to the grid of the detector tube 808. Since positive battery 814 is applied to the anode of this tube immediately upon the operation of relay 816, the tube will be rendered conducting provided, however, that the energy entering transformer 805 exceeds a predetermined quantity, which is fixed by the high grid bias imposed upon the grid of the tube by negative battery 809 as already explained.

When relay 817 releases, it removes ground from conductors 802 and 703 which normally shunts to ground the pass-band filters of the five signal detectors shown in Fig. 7. This, however, is true only if tube 808 has not been rendered conducting in the meanwhile. For, if the intensity of the incoming signal is above a predetermined value and, as a result, tube 808 is rendered conducting, the anode current of this tube flowing through the lower winding of relay 817, causes this relay to remain operated over its lower winding to maintain the short-circuiting ground to the pass-band filters, thereby preventing the actuation of the signaling detectors in response to the energy transmitted through resistance pad 860.

Assuming that the energy which gets through transformer 805 is sufficiently high to render tube 808 conducting and, therefore, to keep relay 817 in an energized position, then, when the energy level subsides below the predetermined minimum value, the direct current voltage component across the combination of resistance 828 and condenser 829 will fall below such a value as to render tube 807 conducting, whereupon relay 815, whose lower winding is in the anode circuit of this tube, will operate and open the circuit of relay 816 by disconnecting anode battery 814, thereby causing relay 816 to release and tube 806 to reset.

The release of relay **816** now removes positive battery from the anode of tube **807** which is in series with the lower winding of relay **817**, thereby causing tubes **807** and **808** to restore.

Relays **815** and **816** are given fast operate and release characteristics by virtue of the biasing circuits through their respective upper windings and by virtue of the circuits through their respective lower windings which are in the anode circuits of tubes **806** and **807**, respectively. Gas-filled tubes discharge rapidly and quench rapidly thereby causing rapid rise and rapid decay of currents. The fast qualities of the circuit of relay **816** and of relay **815** insure that if a signal, say, of less than 25 milliseconds duration appears at the input of the delay detectors **800**, **810** and **820**, relays **817** ad **818** will not be permitted to release because relay **816** will quickly reclose battery **814** on them and prevent relays **817** and **818** from moving from normal so that short duration noises cannot get through to the detectors **710** to **750**.

It will be seen from the above that the purpose of operating the delay detectors in the order given is to prevent the operation of the signaling detectors **710** to **750** for an interval after the signal energy has penetrated the input side of resistance bridge **625** so as to avoid any possible operation of said signal detectors from transients which may be present in the initial portion of the incoming energy and thereby produce false number registration. A further purpose in operating the delay detectors in the order given is to prevent the operation of the signaling detectors by currents produced by extraneous noises. Both purposes are achieved by keeping the signaling detectors short-circuited by means of relay **817** which is released to remove the short circuit when a sampled portion of the energy has been analyzed through the delay detector **820** to operate relay **817** after an interval measured by the release times of relays **817** and **818**, and to maintain it energized if the sampled energy is within the noise level to cause the operation of tube **808** as above described.

When relay **818** operates it connects ground to conductor **831** which extends to the cathode of each of the five detector tubes of the detectors **710** to **750** to sensitize the same to the incoming signals. This means that the detectors become receptive to the incoming signals some 25 milliseconds after they have been applied to the line. The reason for this is to protect the detectors which are not responsive to the particular frequencies making up the signal from operating on the "spectrum" of frequencies produced by the sudden arrival of the applied signal frequencies.

When relay **817** releases and disconnects ground from conductor **802** to remove the short circuit from the five detector channels **710** to **750** thereby making these detectors receptive to the remainder of the incoming signal energy which passes through the resistance pad **660**, said energy now passes into two of the five signal detectors via conductor **703**, resistances **704** and **705** and conductor **706**.

It will be observed that the reed sending instrument **201** at the calling station is equipped with five reeds, each having a natural period which, when set into vibration in the magnetic field of the magnet by the depression of the appropriate numerical key, will produce an alternating current of a definite frequency. For convenience these frequencies have been designated *a*, *b*, *c*, *d*, and *e* and the construction of the sending instrument is such that the depression of each of the ten numerical keys will set two of the reeds into vibration so that the digit represented by the key depressed will be signalized by two currents of specific frequencies according to a code of which the following is an example:

Key depressed	Frequencies produced
1	*bd*
2	*ae*
3	*ad*
4	*ac*
5	*ab*
6	*de*
7	*cd*
8	*ce*
9	*bc*
0	*be*

The depression of any key, therefore, will generate two frequencies which are transmitted over the line into two of the five signaling detector channels **710** to **750**.

Each channel detector comprises a pass-band filter having an upper and lower cut-off frequency a little higher and a little lower, respectively, than the frequency for which the channel is tuned, a variable resistance pad for adjusting the sensitivity of each channel with respect to every other channel, and a detector coupled to the pad by a coupling transformer. The detector comprises a screen grid vacuum tube whose grid is connected to a terminal of the secondary winding of the coupling transformer, the other terminal of which is connected to a terminal of a tuned feedback network. The remaining terminal of each of the feedback networks is connected to conductor **708** which extends to the grounded positive side of filament battery **707** through resistance **709**. The plate of each tube in each of the conductors is connected serially with a thyrite element, with the winding of a relay and with the screen grid of the tube into a complete path. Thus if we consider channel **710**, for illustration, the tuned feedback network is designated **711**, the tube **712**, and the plate thereof is connected to thyrite element **713**, the other side of which is connected to conductor **715** which extends to one side of relay **902**. The other side of said relay is connected to conductor **716** which extends to the screen of tube **712** and to thyrite element **714** one terminal of which is grounded. Between the plate and the screen grid there is a bridged resistance **717** while from the plate on the left side of thyrite element **713**, a connection extends through resistance **724** and condenser **725** to the common joining point of rectifiers **722** and **723** of the tuned feedback network **711**.

In the same manner and through identical circuit networks, relay **903** is connected to channel **720**, relay **904** to channel **730**, relay **905** to channel **740** and relay **906** to channel **750**.

Now let it be assumed that channel **710** is receptive to frequency *a* which lies mid-way between the upper and lower frequency cut-off of its associated pass-band filter; channel **720** to frequency *b*; channel **730** to frequency *c*; channel **740** to frequency *d* and channel **750** to frequency *e* and that, further, each of the channels is adjusted through its associated variable resistance pad to a loss that makes the incoming signal in each channel the same. In order to describe how an incoming signal effects the operation of a signal relay in the anode circuit of a channel detector, let it be further assumed that the subscriber at station A depresses the key **2**

which is productive of frequencies *a* and *e* the former of which passes through channel 710 and the latter through channel 750. Confining our attention to channel 710, it will be observed that the grid of detector tube 712 has a normal negative bias to filament battery 707 over a path which extends through the secondary winding of transformer 733, resistance 718, conductor 708, negative potential drop across resistance 709 to ground due to current flow through itself via resistance 726, filament of detector tube 734, to the negative pole of the battery 707. However, while the grid is thus negatively biased, the value of this bias, due to the resistance of the bias path is such that current does flow through the cathode-anode circuit even though no signal is coming through the channel, which circuit may be traced from the positive pole of battery 727, resistance 729, conductor 716, winding of relay 902, conductor 715, thyrite element 713, the space current path between the anode and cathode of tube 712, conductor 835, to ground on the contacts of relay 816. This current, however, is insufficient to operate relay 902.

When the current of frequency *a* passes through the channel, it is amplified somewhat through the detector tube 712, and the positive component thereof is fed back from the anode circuit through resistance 724 and condenser 725 to the common juncture of rectifiers 722 and 723 whence it passes through rectifier 722 to set up a positive component through condenser 721 and inductance 719 to ground via conductor 708 and resistance 709 in shunt with by-pass condenser 732, charging condenser 721 in the meanwhile. This positive component now offsets the normal negative bias of the grid which, in being thus rendered less negative, causes an increase in the quantity of current to pass through the anode circuit. As a result of this increase in current, relay 902 operates to cause the registration of the *a* frequency component of the digit 2 as explained hereinafter. On the other hand, the negative component of the incoming signal causes current to circulate in the opposite direction to that of the positive component so that the current flow is now from ground through by-pass condenser 732, conductor 708, rectifier 723, condenser 725, resistance 724, through the space path in the tube 712, cathode of the tube, conductor 835 to ground through the contacts of relay 816. Thus the negative component of the incoming signal does not operate to increase the negative bias on the tube which, if it did, would have the effect of decreasing the current through the relay 902 and thereby produce a vibration thereof. Furthermore, during the passage of the negative component of the signal over the path above traced, condenser 721 which was charged during the passage of the positive component, discharges very slowly through high resistance 718 so as to maintain practically the same bias on the grid as was applied thereto during the time when the positive cycle of the signal was passing through the feedback network. This has the tendency of producing practically a steady state current through the anode circuit and therefore through the winding of relay 902.

Mention has been made of the fact that the feedback network 711 is a "tuned" feedback. The tuned portion comprises condenser 721 and inductance 719 and the electrical constants of these two elements are designed to short circuit the fundamental frequency present in the incoming series of positive components of incoming energy. If these frequencies were not short-circuited by the tuned network, the negative components thereof would otherwise appear and tend to cancel the effect of the positive half cycle of the energy applied to the grid in the manner above described.

In the same manner, the transmission of the current of frequency *e* through channel 750 causes operations identical with those described above which result in the operation of relay 906. Referring, now, to the table of frequencies in relation to keys depressed at device 201, it will be seen that the depression of the various keys and the production of the currents of the different frequencies enumerated will cause the operation of the relays 902 to 906 in the following order.

Key depressed	Frequencies produced	Relays operated
1	*bd*	903, 905
2	*ae*	902, 906
3	*ad*	902, 905
4	*ac*	902, 904
5	*ab*	902, 903
6	*de*	905, 906
7	*cd*	904, 905
8	*ce*	904, 906
9	*bc*	903, 904
0	*be*	903, 906

When the signal energy has completely come through, there will no longer be positive components of it to reduce the negative bias on the grid of the detector tubes and the current in the anode circuit thereof decreases to the value prevailing with the normal negative bias on the grid of the tube and relay 902 releases in consequence. Resistance 724 aids in causing the detector circuit and relay 902 to have a small operate to release ratio for the signal into the transformer 733.

Referring, now, to the operation of that part of the sender which responds to the operation of the frequency responding relays 902 to 906, inclusive, it will be recalled that when relay 1300 operated, conductor 1318 was joined to conductor 417 which was grounded by relay 403. The ground on conductor 1318 serves to control locking circuits to various relays of the sender, is connected to the armature contacts of the frequency responding relays 902 to 906 so as to make these relays effective when operating in response to incoming signals in the manner to be shortly described, to operate relays 907 to 911, inclusive, over the back contacts of the frequency responding relays through obvious circuits completed therethrough, and to cause the operation of relay 925 over a circuit which extends from battery through the winding of said relay, No. 4 back contacts of relay 927 to ground on conductor 1318. Relay 925, on operating, connects the winding of each of the relays 920 to 924, inclusive, to each of the front contacts, respectively, of relays 902 to 906, while the operation of relays 907 to 911 causes a circuit to be completed for relay 912 from battery through the winding of said relay serially through the bottom contacts of said relays 907 to 911 to ground on conductor 1318. Relay 912 operates and locks to ground on said conductor.

When two of the relays in the group of frequency responding relays 902 to 906 operate in response to the subscriber depressing one of the numerical keys and producing thereby the combination of two frequencies that results in the operation of any two relays in said group of frequency responding relays, the circuit of the corresponding relay in the group of relays 907 to 911 becomes opened and the relay releases in

consequence. If, for example, the key depressed happens to be that of the digit 2, relays 902 and 906 operate. Since relays 907 and 911 have their circuits closed over the respective back contacts of these relays, then when they operate, the circuits of relays 907 and 911 are opened and these relays release. The operation of relays 902 and 906, on the other hand, closes circuits which cause the registration of the digit 2 on the relays of register 900 which is reserved for the first or PBX digit. In the case of relay 902 a circuit is completed from ground on conductor 1318, front contacts of relay 902, No. 1 contacts of relay 925, winding of relay 920 to battery. Relay 920 operates and locks over its No. 2 contacts to ground on conductor 1318. Another circuit path is completed from ground on conductor 1318, front contacts of relays 906, No. 5 contacts of relay 925, winding of relay 924 to battery. Relay 924 operates and locks over its No. 2 contacts to ground on 1318.

The release of any of the relays in the group of relays 907 to 911 as, for example, relays 907 and 911, is effective in closing a circuit for relay 913 which extends from battery through the winding of said relay, No. 1 contacts of relay 915, back contacts of relay 911 or 907, top contacts of relay 912 to ground on conductor 1318. Relay 913 operates and extends ground on conductor 1318 to the lower winding of relay 915 via the top contacts of relays 912 and 913 and also the back contacts of relay 914, but relay 915 remains short-circuited by the same ground through its No. 1 contacts as above described. When the incoming signal has been completely transmitted and, as a consequence, the frequency responding relays 902 and 906 release, the previously described circuit paths for relays 907 and 911 are again closed through the back contacts of said relays 902 and 906, causing relays 907 and 911 to reoperate, whereupon the short circuit around the lower winding of relay 915 is removed and this relay now operates to battery in series with the winding of relay 913.

Relay 915 operates and, over its No. 4 contacts, completes a circuit extending from ground on conductor 1318, conductor 929, No. 1 back contacts of relay 1027, conductor 931, winding of relay 927 to battery. Relay 927 operates, locks over its No. 2 contacts to ground on conductor 1318 and, by breaking its No. 4 back contacts, opens the circuit of relay 925 which thereby releases. Upon closure of its No. 4 front contacts, relay 927 completes a circuit for relay 1025 over a path which extends from battery through the winding of said relay, No. 4 back contacts of relay 1027, conductor 1001, No. 4 front contacts of relay 927 to ground on conductor 1318. Relay 1025 operates and connects the front contacts of the five frequency responding relays 902 to 906 to the windings of relays 1020 to 1024, respectively.

Upon the operation of another or possibly the same set of two frequency responding relays, in response to the depression of another or the same key for the second digit at the sending device 201, two of the relays 902 and 906 will operate in the manner already described and, by their operation, cause the release of the associated respective relays in the group of relays 907 to 911 and, further, the operation of the two relays in the group 1020 to 1024 whose circuits are completed through the front contacts of the operated frequency responsive relays. Thus, if the second digit happens to be a "9" then, according to the above chart, relays 903 and 904 will be operated and relays 908 and 909 will be released. A circuit is now closed for relay 914 which extends from battery through the upper windings of relays 914 and 915, No. 2 contacts of relay 915, back contacts of relay 908 or 909, top contacts of relay 912, to ground on conductor 1318. Relay 914 operates, locks over its lower winding and contacts to ground on conductor 1318 via the lower contacts of relay 913 and the top contacts of relay 912 and, by breaking its upper contacts, opens the operating winding of relay 915 which will now hold over its locking circuit only so long as relays 909 and 908 remain unoperated, after which (when relays 903 and 904 release) it will release and restore to normal.

The operation of relay 903 closes a path from ground on conductor 1318, front contacts of relay 903, conductor 933, No. 2 contacts of relay 1025, winding of relay 1021 to battery. Relay 1021 operates and locks over its No. 2 contacts to ground applied to conductor 1323 over the No. 6 contacts of relay 1300. The operation of relay 904 closes a circuit extending from ground on conductor 1318, front contacts of relay 904, conductor 934, No. 3 contacts of relay 1025, winding of relay 1022 to battery. Relay 1022 operates and locks over its No. 2 contacts to ground on conductor 1323. In the operation of relays 1021 and 1022 of the register 1000 the digit 9, comprising the first digit of the office code, has been recorded in response to the operation of the two frequency responding relays 903 and 904. When these relays release at the termination of the incoming signal, relays 908 and 909 reoperate over previously described paths in consequence of which the holding circuits for relays 914 and 915 are opened whereupon said relays release, relay 915 closing a path for relay 1027 which extends from ground on conductor 1318, No. 3 contacts of said relay, conductor 932, No. 1 contacts of relay 927, conductor 1002, No. 1 back contacts of relay 1037, winding of relay 1027 to battery. This relay operates, locks over its No. 2 contacts to ground on conductor 1323, opens the circuit of relay 1025 at its No. 4 back contacts causing said relay to release and breaks the operating paths between the relays of register 1000 and the front contacts of the frequency responding relays 902 to 906 and, upon the closure of its No. 4 front contacts, closes a path for relay 1035 which extends from ground on conductor 1318, No. 4 front contacts of relay 927, conductor 1001, No. 4 front contacts of relay 1027, No. 4 back contacts of relay 1037, winding of relay 1035 to battery. Relay 1035 operates and connects the windings of a group of relays 1030 to 1034 of the register 1010 to the front contacts of the frequency responding relays 902 to 906. The relays of register 1010 are used to record the third digit of the wanted designation; that is to say, the second digit of the called office.

In the same way, as above described for registering the first and second digits, successive digits are registered on the succeeding registers 1010, 1060, 1070, 1100, 1110, 1160, 1170. It is not believed necessary to trace out illustrative current paths by which the relays in each register operate in response to the operation of the corresponding relays in the frequency responding relays 902 to 906 except to note the fact that as each digit is registered, relay 915 either operates or releases to operate a relay in the chain 927 to 1157 depending upon the register last used for recording a digit and so releasing the relay in the chain of 925 to 1155 of that register and

operating the corresponding relay of the next register.

Before continuing with the description of the further operation of the invention it is desirable to point out that the number of registers included in the sender is a function of the maximum number of digits that may be contained in a wanted designation. In the sender of the present embodiment of the invention, nine registers are utilized because the wanted designation may consist of nine digits to record which nine registers are necessary; namely, a register (900) for the PBX digit, three registers (1000, 1010 and 1060) for the ABC code of the office in which the called line is located; four registers (1070, 1100, 1110 and 1160) for the thousands, hundreds, tens and units designation of the line and one register (1170) for a station's digit. If the designation consists of less or more digits the number of registers may be reduced or increased accordingly.

Having registered the desired number, it now becomes necessary to selectively position the various selectors to reach the terminals of the wanted line identified by that number. In the present embodiment of the invention it is assumed that these selectors comprise step-by-step switches of the well-known Strowger type that, operating in response to a train of impulses, move to position the various brush shafts vertically to terminal levels from which, in the case of selectors, the brush shafts are automatically caused to hunt in a horizontal movement to select an idle line going in the wanted direction and from which, in the case of a connector, the brush shaft is actuated by a second train of impulses for selective positioning upon the terminals of the wanted line. Each digit registered in the sender, therefore, must be translated into a train of pulses which is transmitted over the line conductors 422 and 423 to position thereover the number of selectors required to establish a talking connection between the calling and called subscribers.

It will be recalled that when the sender became connected to the sender connector and thence to the PBX selector shown to the left of Fig. 5, relay 515 operated over a loop closed in the sender including the No. 2 normal contacts of relay 12' and that, as one result, relay 516 operated to ground the holding conductor 513. This condition prevails until the sender is ready to selectively position the PBX selector to whatever trunk level is indicated by the first digit dialed, which is done by causing the selector to be stepped up to the required level through the pulsing of relay 515 by impulses produced by the sender in accordance with the value of the first digit. To produce these impulses relays 1301, 1302 and 1303 are employed. These relays are polarized and, as long as ground is connected to the No. 4 contacts of relay 1300, pulse at the approximate rate of ten cycles per second, relay 1301 closing its contacts while relays 1302 and 1303 open theirs and vice versa. Relay 1301, with its network of condenser 1326 and resistances 1324, 1325 and 1327 cause the pulsing, relay 1302 acting upon the counting relays 1 to 12 and their prime relays 1' to 12' to count the cycles, while relay 1303 operates to open and close the loop for relay 515 by opening and closing the serial connection between conductors 415 and 416, joined over paths already traced, with the trunk conductors 423 and 422, respectively, to produce the pulses for activating relay 515.

When, upon the operation of relay 1300, ground is applied to conductor 1321, a circuit is established for momentarily operating relays 1301, 1302 and 1303, which circuit extends from ground on said conductor, No. 3 contacts of relay 1317, condenser 1326, No. 4 contacts of relay 1317, upper winding of relay 1301 and thence over one parallel path through the windings of relays 1302 and 1303, resistance 1325 to the other side of condenser 1326, and another parallel path through the No. 5 contacts of relay 1317, resistance 1327 to battery. All three relays operate and condenser 1326 is charged, but the relays are so poled that relays 1301 and 1303 close their contacts in the operation while relay 1302 opens its contacts. When relay 1301, in the act of operating, pulls its armature in the make direction, current flows continuously through its primary winding in a direction that tends to move the armature over to its make contact, but a current in an opposing direction and somewhat stronger effect flows through the secondary winding so that the armature does not move at once. The current through the secondary winding and the windings of relays 1302 and 1303, is, however, charging the condenser 1326 at the same time so that, after the condenser is charged, the current through the secondary winding ceases and the armature of relay 1301, in response to the effect of the current through the primary winding, is moved to make with its contact while the armature of relay 1302 breaks with its own. The operation of relay 1301 causes a reversal in the direction of current flow in both windings of relay 1301 and the armature hesitates again as the condenser 1326 discharges, and then breaks the front contact. Thus relay 1301 pulses back and forth and relays 1302 and 1303 with it, the former making and the latter breaking their respective contacts.

When the first digit has been registered in the relays of register 900 and relay 927 operates in consequence thereof, a circuit path is completed for relay 926 which extends from battery through the winding of said relay, No. 3 contacts of relay 927, No. 5 back contacts of relay 928, conductor 1214 to ground on the No. 1 contacts of relay 1226. Relay 926 operates and through its contact sets connects the relays of the first digit register 900 with the relays 1220 to 1224, inclusive and respectively, so that whatever relays were operated in the register 900 as the result of the depression of the first digit key at the subscriber station, corresponding relays will be operated in the group of relays 1220 to 1224. Thus, if the key depressed is 2 and, as a result, relays 920 and 924 are operated in accordance with the above-mentioned code, relay 920 will complete an operating circuit for relay 1220 which extends from ground on conductor 1318, No. 2 contacts of said relay, No. 1 contacts of relay 926, conductor 935, winding of relay 1220 to battery. Similarly, relay 924 closes a circuit for relay 1224 extending from ground on conductor 1318, No. 2 contacts of relay 924, No. 5 contacts of relay 926, conductor 936, winding of relay 1224 to battery. Relays 1220 and 1224 operate to perform functions noted hereinafter.

The operation of the relays in the group of relays 1220 to 1224, in accordance with the combination required by the code of the digit, results in the operation of one of the prime re-

lays 1' to 9' in accordance with the following code:

Key	Register relays operated	Pulse relays	Counting relays
1	921-923	1221-1223	9'
2	920-924	1220-1224	8'
3	920-923	1220-1223	7'
4	920-922	1220-1222	6'
5	920-921	1220-1221	5'
6	923-924	1223-1224	4'
7	922-923	1222-1224	3'
8	922-924	1222-1224	2'
9	921-922	1221-1222	1'
0	921-924	1221-1224	

The operation of relays 1220 and 1224 for the digit 2, for example and in accordance with the above table, causes a circuit to be completed for prime counting relay 8' extending from battery through the lower winding of relay 1225, No. 7 contacts of relay 1224, No. 5 contacts of relay 1220, winding of relay 8', bottom contacts of relay 9', No. 4 contacts of relay 10' to ground on conductor 1319 applied thereto over the No. 1 contacts of relay 1300. Relay 8' operates as well as relay 1225 which, over its upper contacts, locks to ground on conductor 1319 through the No. 2 contacts of relay 1226. With relay 8' operated, the sender is prepared to transmit pulses to the PBX selector in response to which the brush shaft of said selector will be raised a corresponding number of levels to the trunk route over which access is desired.

Returning, now, to the operation of the pulse-producing relays 1301, 1302 and 1303, the first closure of the contacts of relay 1302 completes a circuit extending from ground through the contacts of said relay, conductor 1328, normally made contacts of the No. 1 spring combination of relay 1204, No. 3 back contacts of relay 11', No. 3 back contacts of relay 10', bottom contacts of relay 1225, No. 1 back contacts of relay 12', winding of relay 12 to battery. Relay 12 operates and completes a short circuit around relay 12', which is thus held unoperated by ground on one side of its windings through its own No. 1 back contact and ground on the other side of its contact through the operated contacts of relay 12. When, however, relay 1302 breaks its contacts at the end of the pulse, the short circuit around relay 12' is removed and this relay now operates and holds in series with relay 12. Relay 12', on operating, disconnects the primary winding of dial tone transformer 628 from conductors 416 and 415 and connects these conductors together through the contacts of relay 1303 which, of course, are closed at this time, thereby maintaining the continuity of the loop circuit for relay 515 in the PBX selector.

On the next cycle of the pulse-producing relays, when relay 1303 breaks its contact, the loop around conductors 415 and 416 is opened, causing thereby the release of relay 515 in the selector which, in the manner to be described shortly, causes said selector to take as many steps as the number of times relay 1303 makes and breaks its contacts.

While relay 1303 breaks and makes its contacts to function the selector as above mentioned and as will be subsequently described, relay 1302 makes and breaks its contacts correspondingly to operate the pair of counting relays immediately following the prime counting relay which operated in series with relay 1225. Thus it will be remembered that for the digit 2, relay 8' was operated. Hence for this digit and upon the operation of relay 1302, a circuit path is completed for relay 9 which extends from ground on the contacts of relay 1302, conductor 1328 to the No. 1 armature of relay 12' as traced, front contact making with said armature, top back contacts of relay 9', top front contacts of relay 8', winding of relay 9 to battery. Relay 9 operates and completes a locking path over its contacts in series with the winding of relay 8' which is short-circuited at this time by ground on one side of its winding applied thereto over the No. 4 back contacts of relay 10' and ground on the other side of its winding extended thereto over the contacts of relay 9. When, at the end of the pulse, relay 1302 releases, this short circuit is removed, relay 9' then operates in the locking circuit of relay 9 and releases relay 8'. Upon the beginning of the second pulse, in the transmission of the pulses for the digit 2, the operated relay 9' closes the previously traced ground path through the winding of relay 10 which now operates and locks in the same way as did relay 9 and further holds relay 10' short-circuited until the end of the pulse, at which time relay 10' operates, locks in series with relay 10, opens the locking circuit of relays 9 and 9' at its No. 4 contacts thereby causing them to release, and further opens the locking circuit of relays 12 and 12' at its No. 1 contacts causing these relays to release also.

In the same way, different pairs of counting relay combinations are operated for the different digits. Thus, relays 10 and 10' operate if the first digit is 1, relays 9 and 9' if it is 2, relays 2 and 2' if it is 9, relays 1 and 1' if it is zero. If the first digit is anything but 1, successive cycles of the pulse-producing relays 1302 and 1303 send additional pulses to the selector, and, of course, relay 1302 causes the operation of successive pairs of counting relays until, with the last pulse to the selector, relays 10 and 10' operate. That is to say, the prime relay of the first pair of counting relays operated releases the prime relay which was operated in series with relay 1225, and the prime relay of each successive pair that operates releases the pair operated just prior to it so that, when the last pulse has been sent to the first selector, relays 10 and 10' are the only two counting relays left operated.

When relay 10' operates, relays 12 and 12' are unlocked the effect of which is to reconnect the primary winding of dial tone transformer 626 across conductors 415 and 416 thus holding the selector relay 515 operated and unresponsive to the further opening of these conductors at the contacts of relay 1303. A circuit is further completed for relay 1226 extending from ground on conductor 1319, No. 2 front contacts of relay 10', winding of relay 1226 to battery, causing this relay to operate and release relays 1225 and 926, the last, when it releases, breaking the connection between the operated relays of register 900 and the relays operated thereby in the group of relays 1220 to 1224, causing the relays in the last-mentioned group to release in consequence. Relay 1226, however, connects ground to its No. 3 contacts and closes thereby an obvious circuit for relay 1201 which operates and locks over its No. 3 contacts to ground on conductor 1319, at the same time causing relay 1202 to remain short-circuited by ground on one side of its winding through the No. 3 contacts of relay 1201 and on the other side of its winding

through its own back contacts to ground on the No. 3 contacts of relay 1226. Also, upon the operation of relay 1201, a circuit is completed for relay 928 extending from ground on conductor 1319, No. 2 contacts of relay 1201, conductor 1203, No. 1 back contacts of relay 1028, conductor 1003, winding of relay 928 to battery, causing said relay to operate and lock over its No. 2 contacts to ground on conductor 1318.

In the meanwhile, on the third cycle of the pulse-producing relays, the operation of relay 1302 connects ground to the No. 3 back contact of relay 11' over a path already traced, No. 3 front contact of relay 10' which is operated, No. 2 back contact of relay 4', top back contacts serially of all the prime relays from 9' to 1', inclusive, winding of relay 1 to battery. Relay 1 operates and locks to ground over the No. 2 contacts of relay 11' serially through the winding of relay 1', No. 2 front contacts of relay 1226 to ground on conductor 1319, which ground at the same time keeps relay 1' short-circuited until the end of the pulse when the removal of said ground causes relay 1' to operate and lock in series with relay 1. On the succeeding train of pulses, relay 1302 operates in succession relays 2 and 2', 3 and 3', 4 and 4' and 11 and 11' for the purpose of measuring a period of time during which the PBX selector, on having had its brushes vertically lifted to the desired trunk level, now causes these brushes to rotatively hunt over that level for an idle trunk. It will be observed that the locking circuit of counting relay pair 1 and 1' is controlled through the No. 2 contacts of relay 11'. On the next three cycles of the pulse-producing relays, counting relay pairs 2 and 2', 3 and 3' and 4 and 4' operate, each succeeding pair releasing the previous pair. On the next pulse cycle after the operation of relay 4 and 4', the ground on conductor 1328 is applied to the path which extends over the No. 2 contacts of relay 4', No. 2 contacts of relay 1', winding of relay 11 to battery, causing said relay to operate and lock in series with relay 11' to operating ground, relay 11' remaining short-circuited by ground on conductor 1319 being applied to the other side of its winding through the No. 2 normally made contacts of relay 1204. At the end of this pulse cycle, relay 11 operates and, in doing so, releases counting relay pairs 1 and 1', 4 and 4' and 10 and 10'. When relay 10' releases, the circuit of relay 1226 is opened, causing said relay to release which, in turn, removes the short circuit around the winding of relay 1202 which now operates and holds to ground over the No. 3 contacts of relay 1201 to ground on conductor 1319.

On the next pulse cycle, the closure of the contacts of relay 1302 completes a circuit for relay 1204 extending from battery through the winding of said relay, No. 3 contacts of relay 11', No. 1 normally made contacts of relay 1204, conductor 1328 to ground on the contacts of relay 1302, causing said relay to operate and lock to ground on said conductor over its No. 1 operated contacts. The operation of relay 1204 releases counting relays 11 and 11' and, when the contacts of relay 1302 open, relay 1204 releases, thereby completing the functioning of the interrupter for the transmission of the series of pulses that correspond to the first digit including the delay interval measured by operating counting relay pairs 1 and 1', 2 and 2', 3 and 3', 4 and 4' and 11 and 11' to allow for trunk hunting.

With the operation of relay 928 as above described a path is closed for relay 1026 which extends from battery through the winding of said relay, No. 3 contacts of relay 1027, No. 4 back contacts of relay 1028, conductor 1004, No. 4 front contacts of relay 928, conductor 1214 to ground on the No. 1 contacts of relay 1226. Relay 1026, in operating, connects the No. 2 contacts of the relays of the second register 1000 with the windings of relays 1220 to 1224. The two relays in the register 1000 which were operated in response to the transmission of the second digit have their No. 2 contacts closed to ground on conductor 1318 and these now apply ground over the contacts of relay 1026 to the winding of corresponding relays in the group of relays 1220 to 1224 causing them to operate in the same manner as previously described for the relays of register 900.

The operation of a pair of relays in the group of relays 1220 to 1224 causes, as in the case of the first digit, the operation of the particular prime relay as determined by the above table, the consequent transmission of a group of impulses determined by the relay combination operated thereafter to move the brushes of the next selector which, in this case, would be the first or A selector of the office code, to the level determined by the number of impulses in the group, and the measurement of an interval after the impulses are transmitted to permit the selector sufficient time to hunt for an idle path in the level chosen. The operations involved are the same as those already described for the first or PBX digit except that, at the end when the operation of relay 1226 causes the release of relay 1201 which is locked up in series with relay 1202 to ground on conductor 1319, the ground applied to resistance 1205 has the effect of causing relay 1202 to hold locally to this ground over the No. 3 normal contacts of relay 1201. When relay 1226 releases, in response to the release of relay 10', relay 1202 releases also. The release of relay 1201 completes an operating path for relay 1028 extending from battery through the winding of said relay, No. 1 back contacts of relay 1038, conductor 1006, No. 2 contacts of relay 928, conductor 1005, No. 1 contacts of relay 1201 to ground on conductor 1319. Relay 1028 operates and locks over its No. 3 contacts to off-nomal ground on conductor 1318. The release of relay 1226, on the other hand, closes an operating path for relay 1036 extending from battery through the winding of relay 1036, No. 3 contacts of relay 1037, No. 4 back contacts of relay 1038, No. 4 front contacts of relay 1028, conductor 1004, No. 5 front contacts of relay 928, conductor 1214 to ground at the No. 1 contacts of relay 1226. This process continues, relay 1201 operating on one digit and releasing on the next to cut in the relays of the various registers to the group of relays 1220 to 1224 and the impulses corresponding to the digits are sent out in succession, each one following the preceding one as soon as a selector hunting time has been measured as described above.

The signal which is given to the trunk that the sender has completed its pulsing functions so that the trunk may close through the subscriber's line to the selector train is given by the connection of ground to conductor 420 which is connected over the No. 7 contacts of relay 405 to the winding of relay 408. Since the connection may be completed in a number of ways, depending upon the character of the switching

train and the destination of the call, such a ground is controlled by the transmission into the sender of a certain predetermined digit or number of digits which tells the sender the number of digits that it will need for pulsing operations to establish the connection. In the present embodiment of the invention it is assumed that the subscriber's station A is located in a PBX exchange from the terminal banks of whose selector access may be had, for instance, to a distant central automatic office, or to another line in the same PBX exchange, or to an operator at said PBX exchange or to another PBX exchange altogether. These various outlets are located on the different levels of the PBX selector which are ordinarily reached by dialing a digit corresponding to the wanted level and the selector is directly responsive to the impulses produced by the dial in reaching that level, after which other selectors in the train are similarly responsive to the impulses of the digits that follow in being directly set upon desired outlets including the terminals of the wanted subscriber's line. In my invention, the selectors are directively set by the sender which thus must know how many trains of pulses must be transmitted to reach a wanted line whose location, of course, may be on one of the outlets of the PBX selector or on one of the outlets of a final connector, reached from one of the PBX outlet levels by a train of intervening selectors each of which requires a train of pulses for directive setting. Hence the first PBX digit, designating a corresponding outlet level in the PBX selector, informs the sender of the total number of selectors required to reach the wanted line and, therefore, the time when the line can be cut through by the operation of relay **408**. Thus, if the trunks for the automatic exchange through which the called line B can be reached are located on the ninth trunk level of the PBX selector, the registration of the digit 9 in register **900** indicates that a maximum of nine digits may be recorded in the sender for which a corresponding number of trains of impulses will have to be transmitted before the sender can close the circuit of relay **408** by grounding conductor **420**. On the other hand, if the first digit is a 7 it indicates a long distance call for which no more digits will be necessary inasmuch as the trunks direct to the long distance office come off the seventh level of the PBX selector. Similarly if the first digit is a 2, 3, 5 or 6 it indicates a four-digit call in the home private branch exchange for which the remaining three digits are used to directively position the first and second selectors and the connector at said private branch exchange so that ground to conductor **420** is not applied until four trains of impulses are transmitted in response to four digits received. Yet again if the first digit is an 8 it indicates a call for divers other private branch exchanges, the discrimination between which is made by the second and third digit following the digit 8.

To provide for these different call classes, one arrangement is to cause the connection of ground to conductor **420** to be controlled by relays **938**, **916**, **917**, **918** and **919** in combination with the various relays of the registers involved. Thus, if the first digit dialed is 9, indicating thereby that the call is to be completed through an automatic central office, relays **921** and **922** will have been operated in register **900** and, accordingly, a path is closed for relay **938** extending from battery through the winding of said relay, No. 3 contacts of relay **922**, No. 1 contacts of relay **921** to ground; if the first digit is 8, relays **922** and **924** will have been operated in register **900** and an operating path is completed from relay **916** extending from battery through the winding of such relay, No. 3 contacts of relay **924**, No. 1 contacts of relay **922** to ground; if the third digit is a zero, relays **1031** and **1034** will have been operated in register **1010** and an operating path is completed for relay **917** which extends from battery through the winding of said relay, conductor **941**, No. 4 contacts of relay **1031**, No. 1 contacts of relay **1034** to ground; if the third digit happens to be a 2, relays **1030** and **1034** will have been operated in register **1010** and an operating path is completed for relay **918** extending from battery through the winding of said relay, conductor **942**, No. 3 contacts of relay **1030**, No. 1 contacts of relay **1034** to ground; finally, if the third digit happens to be a 5, relays **1030** and **1031** are operated in register **1010** and an operating path is completed for relay **919** extending from battery through the winding of said relay, conductor **943**, No. 3 contacts of relay **1031**, No. 1 contacts of relay **1030** to ground. It is obvious, of course, that the control of ground on conductor **420** may be varied to suit different conditions by circuit expedients similar to those just indicated. The following table shows one arrangement based upon 1, 2, 3 to 9 digit calls for which one of the relays **938**, **916**, **917**, **918** and **919** are operated.

First digit	Second digit	Third digit	Total digits for the call	Character of call	Relay operated
2	----------	----------	4	Local PBX	None.
3	----------	----------	4	do	Do.
5	----------	----------	4	do	Do.
6	----------	----------	4	do	Do.
4	----------	----------	1	Vacant level	Do.
7	----------	----------	1	Long distance	938.
8	0	----------	2	Operator at PBX (1)	916.
8	1	0	3	Operator at PBX (2)	916, 917.
8	1	2, 3, 4	6	Subscriber at PBX (2)	916, 917.
8	2	----------	2	Manual PBX 3	916.
8	3	----------	2	Manual PBX 4	916.
8	4	----------	2	Manual PBX 5	916.
8	5	0	3	Operator at PBX 6	916.
8	5	2, 3, 5	6	Subscriber at PBX 6	916, 918, 919.
8	6	0	3	Operator at PBX 7	916.
8	6	2, 3, 4, 5	5	Subscriber at PBX 7	916, 918, 919.
8	7	0	3	Operator at PBX 8	916.
8	7	2, 3	6	Subscriber at PBX 8	916, 918.
8	8	0	3	Operator at PBX 9	916.
8	8	2, 3, 4	5	Subscriber at PBX 9	916, 918.
8	9	----------	2	Manual PBX 10	916.
9	----------	----------	9	Automatic central office	938.

It is not believed necessary to trace out all the circuits involved for the different classes of calls by which ground is connected to conductor 420 except to give an illustrative example with a call for the central office for which the first digit is 9 and relay 938 is operated.

It will be observed that if relay 938 operates, the lead extending from conductor 420 to the No. 2 back contacts of said relay is broken, whereupon ground is connected to said conductor only upon the operation of the chain of relays 1304 to 1307, inclusive. These relays operate when all digits except station digits have been pulsed over the train of selectors and measure off time to determine whether, if the call is completed through a central office, the subscriber's number will or will not contain a ninth digit to designate a station. Most connections which are completed via the originating private branch exchange and the central office through which the connection will clear, will necessitate only eight digits; namely, the initial digit 9, three other digits for the office code registered on registers 1000, 1010 and 1060, and four digits for the thousands, hundreds, tens and units designation of the called subscriber's number. Calls to manual offices for numbers over 10,000, or for party lines with station letters, require an additional digit for station designation and there is no way of determining whether eight or nine digits will be keyed when the first digit is a 9. Hence when the trains of pulses corresponding to eight digits have been transmitted, a period of two or three seconds will be measured by the operation of relays 1304 to 1307, inclusive. If a ninth digit has not been received by the time relay 1307 operates as described hereinafter, ground will be connected to conductor 420 over a serial path extending from ground on the top contacts of relay 1304, top contacts of relays 1305, 1306 and 1307 to operate relay 408. In other words, the signal to the trunk will not be given to connect the subscriber's line through to the selector train until, in response to the first digit 9 which indicates to the sender that the call is an eight or a nine-digit call that is to be completed through a central office, said signal will not be transmitted to the trunk until the sender has completely and selectively operated the selector train through the pulse trains determined by the digit keys. If the first digit happens to be an 8, thereby indicating a local or distant private branch exchange call, the sender will have no other function beyond that of selectively positioning the switches to reach the private branch exchange and the number of such switches will be indicated by the character of the second or second and third digits. In this manner ground on conductor 420 is applied when one, two, three, four, five, six or nine digits have been sent, as the case may require, and, with the exception of a call whose first digit is 4 or 7, said ground is controlled by one or more of relays 936, 916, 917, 918 and 919 in combination with one of the operated relays 926, 1026, 1136, etc. subsequent to the transmission of the last train of pulses for the last digit of the call.

The result of grounding conductor 420 is to operate relay 408, which connects the line through in the manner shortly to be described and breaks all connections to the sender. When relay 408 operates, relays 401 and 403 release, in turn releasing relay 402 followed by the release of relay 404 and that of relay 405. The release of relay 405 disconnects ground from conductor 414, causing the release of relay 1300. Upon the release of said relay, a self-interrupting circuit is furnished for the off-normal stepping magnet 1310 of switch 1330 extending from ground on the No. 2 back contacts of relay 1300, brush 1311 and commoned terminals to interrupter contacts and winding of magnet 1310 to battery. This magnet operates on self-interruptions and drives the brushes of the switch to normal. The release of relay 1300 disconnects ground from all off-normal conductors thereby restoring to normal all the relays in the sender which have been locked thereto.

In case of a faulty manipulation of the key-set 201 at the substation and, as a result, three or more reeds are plucked for any one digit, the three corresponding relays in the group of relays 902 to 906 will, of course, operate causing, in turn, the registration of such false operation in the appropriate register concerned. However, when the pulses corresponding to the digit supposed to have been recorded in this register are to be transmitted, three instead of two relays in the group of relays 1220 to 1224 will be operated from said register as above described, in which event a circuit is completed for relay 1200 extending from battery through the winding of said relay, the No. 4 or 3 contacts of any two relays in the group of relays 1200 to 1224 which operate for any particular digit plus any other relay, to ground. For instance, the false operation of relays 1222, 1223 and 1224 will complete the path for said relay over the No. 3 contacts of relay 1224, the No. 2 contacts of relay 1223, the No. 1 contacts of relay 1222 to ground on conductor 1319, causing said relay to operate and lock over its No. 3 contacts to ground on conductor 1319. Relay 1200 closes its No. 6 and No. 7 contact sets, the former closing a path over conductors 1206 and 1207 through the amplifier 631 and condensers 633 and 634 to the fourth arm of the bridge 615 and thence over the subscriber's loop as already traced and the latter serially connecting together the two primary windings of transformer 632 over conductors 1208 and 1209. The other two terminals of the primary windings of this transformer are connected to a source of "reorder" tone 629 and the alternating current generated thereby, which is above the voice frequency range, is induced through the secondary windings of transformer 632, amplified through a suitable amplifier 631 and transmitted over the line loop to the station where it is heard by the subscriber and understood by him as an instruction to restore the handset to its cradle and initiate the call over again. Over its No. 4 contacts relay 1200 short circuits conductors 415 and 416 to prevent the transmission of pulses to the selector and, over its No. 5 contacts, it opens the conductor to the "stuck sender" register 1316 to prevent the registration of a stuck sender condition as will be shortly described. If the handset, in response to the reorder tone, is not restored promptly, the timing circuit 1330 may be easily adapted by well-known means to extend the line to the succeeding sender connector and the sender dismissed.

If the substation switchhook is falsely depressed while the sender is engaged, it will cause a surge on the line which is apt to operate several or all of the channel responding relays 902 to 906. If this should occur as the result of a fumbling action in removing the handset from the switchhook, the sender will overlook this entirely because if, at any time the switchhook is

depressed for too short a time to release the sender, relay 403 will release and remove ground from conductor 417. This conductor is joined to conductor 1318 which extends to the armature of the channel responding relays over the No. 7 contacts of relay 1308 to which, of course, ground is applied. Now if the first digit has not yet been recorded when the fumbling of the switchhook occurs, the operation of relays of any of the channel responding relays 902 to 906 consequent to the surge resulting therefrom will not cause a registration inasmuch as ground will not be connected to their armatures by virtue of the release of relay 403. If the first digit has been recorded and the pulses corresponding to it for the PBX selector have been transmitted and, in consequence, relay 928 is operated, no further protection is provided against fumbling because ground on the No. 1 contact of this relay is connected to conductor 1318, thereby maintaining ground to the armatures of the channel responding relays notwithstanding the removal of ground by the release of relay 403.

Relay 403 is made slow-operate by the connection of rectifiers 409 and 422 in shunt of both its windings so as to prevent the relay, on the reclosure of the loop after switchhook fumbling, from operating too quickly to reapply ground to conductor 427 and thence to conductor 1318 before the surge is terminated.

If a sender is held beyond a reasonable time because the subscriber keys no digits or an insufficient number of digits, or because some reed signal is given as a single tone instead of two tones, or because of trouble in any of the circuits of the sender, a tone will be transmitted to the subscriber station for an interval of time, and if at the end of this interval the receiver is not restored, conductor 420 will be grounded to cut the line through to the PBX selector, where, as is well known, the usual alarms will be given and the sender will be dismissed. In order to accomplish these functions, switch 1330 is used to measure the holding time of the sender and to control circuits to cause its dismissal under the conditions assumed. When the brushes of this switch step off their respective normal terminals as the result of magnet 1310 taking its first step and interrupter 1320 makes its first conducting segment after relay 1300 has operated, an obvious circuit is closed for relay 1308 over the brush 1315. Relay 1308 operates and locks to off-normal ground on conductor 1321 over its No. 3 contacts and connects ground over its No. 1 and No. 2 contacts to conductors 1331 and 1332, respectively. At the same time, over its No. 4 contacts, it closes a partial path for relay 1309, which relay operates only when the switch has taken ten steps and brush 1316 connects with the tenth terminal of its cooperating arc. This occurs when the sender has been held approximately twenty-one seconds, at which time relay 1309 operates and connects ground over its No. 2 contacts to conductor 920 which, over the No. 2 back contacts of relay 938 connects with conductor 420 that traces back to the winding of relay 408, causing said relay to operate, cut the line through to the PBX selector and dismiss the sender as already described. On any call not through the central office which means that relay 938 is normal, conductors 1331 and 1332 will be joined over the No. 5 front contacts of relay 938 to the filter circuit to send a tone to the station when relay 1308 operates. On a call through the central office, relay 938 being operated, ground will be connected to the filter circuit when relay 1309 operates and to conductor 420 ten seconds after that. At the same time tone is started over brush 4 of the switch and operates the stuck sender register 1316.

Returning now to the operation of the various selectors in response to the pulse trains produced by the sender in the manner already described, it will be recalled that conductors 422 and 423 are looped in the sender through the No. 2 front contacts of relay 12' and the front contact of the pulsing relay 1303, in consequence of which relay 515 of the PBX selector operates, in turn operating relay 516 as already noted. Relay 516 connects ground through its No. 1 contacts to conductor 513 to hold the line-finder switch and the cut-off relay 303 in operated positions.

When relay 1303 opens and closes the loop of relay 515 in producing the pulses corresponding to the first digit recorded in register 900 and later stored in the group of relays 1220 to 1224, relay 515 is alternately released and reoperated as many times as relay 1303 releases and reoperates prior to the reclosure of the loop by the release of relay 12'.

The first release of relay 515 closes a circuit from battery through the winding of the vertical stepping magnet 526, winding of relay 525, No. 2 front contacts of relay 516, back contacts of relay 515, No. 4 back contacts of relay 514 to ground. The current in this circuit operates magnet 526 and relay 525, the former stepping the shaft (not shown) and brushes of selector PBX up to the first level of the terminal bank. The reoperation of relay 515 opens the above-traced circuit through the windings of magnet 526 and relay 525, but these windings are held energized through the No. 2 contacts of relay 525 and contacts 530, actuated by the movement of the vertical holding pawl 532 of double dog 531 while the shaft and brushes are being elevated, and through the back contact of release magnet 529, conductor 518 to ground on the No. 4 contacts of relay 514. By holding the magnet 526 operated while the shaft is moving between levels, the vertical driving pawl (not shown) is held in engagement with the vertical ratchet to prevent the shaft from being carried up by its momentum more than one step in response to one impulse. When the holding pawl 532 engages the ratchet to hold the shaft in its first vertical off-normal position, contacts 530 are opened and the magnet 526 releases. Relay 516 is slow in releasing and remains operated during the receiving of the impulses by relay 515. Relay 525 is also slow in releasing and remains operated until all of the impulses, corresponding to the first digit, have been received. Each succeeding release and reoperation of relay 515 is effective in a similar manner to advance the shaft and brushes of the PBX switch one step, overstepping being prevented by the closing of contacts 530 while each vertical step is being taken.

As soon as the shaft is moved out of its normal position, the vertical off-normal springs VON 528 are actuated thereby disconnecting the battery potential through resistance 527 from the test conductor 513. Were the PBX selector an intermediate selector instead of the first selector in the train, the disconnection of this battery potential from conductor 513 would render the selector non-selectable, by a preceding selector,

for use on another call. The actuation of the vertical off-normal springs VON 528 also closes a circuit for operating relay 521, which circuit extends from battery through resistance 518, normally made contacts of the rotary stepping magnet 526, winding of relay 521, Nos. 4 and 5 contacts of the "10th rotary step" springs 524, Nos. 3 and 4 contacts of the vertical off-normal springs 528, conductor 518 to ground through the No. 4 contacts of relay 514. The release of relay 525, after the last impulse in the train of impulses for the first digit has been received, closes a circuit for operating the rotary stepping magnet 526; this circuit extending from battery through the winding of magnet 526, No. 1 contacts of relay 521, No. 1 contacts of relay 525, front contact of relay 515 to ground through the No. 4 contacts of relay 514. The operation of magnet 526 rotates the brushes 541, 542 and 543 into engagement with the first set of terminals in the level of the bank selected in response to the number of impulses transmitted by the sender as above described. The operation of magnet 526 also opens the operating circuit for relay 521 and connects the winding of relay 521 in series with the lower winding of relay 514 to the test brush 543. If the terminal with which test brush 543 is in contact is not connected to an idle-indicating potential, either because the test conductor of the trunk is open or because the switch to which the trunk connects is off-normal or in use, relay 521 releases thereby causing the release of magnet 526. The release of magnet 526 disconnects the winding of relay 521 from the test brush 543 and again closes the operating circuit of relay 521. The reoperation of relay 521 causes the reoperation of magnet 526 thereby advancing the brushes of the private branch exchange selector PBX to the next set of terminals in the selected level. Relay 521 and magnet 526 continue their cycle of operations until brush 543 encounters a test terminal which is connected to the idle-indicating potential, or until the tenth and last set of terminals in the level is reached, at which time the actuation of the "10th rotary step" springs 524 prevents the reoperation of relay 521. These operations take place during the interval when the sender, between the first train of impulses and the second, measures off time to allow for trunk hunting by the operation of counting relay pairs 1 and 1', 2 and 2', 3 and 3', 4 and 4' and 11 and 11' and relay 1204 as already described. If the switch is rotated to the 10th rotary position and the test terminal of the tenth set of terminals is not connected to the idle-indicating potential when brush 543 engages this terminal, the busy tone source 523 is connected through Nos. 1 and 3 contacts of springs 524, the upper winding of relay 515, the No. 1 back contacts of relay 514, thence as already traced to the primary winding of transformer 528. If a portion of the interval measured by the sender for trunk hunting between trains of impulses is available, relay 12' will be down and the busy tone will induce a current in the secondary winding of said transformer that will activate the amplifier detector 513 to operate relay 508 as already described, whereupon the dial tone circuit is activated in the manner already described to transmit tone to the subscriber. The interval, however, will not be long enough for him to appreciate its significance and if, in consequence, he maintains the connection, the sender will continue to transmit the remaining train of pulses which, however, will result only in an ineffective pulsing of relay 515. When the sender causes the operation of relay 408, the line loop is closed through in the manner described hereinafter so that the relay 515 is held over the right windings of transformer 431 and the busy tone is induced into the left winding which includes the line loop and the station instrument through which the subscriber hears it, restores and then endeavors to reestablish the connection.

When the test brush 543 encounters a terminal which is connected to the idle-indicating potential, relay 521 is held operated and the lower winding of relay 514 is energized over the circuit already traced. Assuming the call to be a three-digit call, that is, for a subscriber B located within the same private branch exchange, the terminal level to which the brushes 541, 542 and 543 have been raised gives access to a group of connectors, and the particular terminals to which these brushes have become connected have their conductors extending to an idle connector C which is to be selectively positioned by the two trains of impulses that are produced by the sender in response to the registration of the second and third digit of the wanted designation. The circuit for holding relay 521 operated, to prevent further advance of the brushes of the private branch exchange switch PBX is, then, traced from battery through resistance 575, Nos. 6 and 7 contacts of the vertical off-normal springs VON 568, conductor 557, through the test terminal and brush 543, lower winding of relay 514, front contacts of magnet 526, winding and No. 2 contacts of relay 521, Nos. 3 and 4 contacts of the vertical off-normal springs 528, over conductor 518 to ground through the No. 4 contacts of relay 514. Relay 514 is sufficiently energized by the current through its lower winding to close its No. 3 contacts and thus cause the complete operation of this relay by energizing its upper winding. If the brush of more than one hunting selector should engage terminals connected to the same connector, the drop in potential, due to the resistance through which the idle-indicating battery potential is connected to the test terminals, prevents the operation of the test relay in any of these selectors, thereby preventing a double connection. Should the test conductor connected to any set of terminals to which the brushes of the PBX switch are advanced be open, relay 514 would not be operated and the release of relay 521 would cause the advance of the switch to the next set of terminals. With relay 514 operated, a temporary busy indicating ground potential is connected from the No. 1 contacts of relay 516, over conductor 513, through the No. 2 front contacts of relay 514 and brush 542 to the test terminal of the seized connector. The operation of relay 514 also causes the release of relays 521, 515 and 516 and the release of magnet 526. Conductors 422 and 423 are now connected through brushes 542 and 541, respectively, to the windings of line relay 559 of connector C. Relay 559 operates over the sender loop thereby causing the operation of relay 560. Relay 560 connects a busy-indicating and holding ground potential through its No. 1 contacts over conductor 557 to the test terminal with which brush 543 of the private branch exchange selector PBX is in contact to hold relay 514 operated. This holding potential is further extended through the No. 3 contacts of relay 514 to hold the relay locked and to brush 323 of the

line finder LF to hold operated the cut-off relay 303 of line A.

The next train of pulses transmitted by the sender will be that corresponding to the second digit of the wanted designation and relay 559 is alternately released and reoperated in response to each of these impulses. The first release of relay 559 closes a circuit from ground at its top back contact, No. 2 front contacts of relay 560, Nos. 5 and 3 contacts of the vertical off-normal springs VON 568, through the winding of relay 564, winding of the vertical stepping magnet 565 to battery. Relay 564 and magnet 565 both operate, the operation of the latter being effective to step the shaft (not shown) and brushes of the connector switch C up to the first level of the terminal bank. The vertical off-normal springs VON 568 are actuated as soon as the shaft is moved out of normal position, the circuit for operating magnet 565 and relay 564 being thereby changed to include the No. 4 front contacts of relay 564 and the Nos. 4 and 5 contacts of the vertical off-normal springs VON 568. The actuation of the vertical off-normal springs VON 568 also disconnects the idle-indicating battery potential from test conductor 557 to prevent seizure of the connector C by any other hunting PBX selector until after the switch C has been restored to normal. The reoperation of relay 559 at the end of the first impulse of the train causes the release of magnet 565 unless the first impulse is not sufficiently long to insure proper switch operation, in which case the magnet 565 and relay 564 are held operated by the current in a circuit traced through No. 1 front contacts of relay 564, Nos. 4 and 5 contacts of the vertical off-normal springs VON 568, No. 2 front contacts of relay 560, No. 2 front contacts of relay 564, contacts 570 closed by the actuation of the double dog 571 while the shaft is moving between normal and the first level, to ground at the back contact of release magnet 567. Each succeeding release and reoperation of relay 559 in response to the impulses transmitted by the sender, causes the operation and release of magnet 565, the brushes 581, 582 and 583 being stepped up to the corresponding level of the terminal bank. The closing of the contacts 570 by the actuation of the double dog 571, while the shaft is being stepped from each terminal level to the next, maintains the energization of magnet 565 in response to each release of relay 559 for a sufficient length of time to prevent overstepping. Relay 568 is slow in releasing and remains operated during the receipt of the sender impulses by relay 559. Relay 564 is also slow in releasing and does not release until all of the impulses of the train have been received by relay 559.

During the interval between the second and third train of pulses during which the sender measures off time to allow for selector trunk hunting, nothing occurs in the connector, relay 559 being held alternately over the loop and through the primary winding of the dial tone detecting transformer 628 in the same manner that relay 515 was held. When the hunting time interval is over and the sender transmits the last pulse train corresponding to the third and last digit of the number, relay 559 again alternately releases and reoperates by virtue of each of the impulses in the train. The release of relay 559, in response to the first of these impulses, closes circuits for operating relay 563 and the rotary stepping magnet 569; these circuits being traced from ground at the back contact of relay 559, No. 2 front contacts of relay 560, Nos. 4 and 5 contacts of the vertical off-normal springs VON 568, No. 1 back contacts of relay 564, No. 3 contacts of relay 562, thence through the winding of relay 563 to battery, and, through the No. 4 contacts of relay 553, winding of magnet 569 to battery. The operation of magnet 569 steps the brushes 581, 582 and 583 into engagement with the first set of terminals in the selected level. The operation of relay 563 connects the winding of relay 562 in series with the No. 6 contacts of relay 553, through the No. 1 front contacts of relay 563 to the test brush 583. The reoperation of relay 559 at the end of the first impulse open the operating circuit for magnet 569, but this magnet is held operated while the shaft is moving from one rotary position to the next by the closing of a holding circuit through contacts 570 due to the actuation by the double dog 571; this holding circuit being traced from ground at the back contact of release magnet 567, through contacts 570, No. 3 contacts of relay 563, to the No. 2 front contacts of relay 560, and thence to the windings of relay 563 and magnet 569 as hereinbefore described. The continued operation of magnet 569 by the circuit through contacts 570 insures against rotary overstepping. Relay 563 is slow in releasing and remains operated until all of the impulses corresponding to the last digit of the called number have been received by relay 559. Since the No. 2 front contacts of relay 563 are in parallel with the No. 3 contacts of relay 562, a temporary operation of test relay 562, upon passing over a busy terminal, does not interfere with the operation of magnet 569 in response to succeeding impulses received by relay 559. Each release and reoperation of relay 559 is, therefore, effective in causing the operation and release of magnet 569 and thus advance the brushes of the connector into engagement with the set of terminals to which the called line is connected.

When the pulse train is transmitted, relay 408 is operated from the sender by the application of ground to conductor 420 as already described. Relay 408, in operating, extends the line conductor 351 over the No. 3 front contacts of said relay, No. 1 back contacts of relay 410, upper left winding of transformer 441, upper winding of relay 411, right filament of ballast lamp 431 to ground. The line conductor 352 is extended over the No. 4 front contacts of relay 408, No. 2 back contacts of relay 410, left lower winding of transformer 441, lower winding of relay 411, left filament of lamp 431, to battery. Relay 411 operates to perform functions noted hereinafter. Over its No. 1 contacts, relay 408 further applies ground to the armature of relay 413 to complete a circuit to the winding of relay 410. Relay 413, however, is operated at this time by ground on the holding conductor 513 as already described so that the circuit for relay 410 is not closed. Over its No. 2 and No. 5 contacts relay 408 connects the right windings of transformer 441 to conductors 423 and 422, while over its No. 6 contacts it locks itself into ground on the holding conductor 513.

If the wanted line B to whose terminals brushes 581, 582 and 583 are connected is busy, test relay 562 is operated due to the energization of its winding when brush 583 comes to rest on the grounded (not shown) test terminal of the line. When relay 563 releases, relay 562 is held operated through the No. 6 contacts of relay 553, No. 1 normally made contacts of relay 563, the No. 2 front contacts of relay 562 over conductor 557 to

ground at relay 560, and a busy tone is thereupon transmitted from tone source 574 through the No. 1 contacts of relay 562 through the lower condenser 558 to the calling subscriber. If the called line is idle, test relay 562 does not operate and when relay 563 releases, a circuit is closed from ground through the No. 1 contact of relay 560, conductor 557, No. 2 back contacts of relay 562, upper winding of relay 553, No. 1 back contacts of relay 563, brush 583 and test terminal, and through the winding of the cut-off relay (not shown) of the called line to battery. Relay 553 is sufficiently energized by the current through its upper winding to close its No. 5 contacts and thus cause the complete operation of this relay by the energization of its lower winding. Relay 553 closes the ringing circuit from the generator 552, No. 2 contacts of relay 553, lower winding and No. 4 back contacts of relay 551, No. 8 contacts of relay 553, brush 582, over the lower conductor of the called line through the ringer at station B, back over the other conductor of line B, the brush 581, No. 1 contact of relay 553 to ground at the No. 1 back contacts of relay 551. Ringing tone is transmitted through condenser 555 to the calling station.

When the receiver is removed at station B, relay 551 is sufficiently energized by the current through its lower winding to close its No. 2 contacts and thus cause the complete operation of this relay due to the energization of its upper winding. Relay 551 completes the talking connection through its Nos. 1 and 4 front contacts and through condensers 550, talking current being supplied to the called station through the windings of relay 558. The operation of relay 558 while the line is closed at station B interchanges the connection between the calling line and the windings of relay 559, the resulting reversal of current being useful for supervision.

When the calling subscriber at station A replaces the receiver on the receiver hook, relay 559 releases followed by the release of relay 560. The release of relay 559 causes a momentary operation of relay 563 before relay 560 releases. The release of relay 560 is followed by the release of relay 563 and the connection of conductor 557 through the No. 2 back contacts of relay 562, upper winding of relay 553, No. 1 back contacts of relay 562, to ground at the No. 3 contacts of relay 553 as a guarding potential in place of the ground previously furnished through the No. 1 contacts of relay 560. While relay 563 is operated after magnet 569 releases, the sleeve conductor 557 is momentarily freed of any ground potential, thereby causing the release of relay 514 of the PBX selector and the release and return to normal of the line finder LF1 through the release of relay 318, and the consequent operation of release magnet 326 over a circuit which extends from battery through the winding of said magnet, Nos. 6 and 7 contacts of vertical off-normal springs VON 316, No. 3 back contacts of relay 318, No. 1 back contacts of relay 316, Nos. 1 and 2 contacts of vertical off-normal springs VON 316 to ground. The release of relay 514 closes a circuit for operating the release magnet 529, which extends from ground on the No. 4 contacts of said relay, back contacts of relay 515, No. 2 back contacts of relay 516, Nos. 5 and 6 contacts of vertical off-normal springs VON 526, winding of release magnet 529 to battery, and the brushes of switch PBX are restored to normal. The release magnet 529 is held operated until the vertical off-normal springs are restored to their normal position, the holding circuit being traced from the winding of magnet 529, through the No. 5 and No. 6 contacts of VON 526, front contact of magnet 529, conductor 518, to ground through the No. 4 contacts of relay 514. When the shaft reaches normal and springs 526 are in normal position, magnet 529 releases and the idle-indicating battery potential is thereupon reconnected through resistance 527 to the sleeve conductor 517. If the called subscriber delays in replacing the receiver on the receiver hook, relays 551 and 553 are held operated under control of relay 558, and ground is connected through the upper back contacts of relays 559 and 560 and the No. 3 contacts of relay 553 to cause the operation of a trouble alarm 556. When the handset is replaced on its cradle at the called station, relay 558 releases followed by the release of relays 551 and 553. With relays 559, 560 and 553 all released, the release magnet 567 is operated. Magnet 567 locks through the upper front contact of the vertical off-normal springs VON 568. When the shaft reaches normal, magnet 567 releases and the idle-indicating battery potential is again connected through resistance 575 to the sleeve conductor 557 thereby rendering the connector C selectable for use on another call.

In the event of a one-digit call (digit 7) through the long distance office from which it is desirable to recall the subscriber when the connection is established, ringing current is applied from the long distance positions to conductors 423 and 422 which is effective in operating relay 412 in a circuit extending from one terminal of the ringing source (not shown) on conductor 423, No. 2 contacts of relay 408, right upper winding of transformer 441, condenser 435, winding of relay 412, right lower winding of transformer 431, No. 5 contacts of relay 408, conductor 422 to other terminal of ringing source. Relay 412 operates, releases relay 413 which thereupon completes the circuit of relay 410 previously traced. Relay 410 operates and connects local ringing source 436 through lamp 437, No. 2 front contacts of relay 410, No. 4 front contacts of relay 408, line conductor 352, over the loop including the calling station ringer on the other side of the line to conductor 351, No. 3 front contacts of relay 408, No. 1 front contacts of relay 410 to ground. The call is answered at the calling station and connection is thereafter established with the calling station in the well-known manner.

While this embodiment of the invention has been described with reference to a step-by-step automatic telephone system, it is evident that it may be readily applied by any one skilled in the art to any other type of system wherein other switching media are utilized as, for instance, panel and cross-bar switches.

What is claimed is:

1. In a telephone system, the combination with a calling line, of a source of tone, means for applying a potential from said source to said line, and means responsive to the impedance of said line for controlling the amount of potential applied to said line.

2. In a telephone system, the combination with a calling line, of a source of tone, a network intermediate said line and said source through which current is transmitted from said source to said line, a variable impedance shunt connected across said network to by-pass a part of the current applied to said line, and means re-

sponsive to the impedance of said line for varying the impedance of said shunt whereby the current passing through said network from said source is divided between said shunt and said line in proportion to their respective impedances.

3. In a telephone system, the combination with a calling line and a signaling battery for said line that includes a resistance in series with said battery, of a source of tone, a network intermediate said line and said source through which current is transmitted from said source to said line, a variable impedance shunt connected across said network having the property of decreasing in impedance with an increase in current therethrough, and a vacuum tube having its grid connected to said resistance and its anode connected in a path that includes said shunt whereby the potential applied to the grid is a function of the line current from said signaling battery, to effect a variation in the impedance of said shunt in accordance with the potential applied to said grid and whereby the current passing through said network from said source of tone is divided between said shunt and said line in proportion to their respective impedances.

4. In a telephone system, a calling line, a selector switch, means for extending said line to said selector switch, a control device, means responsive to the extensinon of said line to said switch for connecting said control device to said line and to said switch, a first source of tone in said switch, a tone detecting device, a relay controlled thereby, means responsive to the connection of said control device to said switch for connecting said first source of tone to said tone detecting device whereby said relay is operated thereby, a second source of tone, means responsive to the operation of said relay for applying said second source of tone to said line, and means responsive to the impedance of said line for controlling the quantity of tone from said second source applied to said line.

5. In a telephone system, a calling line, a selector switch, means for extending said line to said selector switch, a signaling battery for said line that includes a resistance in series with said battery, a control device, means responsive to the extension of said line to said switch for connecting said control device to said line and to said switch, a first source of tone in said switch, a tone detecting device, a relay controlled thereby, means responsive to the connection of said control device to said switch for connecting said first source of tone to said tone detecting device whereby said relay is operated thereby, a second source of tone, a network intermediate said line and said source of tone, a variable impedance shunt connected across said network, said shunt having the property of decreasing its impedance with an increase in current therethrough, means responsive to the operation of said relay for applying said second source of tone to said network, and a vacuum tube having its grid connected to said resistance and its anode connected in a path that includes said shunt whereby the potential applied to the grid is a function of the line current from said signaling battery, to effect a variation in the impedance of said shunt in accordance with the potential applied to said grid and whereby the current passing through said network from said second source of tone is divided between said shunt and said line in proportion to their respective impedances.

6. In a telephone system, a subscriber's line, a telephone instrument and a device on said line for generating alternating currents to set up a wanted designation, means responsive to said currents for automatically establishing a connection from said line, means for rendering the transmitter of said telephone instrument relatively ineffective to produce pulsating currents during the generation of said alternating currents and means responsive to the establishment of said connection for rendering said transmitter effective to produce pulsating currents.

7. The combination with a transmission line of a register sender comprising a plurality of selective receivers, each of said receivers being adapted to respond to a signal current of a particular frequency, a delay circuit, means for coupling said receivers and said delay circuit to said transmission line, normally operated means in said delay circuit for rendering said receivers normally unresponsive to currents incoming over said transmission line, and means in said delay circuit responsive to a portion of a signal current incoming over said transmission line for releasing said normally operated means whereby said receivers are made responsive to said signal current after a predetermined interval.

8. In a telephone system in which signals are transmitted by currents within the voice frequency range over the talking path, selective receivers each responsive to a signal current of a particular frequency within said range, and means responsive to the transmission of said signal currents over said talking path for rendering said selective receiver unresponsive for a predetermined interval.

9. A delay network for the selective receivers of a register sender, each of said receivers being responsive to a signal current of a particular frequency within the voice frequency range, comprising a first relay, means controlled by said first relay in an operated position for short-circuiting signal currents away from said receivers, a second relay controlling an operating circuit of said first relay, means responsive to a signal current for operating said second relay to open said operating circuit of said first relay and other means responsive upon the opening of said operating circuit for delaying the release of said first relay whereby said selective receivers are made responsive to signal currents after a predetermined interval subsequent to the opening of said operating circuit.

10. A delay network for the selective receivers of a register sender, each of said receivers being responsive to a signal current of a particular frequency within the voice frequency range, comprising a thermionic device operative in response to a signal current, a relay adapted to keep said receivers normally short-circuited and means responsive to the operation of said thermionic device for causing said relay to remove the short circuit from said selective receivers.

11. A delay network for the selective receivers of a register sender, each of said receivers being responsive to a signal current of a particular frequency within the voice frequency range, comprising a thermionic device responsive to a signal current, a first relay normally operated to keep said receivers unresponsive to signal currents, a second relay in the circuit of said thermionic device and responsive to the operation thereof, said second relay controlling the operation of said first relay whereby the operation of said second relay causes the release of said first relay, and an impedance network in the circuit of said first relay adapted to delay the release of said first relay for a predetermined interval after said second re-

lay operates whereby said selective receivers are made responsive to signal currents after said predetermined interval.

12. A delay network for the selective receivers of a register sender, each of said receivers being responsive to a signal current of a particular frequency and including an electronic device, comprising a thermionic device operatively responsive to a signal current, a relay adapted to keep said receivers normally short-circuited, means responsive to the operation of said thermionic device for causing said relay to remove the short circuit from said selective receivers and other means also responsive to the operation of said thermionic device for rendering effective said electronic devices in each of said selective receivers.

13. A delay network for the selective receivers of a register sender, each of said receivers being responsive to a signal current of a particular frequency and including an electronic device, comprising a thermionic device operatively responsive to a signal current, a first relay normally operated to keep said receivers unresponsive to signal currents, a second relay in the circuit of said thermionic device and responsive to the operation thereof, said second relay controlling the operation of said first relay whereby the operation of said second relay causes the release of said first relay, a third relay for controlling the operation of said electronic device in each of said receivers, said third relay being in the circuit of said first relay, and an impedance network in the circuit of said first and third relays adapted to delay the release of said first relay for a predetermined interval after said second relay operates, whereby said selective receivers are made responsive to signal currents after said predetermined interval and further adapted to operate said third relay another predetermined interval after said first relay releases whereby said electronic devices are made effective after said other predetermined interval.

14. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, and each of said receivers including an electronic amplifying device, comprising means responsive to an incoming current for keeping said receivers short-circuited for a predetermined interval and other means for keeping said electronic amplifying devices insensitive for another predetermined interval after said short circuit is removed.

15. In a register sender, a plurality of selective receivers, each of said receivers being adapted to respond to a current of a particular frequency, an electronic amplifying device in each of said receivers, a delay circuit, means for coupling said receivers and said delay circuit to a transmission line, means in said delay circuit for shunting currents incoming over said line away from said receivers for a predetermined interval and other means in said delay circuit for keeping said electronic amplifying devices unresponsive to the energy transmitted through said receivers for a predetermined interval after said shunt is removed.

16. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency and each of said receivers including an electronic amplifying device, comprising a first relay, a circuit for said first relay to bias it in an unoperated position, a second relay, a circuit for said second relay to bias it in an operated position, a third relay, a common impedance circuit for said first and second relays controlled through the contacts of said third relay, said common impedance circuit overcoming the bias of the circuits of said first and second relays, respectively, to hold said first relay operated to short-circuit said receivers and said second relay unoperated, means responsive to an incoming current for operating said third relay whereby said common impedance circuit is opened to release said first relay after a predetermined interval to remove the short circuit from said receivers and to operate said second relay a predetermined interval after the release of said first relay to sensitize said electronic amplifying devices.

17. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, comprising means responsive to an incoming current for keeping said receivers short-circuited for a predetermined interval and other means responsive to said current of a particular intensity for keeping said receivers short-circuited beyond said predetermined interval.

18. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, comprising a first detector channel adapted to operate on a current of any frequency, a second detector channel adapted to operate on a current of any frequency but of a particular intensity, means responsive to the operation of said first detector channel for keeping said receivers short-circuited for a predetermined interval and means responsive to the operation of said second channel for keeping said receivers short-circuited beyond said predetermined interval.

19. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, comprising a first detector channel adapted to operate on a current of any frequency, a second detector channel adapted to operate on a current of any frequency but of minimum intensity, a relay normally operated to keep said receivers short-circuited, a first operating circuit for said relay controlled by said first detector channel, and a second operating circuit for said relay controlled by said second detector channel whereby the response of said first detector channel to an incoming current opens said first operating circuit for said relay to remove said short circuit from said receivers after a time interval and whereby the response of said second detector channel to an incoming current closes said second operating circuit to keep said relay operated to maintain said short circuit.

20. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, comprising a first detector channel including a thermionic device adapted to become conducting on a current of any frequency, a first relay in the anode circuit of said thermionic device, a second relay, an operating circuit for said second relay controlled through the normal contacts of said first relay, said second relay in its operated condition maintaining a short circuit on said receivers, a second detector channel including a thermionic device normally biased to become conducting on a cur-

rent of any frequency but of minimum intensity and another operating circuit for said second relay in the anode path of the thermionic device of said second detector channel and controlled through the operated contacts of said first relay, whereby the conductive state of the thermionic device of the first detector channel in response to an incoming current operates said first relay to open the circuit of said second relay and whereby the conductive state of the thermionic device of the second detector channel in response to an incoming current of minimum intensity closes said other operating circuit of said second relay in conjunction with the operated contacts of said first relay.

21. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, comprising means responsive to an incoming current for keeping said receivers short-circuited for a predetermined interval, means responsive to an incoming current of more than a predetermined minimum intensity for keeping said receivers short-circuited beyond said predetermined interval, and means responsive to said incoming current when reduced below a predetermined minimum intensity for removing the short circuit from said receivers.

22. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, comprising means for normally keeping said receivers unresponsive to an incoming current, means responsive to an incoming current for operating said first-mentioned means to render said receivers responsive after a predetermined interval, means responsive to an incoming current of more than a predetermined minimum value for preventing the operation of said first-mentioned means by said second-mentioned means, and means responsive to said incoming current when reduced below the predetermined minimum value for rendering ineffective said second-mentioned means in operating said first-mentioned means to render said receivers responsive after a predetermined interval.

23. The combination with a transmission line and a register sender comprising a plurality of selective receivers, each of said receivers being adapted to respond to a current of a particular frequency, of a delay circuit for said selective receivers, means for coupling said receivers and said delay circuit to said transmission line whereby a current incoming over said transmission line divides between said receivers and said delay circuit, means in said delay circuit responsive to the portion of the current received over said transmission line for shunting the remainder of said current away from said receivers for a predetermined interval, means in said delay circuit responsive to said current if above a minimum intensity for preventing the operation of said means to remove said shunt, and means in said delay circuit responsive to said current when reduced below said minimum intensity for restoring said delay circuit to normal whereby said first-mentioned means is again responsive to a portion of the current received over said transmission line for shunting the remainder of said current away from said receivers for a predetermined interval.

24. A delay circuit for the selective receivers of a register sender, each of said receivers being adapted to respond to a current of a particular frequency, comprising means for normally keeping said receivers short-circuited, comprising a first detector channel including a first thermionic device, a second detector channel including a second thermionic device, and a third detector channel including a third thermionic device, means for applying a normal grid bias to the grids of each of said thermionic devices, said means including other means for giving the grid of said third thermionic device a higher bias than the other two, means for applying an incoming current of any frequency to the grids of said thermionic devices, a rectifying network for the grid of said second thermionic device whereby said incoming current is rectified into negative components to increase the grid bias of said second thermionic device, means responsive to the conductivity of said first thermionic device for operating said means to remove the short circuit from said receivers after a predetermined interval, means responsive to the conductivity of said third thermionic device if the incoming current is of sufficient intensity to overcome the grid bias of said device to prevent the operation of said means for removing said short circuit, and means responsive to the conductivity of said second thermionic device when said incoming current is reduced in intensity so as to lower the negative bias of said device to restore all of said devices to normal whereby said first thermionic device in said first detector channel is again rendered conducting in response to a persistent incoming current for operating said means to remove said short circuit from said receivers after a predetermined interval.

25. A selective amplifier-rectifier comprising a frequency band filter, a stage of amplification including an electronic element, an electromagnetic device in the output of said amplifier-rectifier, and a tuned feedback intermediate the output and input, said tuned feedback being adapted to rectify negative alternating current components of the output current for reducing the negative grid bias of said electronic element.

ALEXIS A. LUNDSTROM.