May 25, 1943. W. H. T. HOLDEN ET AL 2,320,081

TELEPHONE SYSTEM

Filed April 5, 1941 2 Sheets-Sheet 1

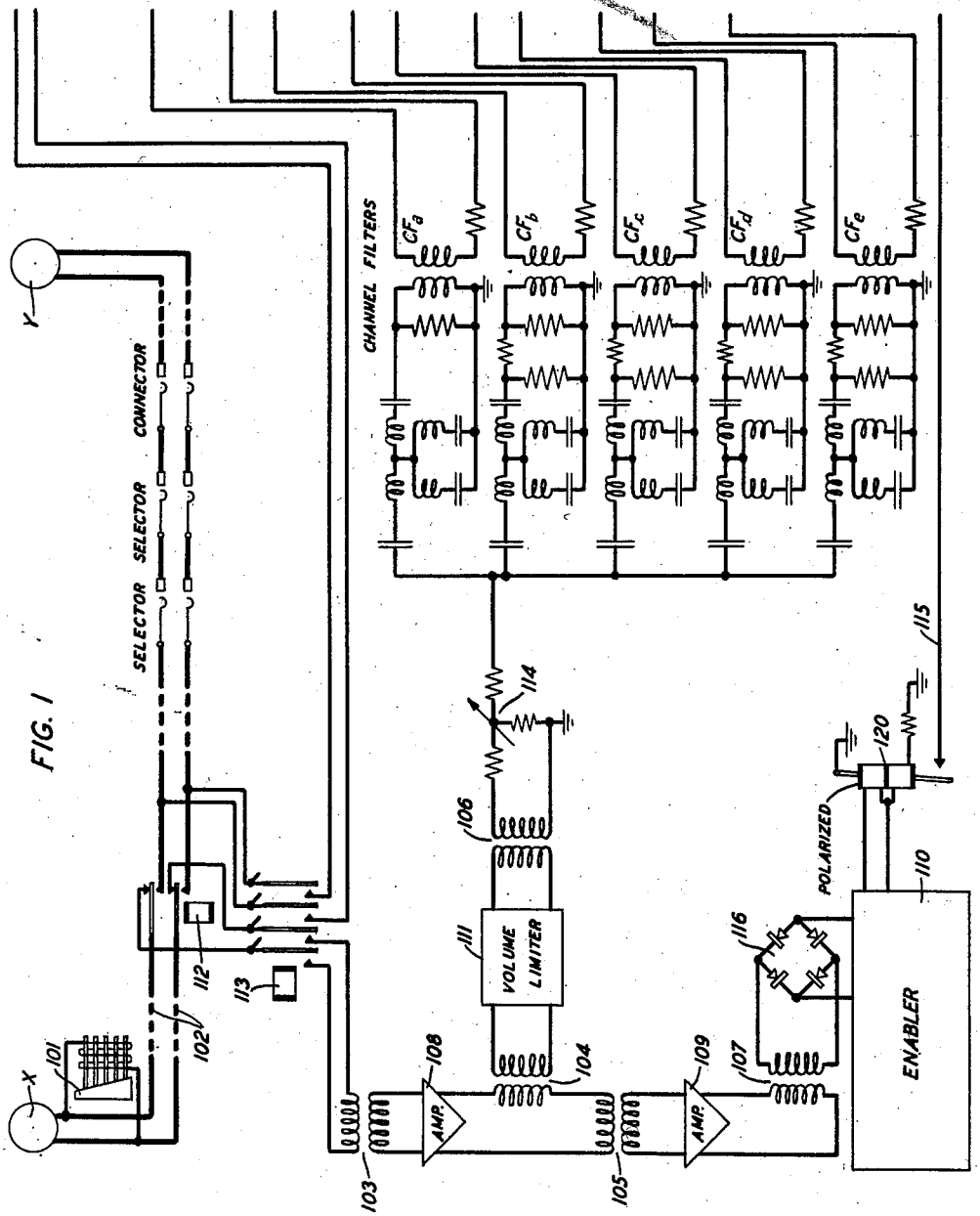

FIG. 1

INVENTORS: W. H. T. HOLDEN
FRANCIS A. HUBBARD
B. F. LEWIS
W. A. MALTHANER
V. G. SPRAGUE

BY P. C. Smith

ATTORNEY

May 25, 1943. W. H. T. HOLDEN ET AL 2,320,081

TELEPHONE SYSTEM

Filed April 5, 1941 2 Sheets-Sheet 2

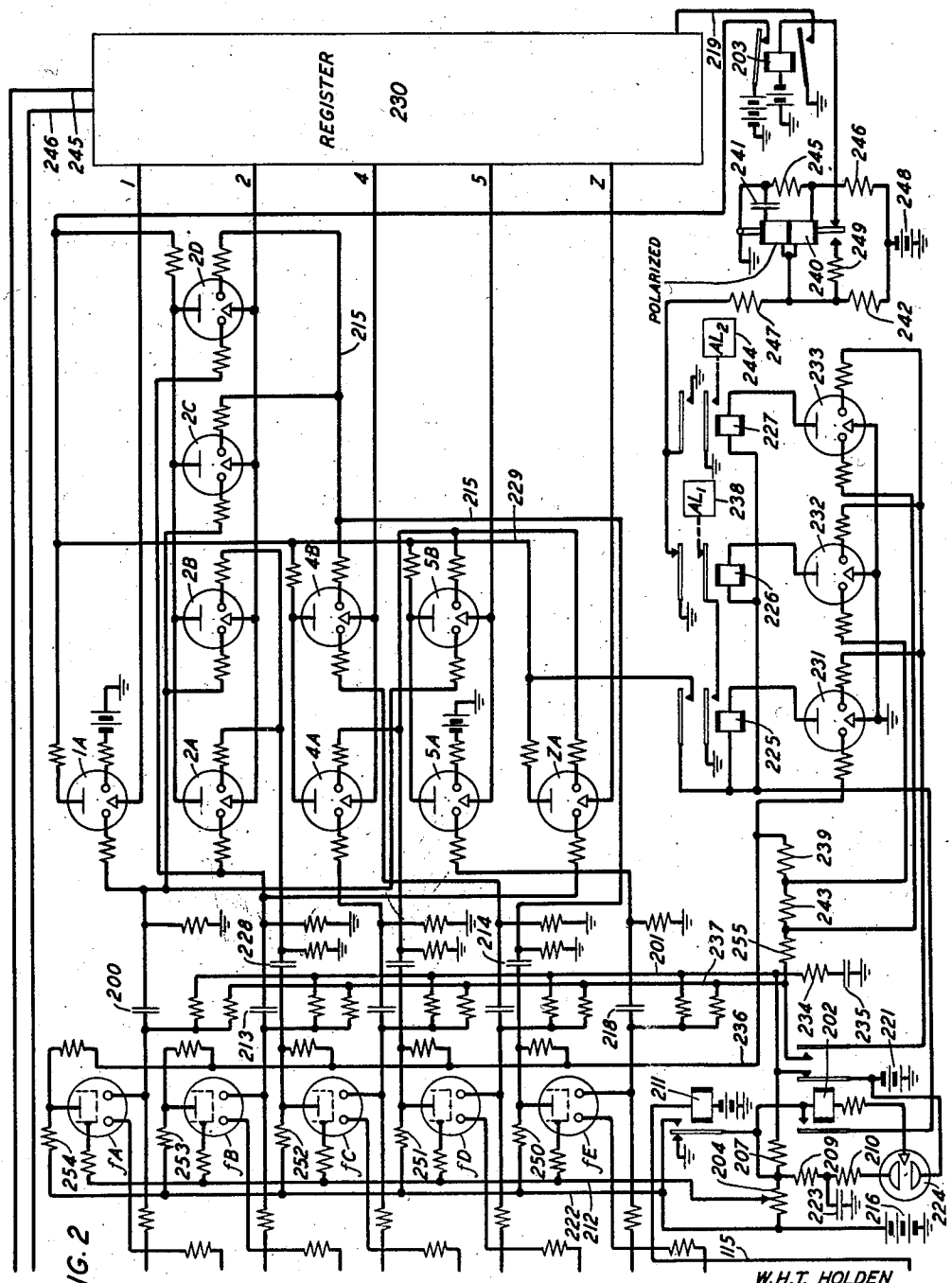

FIG. 2

INVENTORS: W.H.T. HOLDEN
FRANCIS A. HUBBARD
B.F. LEWIS
W.A. MALTHANER
V. G. SPRAGUE

BY P. C. Smith

ATTORNEY

Patented May 25, 1943

2,320,081

UNITED STATES PATENT OFFICE

2,320,081

TELEPHONE SYSTEM

William H. T. Holden, Woodside, N. Y., Francis A. Hubbard, Maplewood, N. J., Benjamin F. Lewis, Bayside, and William A. Malthaner, New York, N. Y., and Vinton G. Sprague, Montclair, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 5, 1941, Serial No. 386,962

8 Claims. (Cl. 179—18)

This invention relates to telephone systems and more particularly to receiving equipment operably connectible with or forming an integral part of a transmission line over which alternating current signals, preferably within the voice frequency range, are transmitted for effecting the operation of said equipment which may be used, in turn, to control the selective positioning of switching apparatus. More particularly, the invention has to do with a code translating circuit for the receiving equipment of a telephone system of the type disclosed, for example, in Patent 2,237,742, issued to A. A. Lundstrom on April 8, 1941. In said application, a telephone system is disclosed of the type in which automatic switches are controlled by means responsive to alternating currents of different frequencies generated at a subscriber's station and transmitted over a line that terminates in a plurality of channel detectors each selectively tuned to a different one of the signal frequencies and responsive thereto to operate a relay which, in combination with a relay operated over another channel detector responsive to a current of another signal frequency in the same signal impulse, serves to function a settable register, or sender, in which is locked in a record of the digit indicated by the two operated relays; that is, by the two frequencies in the pulse transmitted from the subscriber's station.

In systems of this kind where the signal impulses comprise different combinations of frequencies to which the separate channel detectors are respectively tuned to respond and for which a relay or the like is energized for each frequency in the impulse to temporarily register the digit or character designated by the impulse, it is often necessary to change such registration indicated by the combination of different frequencies present in one alternating current impulse into a setting equivalent to that which would be produced, say, by a number of direct current impulses. For instance, in automatic telephone areas wherein register senders responsive to a station dial impulses are used to selectively position automatic switches, telephone exchanges may be included therein whose lines are adapted to transmit wanted designations by alternating current frequency impulses of the kind indicated above, and the register senders would then have to be modified to receive the alternating current impulses on special registers especially adapted for the purpose. From these registers, the circuits which control the selective positioning of the switching selectors would then take the same setting as if they were operated from those registers in the sender which respond to direct current impulses.

Decoding circuits by which a given register code is changed into another code are, of course, old in the signaling arts, such circuits usually comprising auxiliary relay devices intermediate the two registers for effecting the translation. In the present invention, however, the translation is effected through one or more of a group of electronic devices intermediate the channel detectors which respond to the signal frequencies of the different alternating current impulses and the registers of the sender which control the positioning of the switching selectors, said electronic devices being operated singly or in a combination appropriate to the particular digit represented by the signal frequencies, to activate conductors over which the registers of the sender may be operated.

Accordingly, one feature of the invention is a common group of electronic devices, preferably of the gas-filled type, which is associated with the channel detectors and operate in the combination required by the number of channel detectors that respond to the frequencies present in the alternating current impulse designating a digit or character. These electronic devices, when operated, activate one or more of a group of conductors over which the registers of the sender may be set to register the digit designated by the frequencies in the impulse.

In accordance with another feature of the invention the decoding circuit is "self-proving"; that is, will provide a suitable alarm in the event that the number of channel detectors operated is less or more than the precise number called for by any digit or character indicated by the transmitted alternating current impulse, and will further render the registers of the sender unresponsive to succeeding impulses. It is assumed, of course, that each signaling impulse designating a digit or character will always have the same number of frequencies in accordance with a suitable signal code, albeit the frequencies themselves will be present in the different combinations required for each different digit or character in accordance with the code.

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

Figs. 1 and 2 when placed side by side, show schematically certain elements of the telephone system more completely disclosed in the patent

to A. A. Lundstrom, above mentioned, and in which certain other elements to which our invention more directly relates are shown in detail.

Referring now to said figures, X represents a subscriber station in an automatic telephone system, said station being equipped with a device **101** suitably arranged to produce one or more currents of different frequencies, preferably in the voice frequency range, in response to the depression of keys or the like that represent digits or other characters making up the wanted designation; **102** represents a line extending from the station instrument to the central office whence, through one of a plurality of selectable sender connectors **113**, the line is extended to a free sender which comprises the coupling transformers **103, 104, 105, 106** and **107**, amplifiers **108** and **109**, the volume limiter **111**, the enabler circuit **110**, the channel filters CF_a CF_b, CF_c, CF_d, CF_e, the channel detector tubes *f*A, *f*B, *f*C, *f*D and *f*E individually so designated in accordance with the frequency to which each of the channels is respectively assumed adapted to respond, the decoding electronic devices 1A—ZA, inclusive, the register **230**, and the self-proving circuit comprehended by the network associated with electronic devices **231, 232** and **233**.

Each channel includes a band-pass filter such as CF_a, and a detector amplifier tube such as *f*A, which comprises a four-electrode gas-filled device having a cathode, a control anode, a main anode and a screen surrounding the main anode. Such a device may be rendered conducting by the application of an appropriate difference of potential between the cathode and control anode, at which time a space discharge current is established thereacross. However, the space current may or may not extend from the cathode to the main anode depending upon the potential bias applied to the screen. If the screen electrode is sufficiently negative relative to the potential of the main anode, no space current will be established between the cathode and the main anode since the difference of potential between the cathode and screen is insufficient to ionize the gas in that portion of the gap which extends between the cathode and the screen electrode. However, if after a space current is established between the cathode and the control anode the potential on the screen anode is rendered positive with respect to the potential of the cathode, ionization of the intervening gaseous space occurs and a conducting path will be established between the cathode and main anode.

The decoding tubes are identified in the drawing as 1A, 2A, 2B, 2C, 2D, 4A, 4B, 5A, 5B and ZA, and may also be of the gas-filled type. Each of these tubes has a main anode which is connected to a positive source of potential through the upper front contacts of relay **203**, which relay is normally energized over the right contact and armature of polarized relay **240**, a cathode connected to one of the conductors 1—Z which extend, over appropriate transfer devices, to groups of direct current register devices (not shown) of register **230**, and a pair of control electrodes which extend through suitable networks, to the appropriate cathodes and anodes of different channel detector tubes *f*A—*f*E. This is true of all the decoding tubes except tubes 1A and 5A each of which has its right control electrode connected to a negative source of potential through a suitable resistance.

Tubes **231, 232** and **233** which may also be of the gas-filled type, constitute, with relays **225, 226** and **227** connected to their respective anodes and relays **240** and **203**, the self-proving circuit which discriminates between an incoming signal which comprises the exact number, an incoming signal which comprises less than the exact number and an incoming signal that has more than the exact number of frequencies.

A common direct current impulse switching register **230** is operatively associated with all the channels through conductors **1, 2, 4, 5** and Z, each of said conductors connecting, respectively, on the channel side, with the cathodes of the decoding tubes in the manner shown in the drawing and, on the register side, with a relay or other electromagnetic device (not shown) in register **230** which is adapted for operative response whenever a potential is applied to the conductor with which it is connected. The register **230** itself is indicated in the drawing only in its most generalized form as it is evident that it can be of any suitable design adapted for setting in response, say, to the setting of another register which responds to a train of direct current impulses transmitted over the subscriber's line and connected thereto by a group of conductors identical to conductors 1—Z shown in Fig. 2 and thus provide an identical setting for the same digit or character, by the activation of conductors 1—Z in the combination called for by an entirely different code. It may, for instance, take the form of the registers of the sender shown and described in Patent 1,862,549 granted to R. Raymond and W. J. Scully on June 14, 1932, in which event it would comprise a group of register relays connectable to conductors 1—Z, through a plurality of appropriate transfer devices which would be controlled over conductor **219**. However, any other switching medium settable over conductors 1—Z in accordance with a defined code will be equally appropriate, and it is understood that no limitation is intended for the invention by reference to the sender of the above patent or any other form of switching device or devices operable over conductors 1—Z and other conductors as explained hereinafter.

The amplifiers **108** and **109** and the volume limiter **111** are commercially available circuit units, while the channel filters CF_a—CF_e except for the modification in the use of gas-filled tubes *f*A—*f*B and their interrelated circuits for activating conductors 1—Z are completely disclosed in the above-mentioned patent to A. A. Lundstrom to which reference is made for a more complete understanding thereof although it is to be understood that the invention is not limited to channels of this description as it is obvious that any other type of channel having an appropriate detector-amplifier circuit responsive to a frequency in the incoming signal impulse will be equally applicable in the operation of our invention.

In the operation of the invention, a call is initiated at station X by the removal of the station instrument from the switchhook whereupon the line is then extended by any suitable means to the central office at which an available sender is then connected to said line through the medium of the sender connector **113**, after which "key tone" is transmitted back to the calling station X by circuits not shown, as a signal that the sending device **101** may be operated to transmit the number of the wanted station Y, all in the manner described in said above-mentioned patent to A. A. Lundstrom.

When any one of the ten keys of the sending

device 101 is operated, two of the five defined frequencies fA—fE are produced in the combination required for the digit designated by the key depressed, and the resulting current is transmitted over a circuit which may be traced from one side of the sending device 101 over the lower conductor of the looped pair 102, inner back contact of relay 112, next to the inner contacts of sender connector cut-in relay 113, primary winding of transformer 103, inner contacts of relay 113, outer back contact of relay 112, upper conductor of looped pair 102 to the other side of the station sending device 101. The current composed of the two frequencies is induced in the secondary winding of transformer 103 and fed into the input side of amplifier 108 whence, after suitable amplification, it is applied from the output side of said amplifier to the input side of transformers 104 and 105, respectively, whence it is further applied, through transformer 104, to the input side of volume limiter 111 and, through transformer 105, to the input side of amplifier 109.

Considering that portion of the signal energy which passes into the volume limiter 111, said energy causes the volume limiter to operate in the known manner to regulate the signal energy output in accordance with its adjustment, which may be such as to limit the magnitude of the output current to that required for the satisfactory operation of the channel detectors and no more regardless of the magnitude of the input energy. The reason for doing this is, of course, to prevent overloading any of the channel detectors which, should such overloading occur in the event of a heavy input signal due, say, to a very short loop 102, would cause false operation of the channel detectors which adjoin those that will respond to the frequencies of the input signal, by currents present in the frequency spectrum generated by the impact of the impulse on the input side of the channels and thus cause the false operation of such channels. Hence by adjusting the volume limiter 111 to a suitable level of output energy above the operate level of the channel detectors, false operation of adjoining channels upon heavy signal currents is avoided.

The energy output from the volume limiter 111 is applied, through transformer 106, to the variable pad 114 whence it is applied through the band-pass filters CF_a—CF_e to the cathode and control anode of each of the detector tubes connected to those filters through which the frequencies of the input signal have passed. The tubes of the two channels involved will break down and be rendered conducting across their cathode-control anode gaps, but no circuit is established thereover through their respective main anodes because the screen electrode surrounding the main anode of each of the tubes has a potential applied thereto measured by the values of said potential as established by ground on the back contact of relay 211 to one side of resistance 204 and battery 216 at the other side of said resistance, the potential supplied to the screen being taken from a suitable slide point of resistance 204. The point of contact along resistance 204 should be so chosen that the potential applied to the various screen electrodes will prevent any current flow from being established between the cathode and the main anode of the conducting channel tube until ground is removed from the common terminal of resistances 204 and 207 by the operation of relay 211 as described hereinafter.

It will be observed that the left control electrode of each one of the decoding tubes 1A—ZA, inclusive, is connected to the cathode of one of the channel detector tubes fA—fE and that these electrodes of the decoding tubes are maintained at ground potential by a separate resistance ground connected to each of them. Even though two of the channel detectors fA—fE have been rendered partially conducting by the incoming signal, the cathode potential thereof will not be effected. Therefore, even though tubes 1A and 5A have negative battery through a resistance connected to their respective right control electrodes, these tubes will not be rendered conducting when channel tube fA or fE, respectively, is rendered partially conducting. However, with the exception of decoding tubes 1A and 5A which have negative battery permanently connected to their respective right control electrodes, the remaining decoding tubes have their right control electrodes connected to a resistance ground and, through a condenser, to the main anodes of selected ones of the different channel tubes, so that the decoding tubes will have no difference of potential applied to their respective control electrodes when the channel tubes to which they are connected have been rendered partially conducting. Tubes 2A and 2B, for instance, have their paralleled right control electrodes connected to ground through a resistance and, through condenser 228, to the anode of channel tube fC, there being similar networks for other decoding tubes, as shown in the drawings.

Considering, now, that portion of the signal energy which is transmitted via the transformer 107 to the enabler 110, said energy is applied to the rectifier bridge 116, whence it is rectified and applied to the timing circuit which constitutes the enabler 110. This enabler which, with the exception of the polarized relay 120, is but schematically indicated is completely shown and described in the copending application of G. Hecht and A. A. Lundstrom, Serial No. 355,712, filed September 7, 1940, and comprises a timing circuit the essential function of which is to operate relay 120 a predetermined interval after the arrival of the signal impulse and to keep it operated for a predetermined interval thereafter during which ground is applied to conductor 115 thereby closing an obvious circuit of relay 211. Inasmuch as the enabler 110 is no part of the invention except in so far as it is an element used to activate the detector tubes of the channels if they are not normally activated, and for which purpose any other suitable element would do, the enabler is neither shown nor described in detail, reference being had to the above-mentioned copending application of G. Hecht and A. A. Lundstrom for a detailed showing and description thereof.

Returning, now, to the operation of the channel detectors subsequent to the application of ground to conductor 115 and the consequent operation of relay 211, the number of channels operated by a single impulse will depend upon the number of signal frequencies present in the impulse which, in turn, will depend upon the signal code used. To illustrate the operation of the invention, it will be assumed, first, that a specific two-frequency signal code is used, by which is meant that each impulse transmitted from station X for each of the ten digits will be made up of two frequencies *a*—*e* in designated

combinations; second, that each impulse so transmitted will cause the operation of the corresponding channel detector tubes *f*A—*f*E as indicated in the following table and, third, that to register a digit in the register **230** in consequence of the operation of the indicated channel detector tubes, a potential must be applied to the register conductors **1**—Z singly or in the combinations shown below opposite the operated channel tubes for the digit:

Digit	Frequency impulse code channel tubes	Direct current impulse code for registering the digit in register 230 conductors activated
1	*f*A, *f*B	1
2	*f*B, *f*C	2
3	*f*A, *f*C	1, 2
4	*f*C, *f*D	4
5	*f*C, *f*E	5
6	*f*A, *f*D	1, 5
7	*f*B, *f*E	2, 5
8	*f*A, *f*E	1, 2, 5
9	*f*D, *f*E	4, 5
0	*f*B, *f*D	Z

Accordingly, when a digit key of device **101** is depressed in conformity with the digit to be transmitted, the two frequencies designated for the digit in the preceding table are generated by device **101** and transmitted into the sender, pass through variable pad **114** and the filter devices CF_a—CF_e and are applied to the cathode and control electrode of each of the detector tubes of the two channels which are tuned to respond to the two frequencies transmitted, and said tubes respond in the manner described, that is, by being rendered partially conductive but otherwise having no other effect. However, when relay **211** operates, it disconnects ground from the common terminal of resistances **204** and **207** and positive potential from source **216** via conductor **212** and the two portions of resistance **204** in parallel is applied to the screen of each of the channel tubes *f*A—*f*E. Since positive potential from source **216** is permanently applied to the anodes of these tubes over conductor **222**, it follows that, with positive potential applied to the screens of the two tubes which were rendered partially conducting by the incoming signal, these tubes are now rendered fully conductive, thereby establishing a space current path from negative battery **221**, right inner contacts of relay **202**, conductor **201**, two undesignated resistances in series over the cathode-anode paths of whatever channel detector tubes were rendered partially conducting by the incoming signal, conductor **222**, to positive battery **216**. The channel tubes involved are thus rendered fully conducting to perform functions which are noted hereinafter.

In the meanwhile, when relay **211** operated, it not only caused the application of battery **216** to the screen electrodes of the channel detector tubes as previously described, but it also caused the application of the same battery to one side of condenser **223** through resistance **209**. Now the capacity of condenser **223** is so chosen that it will charge to the potential required to break down gas-filled electronic device **224** in the length of time that it is desired to keep fully conducting the two channel detector tubes which have responded to the frequencies of the signal impulse. The reason for this is that, for correct signaling, the channels must be kept immune from responding to currents which may be induced by noise and the like, and it has been found that the most efficient way of doing this is to cut off the response of the channel some time before the signal impulse is fully dissipated. Hence when condenser **223** is charged to the required value, device **224** will be rendered partially conducting by the positive potential on the condenser applied to the upper control electrode of the tube through resistance **210** and by the negative potential of battery **221** applied to the lower control electrode of the device, at which time a space current will be established through the main anode and resistance in series therewith, winding of relay **202**, front contacts of relay **211** to positive battery **216**. Relay **202** operates upon the tube becoming fully conductive, locks over its left contacts, outer contacts of relay **225** (which relay is operated at this time as will be shown hereinafter), conductor **229**, upper contacts of relay **203** to battery. At its right inner contacts, relay **202** disconnects negative battery **221** from the cathode of each of the channel detector tubes and from condenser **235** which, while relay **202** is normal, becomes charged to the potential of said battery **221**. The charged condenser **235** now discharges through resistance **234** back through the cathodes of the conducting channel tubes and causes them to sustain their conductivity for an interval determined by the capacity of the condenser even though battery **221** is disconnected from their respective cathodes. When the condenser is fully discharged, the channel tubes will quench and are thereby rendered non-conducting since, with relay **202** operated, no cathode potential is available to sustain their conductivity. Over its right outer contacts, relay **202** completes a potentiometer circuit to electronic devices **231**, **232** and **233**. Thus during the interval that condenser **223** is being charged, the channel detector tubes which have been rendered fully conducting by the operation of relay **211** are functioning to apply appropriate circuit conditions for operating the decoding tubes **1**A—ZA whereby the digit or character represented by the plural frequency pulse is registered in register **230**, as described hereinafter, and, when relay **202** operates, the channel detector tubes are quenched after a time interval measured by the discharge time of condenser **235** even though the plural signal impulse may still be fully applied over the channels.

Returning, now, to that interval in the operation of the invention which is marked between the operation of relay **211** and the operation of relay **202**, that is, in the interval when the channel detector tubes operated by the frequencies of the incoming pulse are rendered fully conducting, the decoding tubes **1**A—ZA are operated singly or in combination from the fully conducting channel tubes which, in turn, are operated in combination of two to designate one of the ten digits as noted in the above table. If the signal impulse comprises frequencies *a* and *b*, thereby designating the digit **1**, channel tubes *f*A and *f*B will operate. When these tubes are rendered fully conducting by the operation of relay **211**, decoding tube **1**A will be rendered conducting between its two control electrodes by the negative battery connected to its right control electrode and by the positive potential applied to its left control electrode from the available cathode voltage of tube *f*A via condenser **200**. Inasmuch as positive battery is connected to the main anode of tube **1**A from the contacts of relay **203**, and since the cathode of the tube is connected to signaling conductor **1** over which negative battery is applied through a register relay (not shown) in the register **230**, a cathode-main anode conduc-

tive circuit is established which results in the operation of the register relay connected to said signaling conductor.

If the incoming signal impulse comprises frequencies *b* and *c*, thereby designating the digit 2, channel tubes *f*B and *f*C will operate and a breakdown potential is applied to the control gap of decoding tube 2A, the negative potential therefor being obtained from the main anode of tube *f*C via condenser **228** to the right control electrode of tube 2A and the positive potential being applied from the cathode of tube *f*B via condenser **213** to the left control electrode of tube 2A. As in the case of tube 1A, the cathode of tube 2A is connected to signaling conductor **2** which, in the register **230**, is connected to a relay having negative battery applied to its other terminal. Since positive battery is applied to the main anode of tube 2A, the cathode-anode gap in the tube becomes conductive thereacross and establishes a current path therethrough which results in the operation of the relay in register **230** which is connected to signaling conductor **2**.

In the same way as above described, the operation of any two channel detector tubes in accordance with the preceding table, results in the operation of one or more decoding tubes by breakdown potentials applied to their respective control electrodes and the consequent breakdown of the control gap thereacross, said breakdown potential being supplied from the cathode of one of the operated channel tubes and the anode of the other operated channel tube. These decoding tubes, in operating, break down their respective main gaps and complete circuits therethrough which result in the operation of those register relays in register **230** which are respectively connected to the signal conductors 1—Z forming parts of the main gap circuit. The decoding tubes operated for each of the digits and the signal conductors activated thereby for each pair of channel detector tubes responding to a two-frequency impulse as given in the preceding table, is shown in the following table:

Digit	Channel tubes	Decoding tubes	Signal leads activated
1	*f*A, *f*B	1A	1
2	*f*B, *f*C	2A	2
3	*f*A, *f*C	1A, 2B	1, 2
4	*f*C, *f*D	4A	4
5	*f*C, *f*E	5A	5
6	*f*A, *f*D	1A, 5B	1, 5
7	*f*B, *f*E	2D, 5A	2, 5
8	*f*A, *f*E	1A, 2C, 5A	1, 2, 5
9	*f*D, *f*E	4B, 5A	4, 5
0	*f*B, *f*D	ZA	Z

Thus, as another example of the decoding process, others being evident from the circuit read in connection with the above table, if the impulse is that of digit 8, channel tubes *f*A and *f*E will be rendered conducting. As before explained with reference to digit 1, the operation of tube *f*A will render decoding tube 1A conducting with the consequent operation of the relay in register **230** which is connected to signal conductor **1**. The operation of tube *f*E, on the other hand, will result in the application of breakdown potential to the control electrodes of tubes 2C and 5A, the former having negative potential applied to its left electrode via condenser **200** since this electrode is in parallel with the corresponding electrode of tube 1A, and positive potential applied from the main anode of tube *f*E via condenser **214** and conductor **215**. The cathode of tube 2C is connected to signal conductor **2** to the other end of which, in register **230**, is connected a register relay with a source of negative potential connected to its winding, while the main anode is connected to positive battery over the contacts of relay **203**. Tube 2C breaks down in its main gap to cause the operation of the relay in register **230** which is connected to conductor **2**. Breakdown potential is applied to the left electrode of tube 5A from the cathode of tube *f*E via condenser **218** and to the right electrode from negative battery and the series resistance permanently connected thereto. As with the other decoding tubes, tube 5A has its cathode connected to one of the signal conductors, in this case conductor **5**, so that, when the main gap of the tube is rendered conducting, the relay in the register **230** connected to said conductor is operated. Hence for the registration of the digit 8 from the operation of the channel tubes *f*A, *f*E, it is necessary to operate the three decoding tubes 1A, 2C, 5A which, upon operating, cause the operation of those direct current relays in the register **230** which are respectively connected to the signal conductors **1, 2 and 5.**

It will be recalled that at the time relay **202** operated, the channel tubes are maintained fully conducting thereafter by the interval required to discharge condenser **235**. The capacity of this condenser and the value of resistance **234** in series with it should be so chosen that the discharge time during which the channel tubes are sustained provides sufficient time to operate relays **225, 226** and **227** in the manner described hereinafter depending upon whether one channel tube operates, two channel tubes operate or more than two operate.

It will be observed that conductor **236** is connected, on the one side, through an appropriate resistance for each channel, to the main anode of each tube in each channel and on the other side, to the left control electrodes of tubes **231, 232** and **233** through appropriate resistances. Conductor **201**, on the other hand, connects with the cathode side of each of the channel tubes through two series resistances per channel whence it extends via conductor **237** and the right outer contacts of relay **202** to the right control electrodes of tubes **231, 232** and **233**. The potential difference between these two conductors, which is applied to the left and right control electrodes of said tubes depends, of course, upon the number of channel tubes which are rendered simultaneously conducting. The reason for this is that each conducting channel tube establishes a parallel conducting path which connects with conductor **236**. When no tube is operated, then no potential difference is available between conductors **236** and **237** due to the fact that relay **202** is normal and, therefore, its right outer contacts are open. But if one tube is conducting due, for example, to a single frequency being transmitted over the line, then, in the interval that said tube is being sustained in the conducting state by the discharge of condenser **235**, breakdown potential is applied to the control electrodes of gas-filled tubes **231, 232** and **233** all of which are of identical construction, one branch of said potential path being traced from positive battery **216** through resistances **250** to **254**, inclusive, in parallel, to conductor **236** whence it is further traced to the left electrode of tube **231** via said conductor, to the left electrode of tube **232** via resistance **239**, to the left electrode of tube **233** to via resistances **239** and **243**. The negative side of said potential is supplied from the discharge voltage

of condenser 235 traced over conductor 201, a pair of series resistances in parallel for each channel, conductor 237, right outer contacts of relay 202 to the right control electrodes of each of the tubes 231, 232 and 233 in parallel. Another and parallel circuit to the above is provided over the conducting channel tube, and the value of this combined potential when applied across the three tubes is sufficient to cause their breakdown between their respective control electrodes. The values of resistances 239, 243 and 255 are such that the available potential for the tubes across which they are connected is suitably apportioned to supply the proper breakdown voltage to each of the tubes. The control gaps of tubes 231, 232 and 233 break down, and since positive battery 216 is available at the main anodes of said tubes through resistance 204, left contacts of relay 202, windings of relays 225, 226 and 227 in parallel to the respective main anodes of said tubes, and the negative or grounded pole of said battery is connected to the cathodes of said tubes, the main gaps thereof are thereby rendered conducting through the circuits traced and cause the establishment of current flows that result in the operation of said relays 225, 226 and 227. Relays 225, 226 and 227 lock to battery on conductor 229 over the outer contacts of relay 225. Relay 226 disconnects ground from resistance 247 but this ground is replaced by another ground on the outer contacts of relay 227 so that the circuit conditions of relay 240 are not disturbed. Relay 226 disconnects the alarm 238 while relay 227 activates alarm 244, if one is provided, to give an alarm signal that a one-frequency pulse is received.

If two channel tubes operate, which will be the normal case, the potential across resistances 239, 243 and 255 will be lower than when one tube operates. This is due to the fact that the additionally operated tube provides a second shunt path across the above-mentioned resistances and has the effect of lowering the voltage proportionately thereacross, but will be sufficient, nevertheless, to break the control gaps of tubes 231 and 232. The main gaps of both tubes will then become conducting, relay 225 operating and locking as before described while relay 226 operates and breaks the path to alarm 238 and opens the circuit of polarized relay 240. The upper winding of said relay 240 is in series with condenser 241 and is connected to the junction of resistances 242, 249 and 247 of the potentiometer from ground through the outer contact of relay 226 to battery; the lower winding of relay 240 also connects to the junction of resistances 242, 249 and 247. With relay 226 unoperated, the current through the lower winding of relay 240 will hold the armature of the relay against its right contact. However, when relay 226 operates, ground is removed from resistance 247 and a charging circuit is established for condenser 241 which extends from ground through condenser 241, upper winding of relay 240, resistance 242 to battery 248; the removal of ground from resistance 247 also reverses the direction of current in the lower winding of relay 240. Thus, the charging current which is in a direction to hold the armature engaged with the right contact, temporarily overcomes the effect of the lower current winding which is now in a direction to move the armature to the left contact. This time is controlled by the value of the condenser 241 and resistance 242 and should be such as to permit the complete operation of the relays in register 230. When the charging current to condenser 241 reduces to zero after having charged the condenser, the armature of relay 240 will move to its left contact.

When relay 249 operates, relay 203 releases, thereby disconnecting positive battery from the main anode of each of the decoding tubes which effects, in turn, a disruption of the cathode-anode circuits through those tubes which are operated, including the relays of register 230 operated over the signaling conductors 1—Z forming parts of such circuits. These relays, however, are locked after their operation so that the quenching of the decoding tubes will in no wise disturb their setting. Relay 203 further connects ground over conductor 219. Ground on this conductor completes a circuit (not shown) in register 230 by which an appropriate one of the transfer devices therein is operated to transfer conductors 1—Z to a succeeding set of register relays on which will be registered, in response to the succeeding operation of the channel detector tubes and the appropriate ones of the decoding tubes responsive thereto, the digit designated by said operated channel detector tubes. Since the circuits over conductors 1—Z are disrupted before operation of the transfer devices is begun by the application of ground to conductor 219, there is no overlap of any circuit on any of said conductors that will spill over into the relays of the next register.

When the armature of relay 240 engages its left contact, condenser 241 is discharged and the current in the lower winding also reversed. The discharge current through the upper winding will hold the armature against the left contact for sufficient time to allow the operation of one of the transfer devices in register 230 from the ground on conductor 219. When the discharge has subsided, the armature of relay 241 will return to the right contact and relay 203 will then be reoperated, connecting positive battery potential to the anodes of the decoding tubes and disconnecting ground from conductor 219. By the time the armature of relay 240 is in engagement with its right contact, relays 225 and 226 will have released in virtue of the release of relay 211 which shunts battery 216 from the circuit of relay 202 causing this latter relay to release and open the main anode-cathode circuits of tubes 231 and 232 which include, serially, the windings of relays 225 and 226, respectively. All parts of the circuit are thus restored to normal in preparation for the registration of the next digit.

If the signal impulse comprises three or more frequencies, the potential across resistances 239, 243 and 255 is least and will be sufficient to break down only tube 231 and cause the operation of relay 225 which locks as before and supplies ground to operate alarm 238. The operation of this alarm is indicative of the fact that the false signal was probably due to a false operation of device 101 at station X. Thus, if a signal comprises three or more frequencies, relay 240 is not operated to make the channels ready for the next digit. The circuit, however, may, from this point on, be adapted to dismiss the sender and provide the subscriber with "reorder" tone to restore the receiver and transmit the number all over again. Since this part of a sender operation is not a part of our invention, and since the adaptation of a sender to dismiss on such condition subsequent to giving the subscriber reorder tone is amply described in the above-mentioned patent to A. A. Lundstrom, reference is made to said patent for a description of the means for doing the same.

With register 230 fully set in response to the operation and locking therein of relays designating the digits of the called subscriber Y, the sender will proceed over conductors 245 and 246 to selectively position the selectors and connector to reach the terminals of said line, all in accordance with the teachings of said above-mentioned patent to A. A. Lundstrom.

What is claimed is:

1. In a telephone system, a sender therefor which is adapted for the registration of wanted designations, comprising five channel detectors each adapted to pass therethrough a specific frequency of a two-frequency pulse designating a digit or character, a gas-filled electronic device in each channel responsive to the frequency passed through said channel, a plurality of other gas-filled electronic devices responsive singly or in combination to two of said channel electronic devices, a plurality of conductors selectively activated singly or in conbination by said other gas-filled electronic devices when operated to indicate a digit or character designated by the two frequencies in said two-frequency pulse, and means responsive to the operation of three of said channel gas-filled thermionic devices for rendering ineffective the activation of said conductors.

2. In a telephone system, a sender therefor which is adapted for the registration of wanted designations, comprising five channel detectors each adapted to pass therethrough a specific frequency of a two-frequency pulse designating a digit or character, a gas-filled device in each channel having a control electrode and a screen electrode to control the space discharge circuit over the cathode and anode thereof, means responsive to the frequency passed through a channel detector for establishing a space discharge circuit between the control anode and cathode of said device, means responsive to said frequency after a predetermined interval for applying a potential to said screen electrode whereby a space discharge circuit is established between the cathode and anode of said device, a plurality of decoding gas-filled devices rendered conductive singly or in combination by the establishment of a space discharge circuit between the cathode and anode of each of two of said channel gas-filled devices, and a plurality of conductors selectively activated singly or in combination by said decoding gas-filled devices when operated to indicate a digit or character designated by the two frequencies which caused said two channel detector devices to be each rendered conducting over the cathode-control anode path thereof.

3. In a telephone system, a sender therefor which is adapted for the registration of a wanted designation, comprising a plurality of channel detectors each adapted to pass therethrough a specific frequency of a two-frequency pulse designating a digit or character, a gas-filled electronic device in each channel detector responsive to the frequency passed through said channel detector, a plurality of gas-filled decoding devices responsive singly or in combination to two of said channel electronic devices, a plurality of conductors selectively activated singly or in combination by said decoding devices when operated to indicate the digit or character designated by said two frequencies in said pulse, and an alarm device responsive to the operation of more than two of said channel electronic devices.

4. In a telephone system, a sender therefor which is adapted for the registration of wanted designations, comprising a plurality of channel detectors each adapted to pass therethrough a specific frequency of a plural frequency pulse designating a digit or character, a gas-filled electronic device in each channel detector responsive to the frequency passed through said channel detector, a plurality of gas-filled decoding devices responsive singly or in combination thereto, a plurality of conductors selectively activated singly or in combination by said decoding devices when operated to indicate the digit or character designated by the number of frequencies in said plural frequency pulse, an alarm device, and means responsive to the operation of any single one of said channel electronic devices for operating said alarm device.

5. In a telephone system, a sender therefor which is adapted for the registration of wanted designations, comprising a plurality of channel detectors each adapted to pass therethrough a specific frequency of a plural frequency pulse designating a digit or character, a gas-filled electronic device in each channel detector responsive to the frequency passed through said channel detector, a plurality of decoding gas-filled devices responsive singly or in combination thereto, a plurality of conductors selectively activated singly or in combination by said gas-filled devices when operated to indicate the digit or character designated by the number of frequencies in said plural frequency pulse, an alarm device, and a plurality of electronic means activated by the anode potential from the cathode-anode circuits of said channel electronic devices for operating said alarm device, the value of said potential being determined by the number of said operated channel devices whereby a selected number of said electronic means are activated to cause said alarm to distinguish between the number of said channel electronic devices that have been operated.

6. In a telephone system, a sender therefor which is adapted for the registration of wanted designations comprising a plurality of channel detectors each adapted to pass therethrough a specific frequency of a two-frequency pulse designating a digit or character, a gas-filled tube in each channel detector responsive to the frequency passed through said channel detector, a plurality of other gas-filled tubes responsive singly or in combination to two of said channel gas-filled tubes, a plurality of conductors selectively activated singly or in combination by said other gas-filled tubes when operated to indicate the digit or character designated by the two frequencies in said two-frequency pulse, and an alarm device operative in response to the operation of more than two channel gas-filled tubes for preventing subsequent operation of any of said channel gas-filled tubes on any pulse transmitted within a predetermined interval after the first pulse.

7. In a signaling system the combination with a plurality of detectors each adapted to respond to an alternating current of specific frequency, of a plurality of normally unconducting electronic devices interconnecting said detectors whereby in response to the operation of any pair of detectors the positive component of the breakdown potential for one of said electronic devices is applied thereto by one of said pair of detectors, and the negative component of said breakdown potential is applied by the other of said pair of detectors.

8. In a telephone system, a plurality of channels each adapted to pass therethrough one frequency of a two-frequency current pulse designating a digit or character, each of said channels including an electronic detector adapted to establish a current therethrough in response to the application of a potential derived from the current passed through the associated channel, a plurality of electronic devices each adapted to be rendered conducting upon the application of a breakdown potential to two electrodes thereof, a network interconnecting said electronic detectors and said electronic devices for causing the positive component of the breakdown potential for one or more of said electronic devices, derived from the current through one operated electronic detector, to be applied to an electrode of each of said one or more electronic devices and the negative component of said breakdown potential, derived from the current through another operated electronic detector, to be applied to another electrode of each of said one or more electronic devices whereby said one or more electronic devices are rendered conducting in consequence thereof, and means responsive to the conductivity of said one or more electronic devices for registering the digit or character indicated by the two-frequency current pulse which caused the operation of said two electronic detectors.

WILLIAM H. T. HOLDEN.
FRANCIS A. HUBBARD.
BENJAMIN F. LEWIS.
WILLIAM A. MALTHANER.
VINTON G. SPRAGUE.