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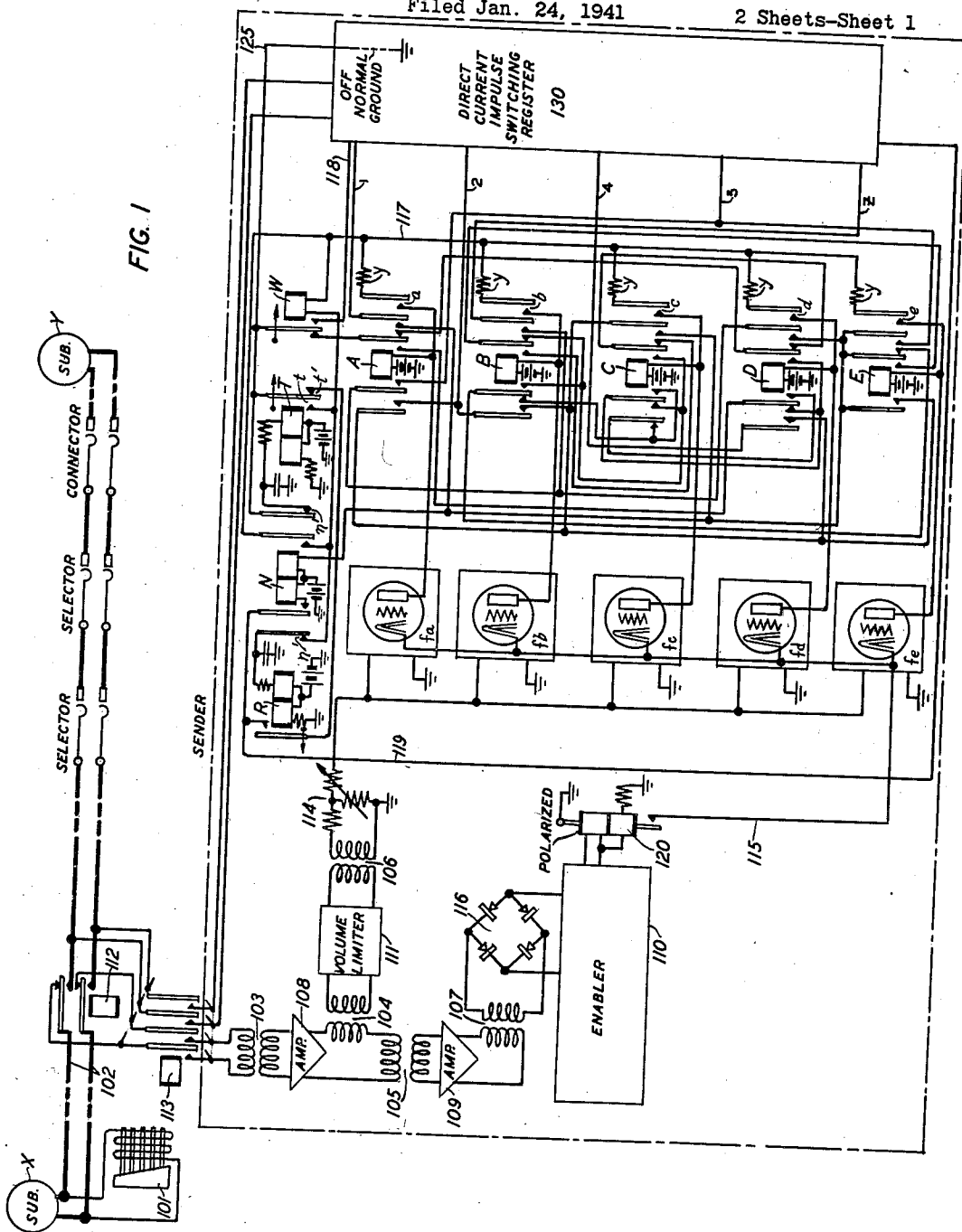
B. D. HOLBROOK

2,317,191

TELEPHONE SYSTEM

Filed Jan. 24, 1941

2 Sheets-Sheet 1



INVENTOR
B. D. HOLBROOK
BY
P. C. Smith
ATTORNEY

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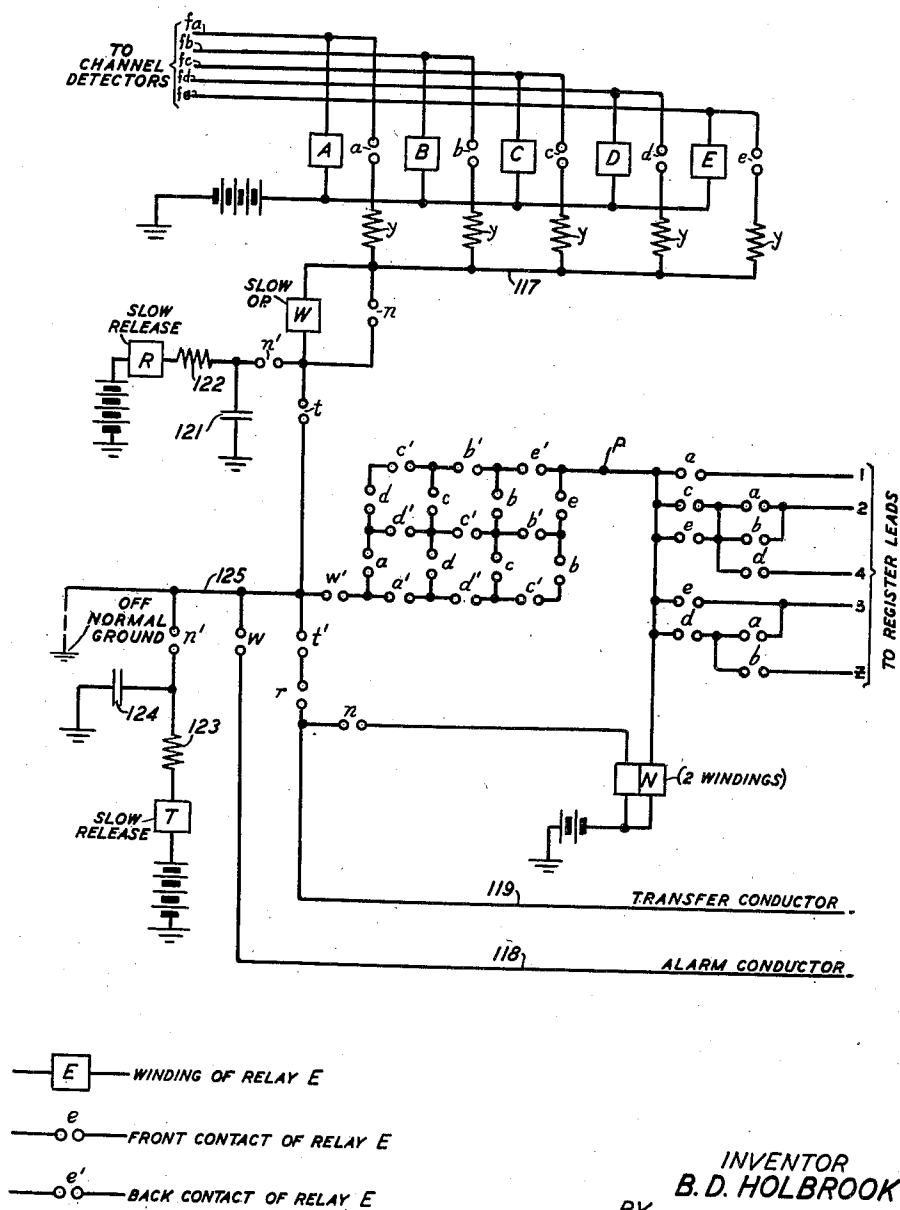
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2 Sheets-Sheet 2

FIG. 2



INVENTOR
B. D. HOLBROOK
BY
P. C. Smith
ATTORNEY

UNITED STATES PATENT OFFICE

2,317,191

TELEPHONE SYSTEM

Bernard D. Holbrook, Madison, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application January 24, 1941, Serial No. 375,713

10 Claims. (Cl. 179—18)

This invention relates to telephone systems and more particularly to receiving equipment operably connectable with or forming an integral part of a transmission line over which alternating current signals, preferably within 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 instance, in the copending application of G. Hecht and A. A. Lundstrom Serial No. 355,712, filed September 7, 1940. 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 terminating 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 into a setting equivalent to that which would be produced, say, by a number of direct current impulses indicated by the original alternating current impulse. For instance, in automatic telephone areas wherein register senders responsive to a station dial are used to selectively position automatic switches, the area itself may be enlarged by the incorporation therein of telephone lines which are adapted to transmit wanted designations by alternating current frequency impulses of the kind indicated above, and the register senders will have to be modified to receive the new impulses on special registers adapted for the purpose. From these registers, the direct current impulse registers are then operated to take the same setting they would have taken had they been operated in response to a station dial by the num-

ber of direct current impulses indicated by the one alternating current frequency impulse. Line extending switches are then controllably positioned by the direct current impulse registers.

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 and electronic tube devices intermediate the two registers for effecting the translation. In the present invention, however, no auxiliary devices of any kind are used between the two registers, the translation being effected by the channel relays of the alternating current impulse register when operating directly in response to the signal frequencies that activate the corresponding detectors of the register. In this manner considerable economy of apparatus is obtained.

Accordingly, one feature of the invention is a relay in each channel which is operatively associated therewith and with one or more corresponding relays in other channels whereby their operation, in the combination required by the frequencies in an alternating current impulse designating a digit or character, activates one or more of a group of conductors intermediate the frequency impulse register and the direct current register by means of which the latter is set to register the digit designated by the frequencies in the impulse which caused the operation of the channel relays of the alternating current impulse register.

In accordance with another feature of this invention the decoding circuit is "self-proving"; that is, will fail to activate the required conductors connecting with the register to be set if the number of channel relays operated is more or less than the precise number called for by any digit or character indicated by the transmitted alternating current impulse and further provides in such an event a suitable alarm that will direct attention to the failure. 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 whatever signaling code is used, albeit the frequencies themselves will be present in the different combinations required by the code for each different digit or character.

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:

Fig. 1 shows schematically certain elements of the telephone system more completely disclosed in

Patent 2,237,742, issued to A. A. Lundstrom on April 8, 1941, and in which certain other elements to which my invention more directly relates are shown in detail; while Fig. 2 shows an "algebraic" representation of the circuit and apparatus of the invention by which the manner in which the decoding arrangement is arrived at is more readily understood.

Referring, now, to Fig. 1, 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 and the channel detectors *fa*, *fb*, *fc*, *fd* and *fe* individually so designated in accordance with the frequency to which each of the channels is respectively assumed adapted to respond. Each channel includes a band-pass filter (not shown), a detector amplifier tube and a relay such as relay A, for example, in the anode circuit thereof which operates when the tube is rendered conductive by the application thereto of the signal current carried by the frequency in the signal for which the band-pass filter of the channel is adapted to pass. A common direct current impulse switching register 130 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 channel relays in the manner shown in the drawing and, on the register side, with a relay or other electromagnetic device (not shown) which is adapted for operative response whenever a potential is applied to its associated conductor. In the drawing, the register 130 is indicated 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. 1 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. The register 130 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 connectible to conductors 1—Z through a plurality of appropriate transfer devices which would be controlled over conductor 119. However, any other switching medium settable over conductor 1—Z in accordance with a defined code will be equally appropriate, and it is understood that no limitation is intended for my invention by reference to the above sender 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 channels *fa*—*fe*, except for the modification in the use of relays A—E 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 a relay in the anode circuit of its detector amplifier circuit and responsive to a frequency in the incoming signal impulse will be equally applicable in the operation of my 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 the 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 contact 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 adjoining those responding to the frequencies of the input signal, by currents present in the frequency spectrum which are 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 (not shown) to the grids of the detector tubes *fa*—*fe* in each of the chan-

nels. Since these tubes are normally inactive by virtue of the absence of ground on conductor 115, the two channels which are to respond to the two frequency components in the current transmitted through the variable resistance pad 114 do not operate at this time.

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 interval ground is applied to conductor 115 and, therethrough to the cathodes of the channel detectors *ja-fe* in order to sensitize them for response to the incoming signal. 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 will do, the enabler is neither shown nor described in detail, reference being had to the above-mentioned copending application Serial No. 355,712 for a detailed showing and description thereof.

Returning, now, to the operation of the channel detectors subsequent to their activation by the application of ground to conductor 115, 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 appropriate combinations; second, that each impulse so transmitted will cause the operation of the corresponding channel detectors and channel relays A-E as indicated in the following code and, third, that to register a digit in the register 130 in consequence of the operation of the indicated channel relays, ground must be applied to the register conductors shown below opposite the channel relays operated for the digit:

Digit	Frequency impulse code channel relays	Direct current impulse code for registering the digit in register 130 conductors grounded
1-----	AB	1
2-----	BC	2
3-----	AC	1-2
4-----	CD	4
5-----	CE	5
6-----	AD	1-5
7-----	BE	2-5
8-----	AE	1-2-5
9-----	DE	4-5
0-----	BD	Z

Accordingly, when a digit key of device 101 is depressed in accordance with the digit to be transmitted, the two appropriate frequencies indicated by the above code for the digit are generated and transmitted into the sender, pass

through variable pad 114 and the filter devices (not shown) before the detector tubes of all the channels, and into the detector tubes of the two channels which are adapted to respond to the two frequencies transmitted. After the channel tubes are sensitized by the application of ground to conductor 115 via the enabler 110 as above described, the tubes of the channels involved for the frequencies transmitted operate to cause current to flow through their respective anode circuits whereby the relays in the group of relays A-E of the activated channels will operate. With the operation of these relays, one condition which is to be satisfied for the correct registration of the code of the digit in the register 130 according to its code as above indicated is that two and only two channels will have been activated and, therefore, that their corresponding relays will have operated. A failure to operate only two channel relays will cause a failure of registration and will further cause an alarm signal to be transmitted to a register to indicate the fact.

The arrangement of the circuit to produce these results will be much easier to follow if the schematic diagram of the circuit does not associate relay contacts with the relays on which they are located, such a diagram of the circuit being shown in Fig. 2, which has been drawn up following the method of analysis described by Claude E. Shannon in "A Symbolic Analysis of Relay and Switching Circuits" published in the *Translations of the American Institute of Electrical Engineers*, volume 57, page 713. In this figure, the relays shown are the same as those of the circuit of Fig. 1 and are similarly identified except that the symbols are differently arranged. These symbols may be briefly explained as follows: Each rectangle represents a relay winding, each pair of (slightly separated) circles a relay contact. The capital letter within each rectangle identifies a particular relay, and the small letter alongside a set of contacts identifies a set of contacts on the relay bearing the capital letter designation, while the front and back contacts of the relays are distinguished by the absence or presence, respectively, of a prime on the identifying letter. Thus a contact marked (*e*) is a front contact on relay E, one marked (*e'*) a back contact on the same relay. Other circuit elements are shown in usual form. With these few conventions understood, the schematic is followed without difficulty.

Let us first consider the means of determining whether or not exactly two channel relays are operated. To do this it is necessary to distinguish between three conditions as follows: (a) none operated, (b) two operated, and (c) one, three, four or five operated. This might be done in a number of ways but in the circuit of my invention it is done entirely by contacts on the channel relays, first, by determining if exactly two channel relays are operated, second, if exactly two are not operated and, third, if any other number of channel relays is operated.

Referring to Fig. 2, and assuming relay W unoperated, and, therefore, having its back contacts *w'* closed, examine the path from off-normal ground to the point marked P. First note that the front and back contacts on each channel relay are so arranged that, starting from the lower left-hand corner and passing through the back contacts *w'*, it is possible to

go only upward or to the right at each junction in the network. This being true, it is possible to extend ground to the point P only by passing through two front (unprimed) contacts and three back (primed) contacts, all on different ones of the channel relays. In other words, it will be possible to pass the ground along only if two relays, and two only, are operated. If ground is extended to the point P, then relay N is operated through its primary or right-hand winding, and the operation of relay N thus indicates that just two channel relays are operated.

The other two cases are distinguished by the alarm relay W. This is a slow-operate relay with its winding in parallel with a front contact of relay N in the common locking conductor 117 of the five channel relays. (The resistance y in each individual locking conductor may be required to make up for the voltage drop through the electronic detector, if the drop is large enough to warrant it.) The front contact of relay T being closed as explained hereinafter, any channel relays that operate will lock through the winding of relay W to off-normal ground. If just two channel relays operate (which is the second condition), relay N will operate before relay W, will close its front contact and will short out the winding of said relay W. The channel relays will then remain locked through the front contacts of relays N and T. If any other number of channel relays operate (which is the third condition), say, either one or more than two, relay N will not operate inasmuch as it is only possible to close its circuit through the front contacts of two operated channel relays and the back contacts of three unoperated ones as previously explained. In this case the winding of relay W will not be short-circuited, and this relay will operate and, with the operated channel relays, will remain locked through the front contact of relay T. The front contact w of relay W grounds the alarm conductor 118 and its back contact w' opens to prevent the subsequent operation of relay N on any application of ground to the register conductors 1—Z as would be the case, for instance, if a pulse operated one of the channel relays and after relay W had operated, another pulse operated another channel relay.

The requirements for grounding the various register conductors 1—Z, given in the table above, are realized by the contacts shown on Fig. 2 between these conductors and the point P. The number of contacts needed is minimized by this arrangement since the point P is only connected to ground when just two channel relays are operated. Thus, for instance, conductor Z is connected to the point P, not only when relays B and D are operated, but also when A, B and E are operated. But in the latter case conductor Z is not grounded since ground is not extended to the point P when three channel relays are operated.

The timing features are provided by the slow release characteristics of relays T and R. Arranged as shown they will operate fast, but their release will be delayed by times which are controlled through the separate condenser-resistance circuit associated with each of them. The releasing time of relay R is made greater than that of relay T by the appropriate choice of the constants of resistance 122 and condenser 121.

The details of the timing action are most easily explained by following the action of the entire

circuit through the seizure of the sender and the reception and registration of one digit.

The seizure of the sender causes off-normal ground to be applied in any suitable manner to conductor 125, whereupon relay T will operate over a circuit completed to said ground on conductor 125, through the back contact n' of relay N. Relay R then operates through the other back contact of relay N (left outer back contact, see Fig. 1) and the front contact t of relay T. Since relay T operates before relay R, its back contact t' opens the ground path to the transfer conductor 119 before the front contact of relay R closes. If no channel relays operate, the circuit will remain in this condition until off-normal ground is removed, whereupon it returns to the unoperated condition where, after an interval, relays T and R release. If off-normal ground is removed for a time greater than the releasing time of relay T but less than that of relay R, ground may be applied to the transfer conductor 119 for the (short) time required to reoperate relay T. However, since no grounds have been applied as yet to the register conductors 1—Z, this will have no effect upon register 130. In practice, furthermore, the arrangements used for furnishing off-normal ground will prevent its reapplication immediately after removal.

With relays T and R operated by off-normal ground on conductor 125, suppose that two channel relays operate. To be specific, let it be supposed that the digit 3 is transmitted from station X and that, therefore, relays A and C operate. They will lock through the winding of relay W (which, being slow to operate, maintains its back contact w' closed during the registration period) and the front contact of relay T to off-normal ground. In operating, they will extend off-normal ground through the network to the point P through the following contacts in order: a , d' , c , b' , e' , and to the register conductors 1 and 2 through other front contacts of relays A and C beyond the point P. These register grounds will be maintained as long as the channel relays are locked up.

The extension of ground to the point P also operates the relay N as previously explained. When this relay operates, one of its front contacts short-circuits the winding of the slow-operate relay W, which has not yet had time to come up, preventing its subsequent operation but maintaining the locking circuits of the operated channel relays A and C. The other front contact of relay N connects the secondary winding of relay N to the transfer conductor 119 which is, however, not yet grounded because relay T is operated and, therefore, contact t' is open. The two back contacts of N also open and remove the grounds from the relays T and R, which remain operated for the time being because of their respective slow release characteristics produced by their associated condenser-resistance networks 123—124 and 121—122, respectively.

When relay T releases, its front contact t opens and removes the locking circuit from the two channel relays A and C; its back contact t' closes and, through the front contact r of relay R, applies ground to the transfer conductor 119 and locks up relay N through its secondary winding and the previously closed contact of said relay as this relay must remain operated until it is desired to reoperate relay T. Ground on the transfer conductor 119 completes a circuit in the register 130 by which an appropriate one of the transfer devices therein is operated to transfer

conductors I—Z to a succeeding set of register relays on which will be registered, in response to the succeeding operation of the channel relays, the digit designated by said operated channel relays. With their locking ground removed, the channel relays A and C then release, removing ground from the register conductors I and 2 and also from the primary winding of relay N. The required overlap of the grounds on the register conductors I—Z and on the transfer conductor 119 is obtained by the release time of the fastest releasing channel relay.

Upon the release of relay R (after the release of relay T) ground is removed from the transfer conductor 119 and from the secondary winding of relay N which accordingly releases in turn. When the back contacts of relay N close, relay T again operates, relay R then reoperates through the front contact of relay T, and the circuit is restored to its original condition and is ready to respond to further operations of the channel relays. The operation of relay T through a back contact of relay N insures the complete restoration of the circuit when relay R releases.

Suppose, now, that some number of channel relays other than two are operated. Ground will not be extended to the point P or to the register conductors, and the relay N will not operate. Relay W, not having its winding short-circuited, accordingly operates and applies ground to the alarm conductor 118. The back contact *w'* of relay W opens the ground path to the point P and prevents subsequent operation of relay N. This prevents the release of relay T and insures that the transfer conductor 119 will not be grounded and that relay W and the channel relays will remain locked up thus blocking further registration until the off-normal ground is removed.

What is claimed is:

1. 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 a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, and a plurality of conductors selectively activated singly or in combination by an invariable number of said relays when operated, to indicate the digit or character designated by the number of frequencies in said plural frequency pulse.

2. 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 a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, and a plurality of conductors selectively activated singly or in combination by an invariable number of said relays when operated and an invariable number of other of said relays concurrently unoperated to indicate a digit or character designated by the number of frequencies in said plural frequency pulse.

3. In a telephone system, a sender therefor which is adapted for the registration of wanted designations, comprising five channel detectors each adapted to pass a specific frequency therethrough of a two-frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, and a plurality of con-

ductors selectively activated singly or in combination by two of said relays when operated and three other of said relays concurrently unoperated to indicate a digit or character designated by the two frequencies in said two-frequency pulse.

4. In a telephone system, a sender therefor which is adapted for the registration of wanted designations, comprising five channel detectors each adapted to pass a specific frequency therethrough of a two-frequency pulse designating a digit or character, a relay equipped with front and back contacts in each channel detector responsive to the frequency passed through said channel detector, a plurality of conductors selectively activated singly or in combination through the front contacts of two of said relays when operated and the back contacts of three other of said relays concurrently unoperated to indicate a digit or character designated by the two frequencies in said two-frequency pulse.

5. 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 a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, a plurality of conductors selectively activated singly or in combination by an invariable number of said relays when operated to indicate the digit or character designated by the number of frequencies in said plural frequency pulse, and an alarm device responsive to the operation of more than said invariable number of relays.

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 a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, a plurality of conductors selectively activated singly or in combination by an invariable number of said relays 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 said invariable number of relays for disabling said alarm device.

7. 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 a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, a plurality of conductors selectively activated singly or in combination by an invariable number of said relays 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 said invariable number of relays for disabling said alarm device and for locking said relays.

8. 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 a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency

passed through said channel detector, a plurality of conductors selectively activated singly or in combination by an invariable number of said relays when operated to indicate the digit or character designated by the number of frequencies in said plural frequency pulse, and an alarm device operative in response to the operation of a different number of relays from said invariable number for preventing subsequent operation of any of said channel relays on any pulse transmitted within a predetermined interval after the first pulse.

9. In a telephone system, a sender adapted for the registration of wanted designations, comprising a plurality of channel detectors each adapted to pass a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, a settable register, and circuits completed between an invariable number of said

relays when operated and said register for setting the register to indicate the digit or character designated by said plural frequency pulse.

10. 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 a specific frequency therethrough of a plural frequency pulse designating a digit or character, a relay in each channel detector responsive to the frequency passed through said channel detector, a plurality of conductors selectively activated singly or in combination by an invariable number of said relays when operated to indicate the digit or character designated by the number of frequencies in said plural frequency pulse, and an alarm device responsive to the operation of less than said invariable number of relays for indicating a received pulse containing less than the required number of frequencies.

BERNARD D. HOLBROOK.