July 4, 1939. R. V. L. HARTLEY 2,164,325

TELEPHONE SYSTEM

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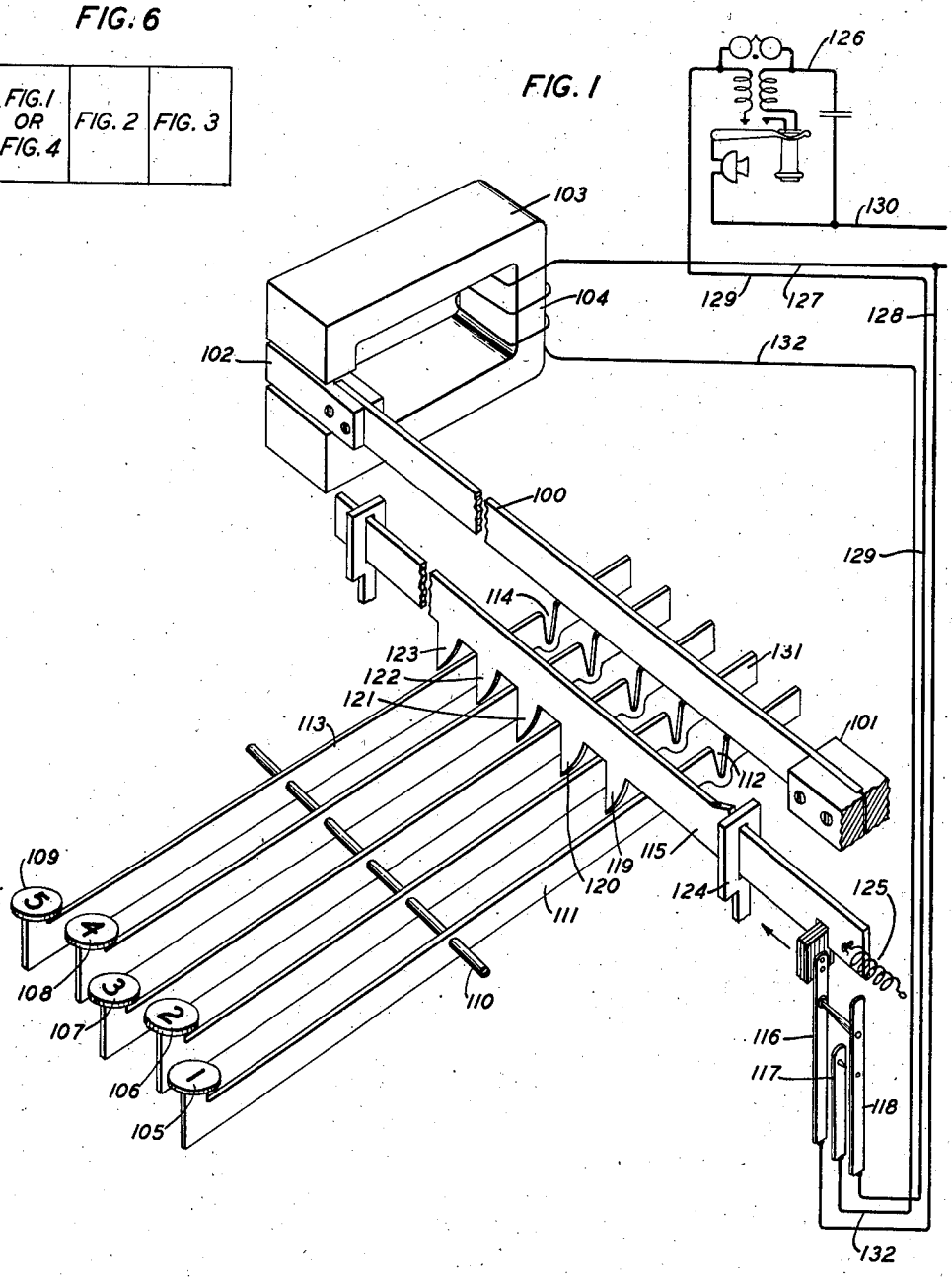
FIG. 6

FIG. 1 OR FIG. 4	FIG. 2	FIG. 3

FIG. 1



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TELEPHONE SYSTEM

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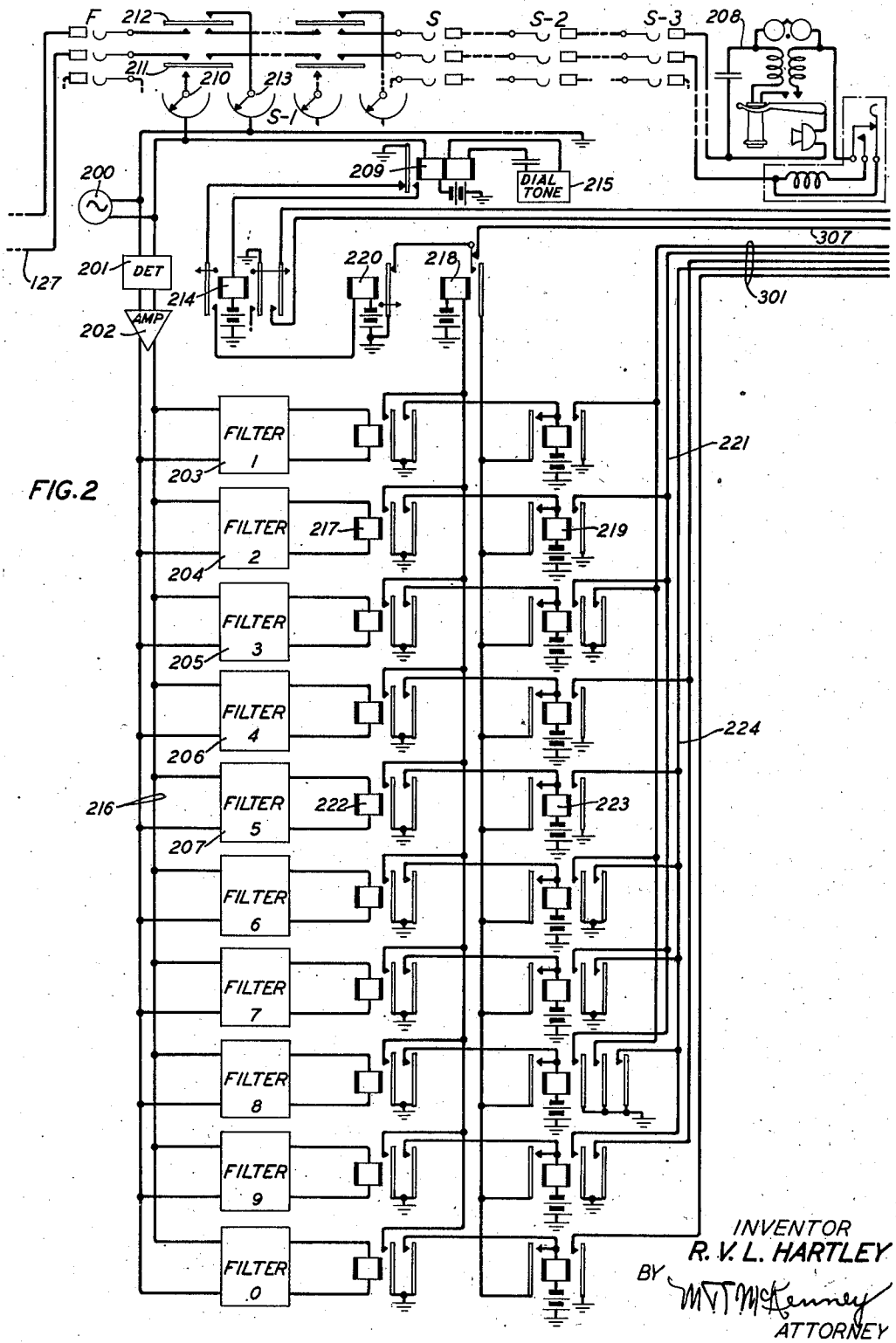

FIG. 2

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TELEPHONE SYSTEM

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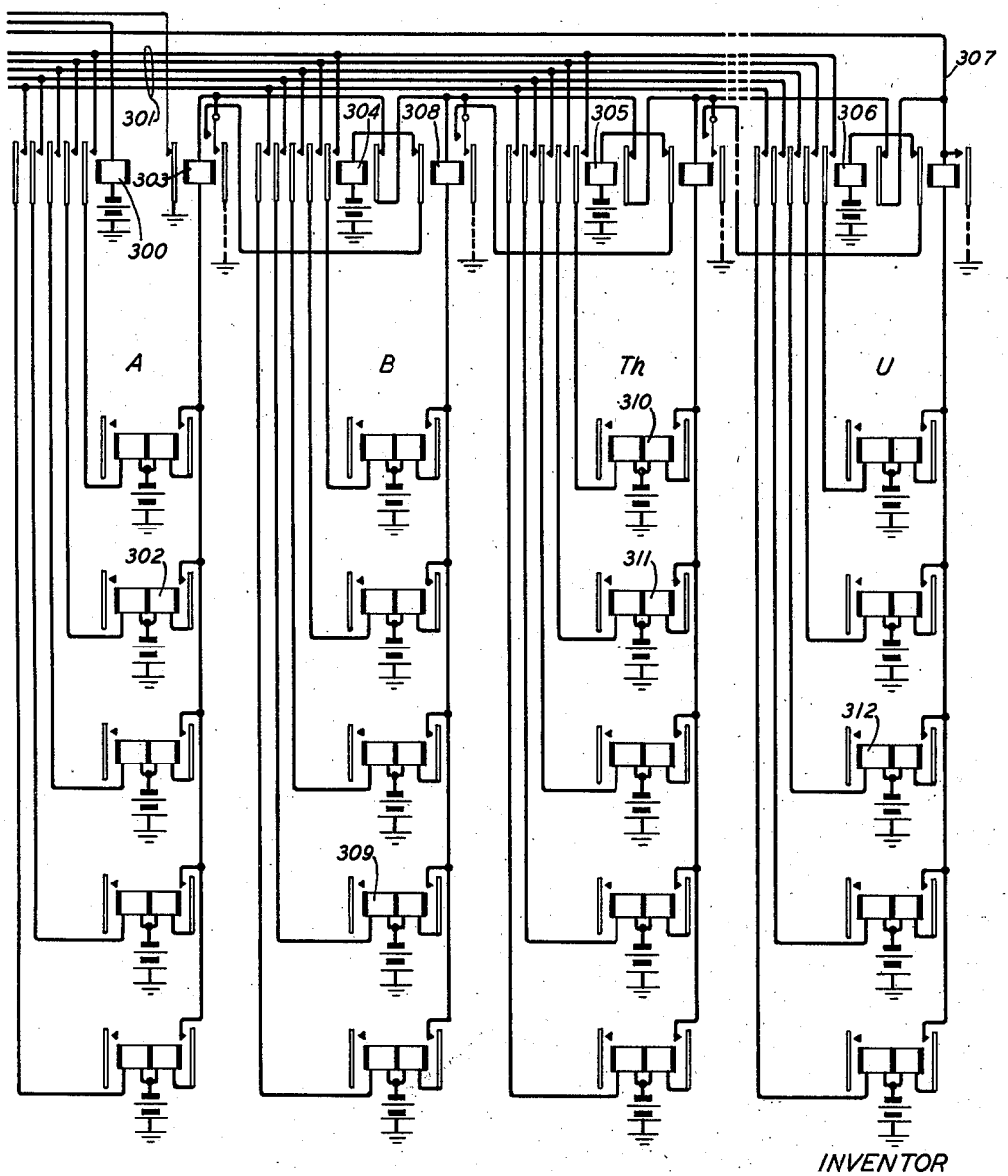
FIG. 3



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TELEPHONE SYSTEM

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FIG. 5

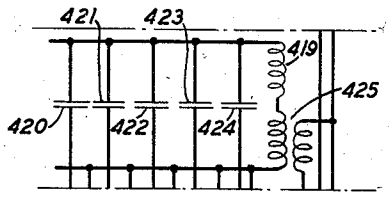

FIG. 4

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UNITED STATES PATENT OFFICE

2,164,325

TELEPHONE SYSTEM

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Application August 31, 1937, Serial No. 161,740

10 Claims. (Cl. 179—18)

This invention relates to signaling and communication systems and particularly to systems in which automatic switches are used for establishing connections.

The objects of the invention are to simplify the acts necessary on the part of subscribers and operators in transmitting and in recording signals, such as telephone designations; to improve the efficiency and to increase the speed of operation of the equipment; and otherwise to improve systems of this kind.

Systems have been proposed heretofore in which the designations of called lines or trunk circuits are transmitted from one point to another by means of currents of different frequencies, the frequencies singly or in combination serving to characterize the different numerals or other characters of the designation.

According to the present invention advantages are secured over these prior systems by providing the substation of a telephone line with an oscillatory device which may be adjusted by the subscriber to oscillate at different resonant frequencies characterizing the different digits of the wanted number. The oscillatory device may be energized by current of a relatively high frequency supplied over the line from the central office to produce in the line a resultant beat frequency current which is utilized at the central office to selectively operate the designation registers. The beat frequency characterizing the different digits of a wanted designation may be separated at the central office by selective filters to selectively operate the central office registers, which in turn control the selective operation of the switches in the establishment of the desired connection. If desired the beat frequency currents identifying the different characters of the designation may be applied, together with current from the central office source, to a beat detector, thereby obtaining currents the frequencies of which correspond to the resonant frequencies of the oscillatory device at the substation. These resultant frequency currents are then selected by suitable devices, such as filters, and utilized to register the designation.

Another feature of the invention is a system of this kind in which the oscillatory device at the substation comprises a single vibrating reed, the natural period of which is adjusted by designation keys, and which vibrates in the field of an electromagnetic device to produce the currents in the subscriber's line.

Another feature is a system of the character above described in which the oscillating device at the subscriber's station consists of an electrical circuit having reactance elements therein which are varied by the designation keys to obtain different natural frequencies of oscillation of the circuit, these resonant frequencies identifying the different characters of a subscriber's designation. The oscillating circuit is coupled to the subscriber's line by means of a transformer which is preferably designed to operate on the curved portion of its flux density characteristic. In this way the current in the line supplied from the central office source energizes the oscillating circuit, and the frequency of the oscillatory circuit combines with the frequency in the line to produce therein a resultant current of beat frequency. The beat frequency currents thus produced in the line are received at the central office in the manner above described, and they are utilized to register the designations.

These and other features of the invention will be described more fully in detail in the following specification and will also be set forth in the appended claims.

In the drawings, Figs. 1, 2 and 3, when arranged in the order shown in Fig. 6, illustrate an automatic telephone system embodying the principles of the invention.

Fig. 1 shows a subscriber's station and illustrates the structure of one form of the number transmitter;

Figs. 2 and 3 disclose the central office in which the subscriber's line terminates and shows in detail the number recording mechanism;

Fig. 4 illustrates an alternative form of the number sending device for use at the subscriber's station; and

Fig. 5 shows a modification of the tuned circuit used in the sending mechanism of Fig. 4.

Experiments have shown that vibratory and oscillatory devices, such as vibrating reeds and oscillating circuits, may be caused to oscillate at their natural periods with considerable ease and with the expenditure of relatively small amounts of energy by exciting the driving elements of these devices with currents of frequencies much higher than the natural vibration frequencies of the devices themselves. By taking advantage of this fact in the present system it is possible to drive an oscillatory device at a subscriber's substation at any one of a number of relatively low frequencies, each of which can be selected to characterize a number or letter of a subscriber's telephone designation, by providing a source of relatively high frequency current at the central office and applying it to the

line for the purpose of exciting the oscillatory device at the substation. If the oscillatory device at the substation is of the type shown in Fig. 1, comprising a vibrating reed having a magnetic element arranged in the field of the exciting coil, the mechanical vibration of this reed in said field produces in the coil and in the line currents of two principal frequencies. One of these is the sum of the frequencies of the exciting current and of the vibrating reed, and the other is the difference of these two frequencies. By properly designing the impedance of the line, it is possible to substantially suppress the sum-frequency currents, leaving the difference-frequency currents predominating in the line for transmitting the telephone designations to the central office. When the sending mechanisms shown in Fig. 4 or in Fig. 5 are used at the substation the vibrating reed is replaced by an oscillatory electric circuit comprising a variable reactance. This circuit is coupled to the subscriber's line by means of a transformer, and by operating the transformer on the non-linear portion of its flux density characteristic, the circuit is caused to oscillate by the presence of the high frequency current flowing in the subscriber's line. The oscillatory circuit operating at its natural frequency causes the sum and difference frequency currents to flow in the subscriber's line. These currents, like those produced by the sending device of Fig. 1, are utilized as will be explained hereinafter to record the wanted numbers at the central office.

Before proceeding to the operation of the system, a description will be given of the equipment used, including the structure of the substation sending mechanisms and the receiving and register circuits of the central office.

The sender or transmitter shown in Fig. 1 comprises a vibratory reed 100 secured to the mounting 101 and equipped at its free end with a magnetic element or armature 102. The armature 102 lies between the pole-pieces of the core 103 on which an exciting coil 104 is wound. The sender also includes a keyboard having the necessary number of individual keys to characterize the numerals and letters which make up the designations of subscribers' lines. Five of these keys are illustrated, keys 105, 106, 107, 108 and 109, but as many more as are necessary may be provided. The key levers are arranged perpendicularly with respect to the reed 100. They are pivoted on rod 110 and extend so that their free ends lie in close proximity to the vibratory reed 100. Each of these key levers is provided with a notch or slot so arranged that when the key is tilted the notch encompasses the reed 100 at a point along the length of the reed which depends upon the particular key involved. These notches are tapered so that the reed is wedged and held firmly in position by the operated key. For example, if key 105 is depressed, the key lever 111 rotates about the rod 110 and the V-shaped notch 112 near the end of said lever engages the reed 100 and holds it firmly against vibration at the point of engagement. The effect of this is to shorten the vibratory portion of the reed by a given amount. Similarly if the key 109 is depressed the corresponding lever 113 is tilted and the notch 114 in the end thereof engages and fixes the reed 100, thereby shortening the vibratory portion of the reed to a corresponding extent. Thus the several keys, which represent different digits or characters, determine the effective length and correspondingly the frequency at which the reed will vibrate during the time it is engaged and held by any one of these keys. In addition to these elements the transmitting mechanism is provided with a cam bar 115 for operating the circuit contact springs 116, 117 and 118. The bar 115 is provided with a series of cams 119, 120, 121, 122, 123, etc., one for each of the several key levers. Normally the cam bar 115 is held against the stop member 124 by means of the retractile spring 125, in this position holding the contact springs 116 and 118 closed and holding the contact springs 117 and 118 open. When any one of the keys is depressed its lever engages the corresponding cam on the bar 115 and forces the bar against the spring 125, permitting contact spring 116 to disengage spring 118 and permitting spring 118 to engage spring 117. The purpose of these springs will be described hereinafter.

The keyboard structure used in the transmitter of Fig. 4 is similar to the one shown in Fig. 1. The vibratory reed and magnetic element is replaced with a series of circuit contacts and a tuned electrical circuit 400. The key levers 401, 402, 403, 404 and 405 are pivoted on the rod 406 and their free ends serve to close the respective contacts 407, 408, 409, 410 and 411. The oscillatory circuit 400 comprises a variable inductance 412, a capacitor 413, and the secondary winding of the transformer 414. Taps are taken from the inductance 412 at separated intervals and connected to the key operated contacts in such a way that the manipulation of any particular key closes the oscillatory circuit and includes therein a corresponding amount of the inductance. The primary winding of the transformer 414 is connected in the subscriber's line. This transmitter, like the one in Fig. 1, is provided with a cam bar 415 which serves to operate the contact springs 416, 417, 418 when any one of the keys is depressed.

The oscillatory circuit illustrated in Fig. 5 is similar to the one connected to the keyboard of Fig. 4 except that the key operated contacts serve to include variable amounts of capacity in circuit with a fixed inductance 419. The variable amounts of capacity are obtained by the individual capacitors 420, 421, 422, 423 and 424. There will be as many of these individual capacitors as are necessary to give the required number of characters. The oscillatory circuit is connected to the line by means of a transformer 425.

A brief description will now be given of the circuits and other equipment at the central office. The subscribers' lines, each of which is equipped with a transmitter, such as those shown in Figs. 1, 4 and 5, extend to the central office and appear in line finder switches, such as the finder F. The finder F serves to extend a calling line through to the first selector S and a sender selector switch S—1 serves to extend the calling line to one of the common central office register senders, such as the one shown in the lower part of Fig. 2 and in Fig. 3. The common register sender includes a number of controlling relays and consists essentially of a frequency detecting and selecting mechanism and a number of relay registers. A source 200 of alternating current of suitable frequency is provided for supplying the subscriber's line with the current to excite the substation transmitter. The alternating currents representing the designations are detected by a detector 201 amplified by an amplifier 202 and applied to a series of selective

filters 203, 204, 205, 206, 207, etc. The number of digital registers will depend upon the size of the exchange area. It may be assumed that the designations in this particular area consist of two letters and four numerical digits. The letter designations are recorded on the relay registers A and B and the numerical designations are recorded on four relay registers, two of which, the thousands and units registers, are shown. The intermediate hundreds and tens registers will be the same as those shown and have been omitted for the sake of simplicity. The alternating currents transmitted over the subscriber's line and having frequencies representing the different designation characters are selected by the filters 203, 204, etc. and then cause the operation of the register relays to register these designation characters for further use in controlling the selective switches S, S—2 and S—3 to complete the connection through to the called subscriber's line.

It will be understood, of course, that the register senders to which this invention has been applied include functions and equipment that have been omitted in the present disclosure for the sake of simplicity. For example, the registers, having registered the code and numerical information received from the calling subscriber's line, control the selective operation of the switches to extend the calling line to the called subscriber's line either in the same or in the distant office. For a better understanding of the manner in which the sender performs the functions that have been omitted in the present disclosure, reference is made to the patent to Raymond et al., No. 1,862,549 of June 14, 1932 and to the patent to Stearn and Scudder, No. 1,395,977 of November 1, 1921. Also the line finder and selector switches, illustrated diagrammatically in the drawings, may be of any well-known types such as those disclosed in the Raymond et al. and in the Stearn et al. patents above noted.

The operation of the system will now be described, and for this purpose it may be assumed that the subscriber at station 126 wishes to call the subscriber at station 208. Assume further that the designation of substation 208 is AL—1234 and that the letter A is the equivalent of the numeral 2 and that the letter L is the equivalent of the numeral 5. When a subscriber at station 126 lifts his receiver to initiate the call, the line circuit is closed, and the finder F is started in operation in the usual way to seize the calling subscriber's line. At the same time the sender selector S—1 becomes effective to extend the calling subscriber's line through to an idle sender. When these operations have been completed, a circuit is closed from battery through the left winding of the line relay 209 in the sender, over brush 210, contact of spring 211 on a controlling sequence switch, thence over the brush of finder F, over conductor 127 of the subscriber's line, conductor 128, closed springs 116 and 118, conductor 129 through the switchhook contacts and returning over conductor 130 through the upper brush of finder F and sequence switch contact 212, brush 213 of sender selector S—1 to ground in the sender. The sequence switch referred to herein may be of the type well known in automatic systems of the kind in which panel selector switches are used. The line relay 209 operates in this circuit and closes an obvious circuit for the slow-release relay 214. Relay 209 operates only in response to the flow of direct current through the operating circuit above traced and does not operate in response to the energy received from the alternating current source 200. Relay 214 closes an obvious circuit for relay 300 and the latter relay operates and extends the register operating conductors 301 through to the windings of the relays of the first code register A preparatory to the operation of these relays. At the same time a tone is sent from the tone device 215 to notify the calling subscriber that the central office equipment is ready to receive the wanted designation.

The calling subscriber now manipulates the key 106 which characterizes the first letter A in the designation of the called subscriber. Key 106 tilts the lever 131 and fixes the period of vibration of the reed 100 to a frequency characterizing the letter A. At the same time the cam lever 115 shifts the springs 116, 117, 118, so that the circuit extending from the central office now leads by way of conductor 127 through the coil 104, conductor 132, through the closed springs 117 and 118, conductor 129, thence through the substation switchhook contacts and over conductor 130 as previously traced. The springs 116, 117 and 118 are so arranged that the continuity of the line circuit is preserved while the coil 104 is being introduced into said line circuit. Since the coil 104 is now included in the line circuit, alternating current from the source 200 flows over this circuit and through the coil 104. As previously mentioned the current generated by source 200 may have a frequency that is substantially higher than the natural frequency at which the reed 100 vibrates. While the invention is not so limited, a frequency of 1000 to 3000 cycles would be suitable for the source 200, whereas the frequencies at which the tuned reed vibrates would be of a much lower order. The high frequency current flowing through the coil 104 causes the reed 100 to vibrate at the natural frequency determined by the depressed key 106. The vibrating armature 102 in the field of coil 104 produces in the line circuit a beat frequency equal to the difference between the frequency of the source 200 and the frequency of vibration of the reed 100. This beat frequency current flowing over the line is applied to the detector 201 together with current from the source 200. The detecting operation therefore produces in the output circuit of the detector a resultant current having a frequency equal to that of the vibrating reed 100. This resulting frequency current is amplified by a suitable amplifier 202 and is applied to the input circuits of the several filters connected to the common circuit 216. There are as many of these filters as there are keys at the subscriber's station and the several filters are selectively designed to pass the frequencies corresponding to the respective keys at the substation. Therefore, the frequency resulting in the circuit 216 from the depression of key 106 is selectively passed by the filter 204 and is excluded by all other filters connected to the calling circuit. Current passing through the filter 204, and amplified, if necessary, causes the operation of relay 217. The relay 217 operates common relay 218 and also operates relay 219. Relay 219 locks in a circuit from battery through its winding and left contact through the make-before-break contact of relay 218 to ground at the back contact of relay 220. Relay 219 at its right contact connects ground over conductor 221 through a contact of relay 300 to battery through the left winding of relay 302. Relay 302 operates to register the digit and prepares to lock in a circuit which will presently be described. When the key 106 is

released by the subscriber, contacts 116, 117 and 118 restore to normal and the coil 104 is removed from the line circuit. Current, therefore, ceases to flow in the filter circuit 204 and relay 217 releases, in turn releasing relay 218. Relay 218 in releasing closes its normal contacts before opening its front contacts. Therefore, before the locking circuit of relay 219 is opened to permit the release of this relay, a holding circuit is closed as follows for the register relay 302: battery through the right winding and contacts of said register relay, winding of relay 303, right normal contacts of relays 304, 305, 306, conductor 307, normal contacts of relay 218 to ground at the contact of relay 220. Relay 302 locks in this circuit, and relay 303 operates. When relay 218 fully releases, it opens the locking circuit of relay 219, and the latter relay releases. Relay 303 releases relay 300 to disconnect the common leads 301 from register A. Relay 303 also closes an operating circuit for relay 304. This circuit may be traced from battery through the winding of relay 304, normal left contact of relay 308 to ground at the contacts of relay 303. Relay 304 operates and extends the leads 301 through to the register B. The operated register relay 302 and relay 303 are now held in a circuit extending to ground through the front contacts of relay 303. The equipment is now in readiness for the receipt of the second digit of the called designation.

When the subscriber manipulates key 109 to transmit the second letter L, the effective vibratory length of the reed 100 is fixed accordingly and the coil 104 is introduced into the line circuit. The vibration of reed 100 sets up a current of a corresponding frequency in the line, and this current is detected, amplified and applied to the common circuit 216. Since the detected current corresponds to the digit 5 it is passed by the selective network 207 and relays 222, 223 and 218 operate. Relay 223 locks as above described and applies ground to the common conductor 224, which now extends through the contact of relay 304 to operate the register relay 309 of the register B. When the subscriber releases the key 109, the coil 104 is removed from the circuit and relays 222 and 218 release. Relay 218 in releasing closes a locking circuit for relay 309 traceable from the right winding and contact of said relay, winding of relay 308, thence as previously traced over conductor 307 to ground. Relay 309 locks and relay 308 operates in this circuit before the holding circuit of relay 223 is broken. On the full release of relay 218, the holding circuit of relay 223 is open and the latter relay releases. Relay 308 in operating causes release of relay 304 to disconnect the leads 301 from the register B. Relay 308 also closes an obvious circuit for the operation of relay 305 which extends the leads 301 through to the relays of the thousands register Th. The operated register relay 309 and relay 308 now hold in a circuit extending to ground through the right contacts of relay 308.

In a similar manner the depression of the keys corresponding to the four numerical digits cause the operation of relays of the thousands, hundreds, tens and units registers. The depression of key 105 for the thousands digit 1 produces a current in the common circuit 216 which is passed by filter 203 to cause the ultimate operation of register relay 310 of the thousands register. The depression of key 106 for the hundreds digit 2 causes the operation of a relay in the hundreds register corresponding to the relay 311 of the thousands register. The manipulation of key 107 for the tens digit causes the operation of two relays of the tens register corresponding to relays 310 and 311 of the thousands register. Finally the manipulation of the key 108 for the units digit 4 causes the operation of units register relay 312.

In a manner well known in the art the operated register relays now serve to control the selective operations of the switches S, S—2 and S—3 to complete the extension of the calling line through to the called line 208. Thereafter the register sender is restored to normal and the parties converse with each other. At the end of conversation release of the switching equipment also takes place in the well-known manner.

If desirable the subscriber's station may be equipped with a number sender, utilizing a tuned electrical circuit for producing the characteristic currents in the line. Fig. 4 shows a sender of this kind, and this figure may be substituted for Fig. 1 to illustrate the system and its operation when the oscillatory circuit is used instead of the vibrating reed. The natural frequency of oscillation of the tuned circuit 400 is adjustable to the desired values by means of the keys. By properly designing the elements in the system including the coupling transformer 414, it is possible to have the transformer operating on the curved portion of its flux density characteristic. By so doing, the energy from the high frequency source 200 causes the circuit 400 to oscillate at any one of its natural frequencies as determined by the key depressed. The oscillation of the circuit 400 produces beat frequency currents in the line and these are detected and amplified and applied to the filters in the manner already described.

If desirable the variable inductance oscillating circuit 400 may be replaced by the oscillating circuit of Fig. 5 which has a variable capacity.

What is claimed is:

1. The combination in a signaling system of a line having a station thereon, a source of alternating current of a given frequency, means for connecting said source to said line to supply current thereto, an oscillating device at said station responsive to current from said source to oscillate at its natural frequency, means for combining the frequency of said source and the frequency of said oscillating device to produce in said line a current of a resultant frequency, and means selectively operable in response to said resultant frequency current.

2. The combination in a signaling system of a line having a station thereon, a source of alternating current of a given frequency, means for connecting said source to the line to supply current thereto, an oscillating device having a plurality of resonant frequencies and operable in response to current flowing in said line from said source to produce in the line currents of frequencies corresponding to said resonant frequencies, said resonant frequencies characterizing different characters of a designation, means to adjust said device to oscillate at any desired resonant frequency, and selective means responsive to the currents produced in said line for registering the characters in a designation.

3. In combination, a line having a station thereon, a source of alternating current of a relatively high frequency, means for connecting said source to said line to supply current thereto, an oscillating device at said station operable at a relatively low natural frequency in response to the high frequency current flowing in said line to produce in said line currents of beat frequency,

means for varying the natural frequency of oscillation of said oscillating device in accordance with the digits of a telephone designation to vary the frequency of said beat frequency currents, and means selectively responsive to said beat frequency currents to register the designation of a telephone line.

4. In combination, a line having a station thereon, a source of alternating current of relatively high frequency, means for connecting said source to said line to supply current thereto, an oscillating device at said station operable at a relatively low natural frequency in response to the high frequency current flowing in said line to produce in said line currents of beat frequency, means for varying the natural frequency of oscillation of said oscillating device in accordance with the digits of a telephone designation, means for detecting said beat frequency currents to obtain currents of frequencies corresponding to the natural frequencies of said oscillating device, and means for utilizing said detected currents to register the designations of telephone lines.

5. The combination in a telephone system of a line having a station thereon, a vibrating reed, means for varying the natural period of said reed to characterize the digits of a telephone designation, means controlled over said line for driving said reed, means responsive to the vibration of said reed for producing in said line currents of corresponding frequencies, and means for utilizing said currents to control the selective extension of telephone connections.

6. The combination in a telephone system of a line, a single vibratory reed, manual means for variably determining the natural period of vibration of said reed to characterize the different digits of a telephone designation, a source of current for driving said reed to produce in said line currents having frequencies corresponding to the vibration frequencies of said reed, and means for utilizing the currents in said line to register the designations of telephone lines.

7. The combination in a communication system of a line having a station thereon, an oscillatory circuit at said station having a plurality of natural periods of oscillation, means for determining the oscillatory periods of said circuit to characterize the digits of a designation, a source of alternating current for causing said circuit to oscillate, means for combining the frequencies produced in said oscillatory circuit with the frequency of said source to produce in the line currents of resultant frequencies, and means responsive to said resultant-frequency current for registering telephone designations.

8. The combination in a telephone system of a line having a station thereon, a source of alternating current and means for connecting the same to said line, an oscillatory circuit at said station including a variable reactance, manual means at the station for including variable amounts of said reactance in said oscillatory circuit to vary the natural period of oscillation thereof, means for coupling said oscillatory circuit to said line to produce in said line currents having frequencies resulting from the combination of the frequencies of oscillation and the frequency of said alternating current source, and means controlled by said resultant-frequency currents in said line for registering the designations of telephone subscribers.

9. The combination in a telephone system of a line having a substation thereon, a designation sender at the substation comprising a single vibratory reed and keys for variably fixing the natural period of vibration of said reed to characterize the digits of a telephone designation, automatic switches, a source of current for driving said reed to produce in said line currents having frequencies corresponding to the natural periods of vibration of said reed, and means responsive to the currents flowing in said line for controlling the selective operation of said switches to extend said line.

10. The combination in a telephone system of a line having a substation thereon, a vibratory reed at said substation and designation keys for variably fixing the natural period of vibration of said reed to characterize the digits of a telephone designation, a source of alternating current connected to said line for driving said reed, means for combining the frequencies of vibration of said reed with the frequency of said source to produce in the line currents of resultant frequencies, a central office to which said line extends, automatic switches in said central office, means at the central office for demodulating said resultant-frequency currents to obtain currents having frequencies corresponding to the vibratory periods of said reed, and means responsive to the currents thus obtained for controlling the selective operation of said switches.

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