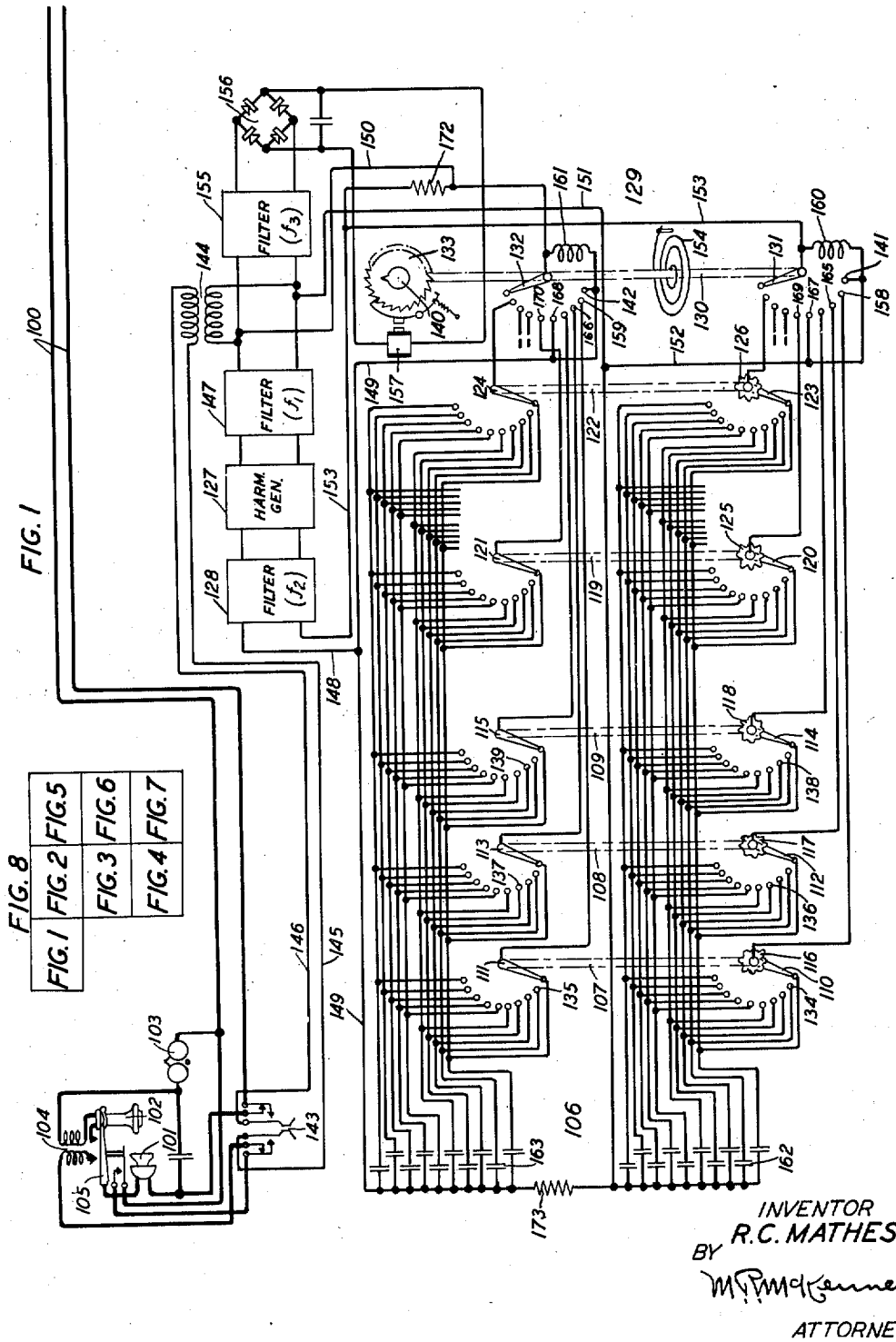
Sept. 30, 1941. R. C. MATHES 2,257,568

COMMUNICATION SYSTEM

Filed June 14, 1939 7 Sheets-Sheet 1



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COMMUNICATION SYSTEM

Filed June 14, 1939 7 Sheets-Sheet 2

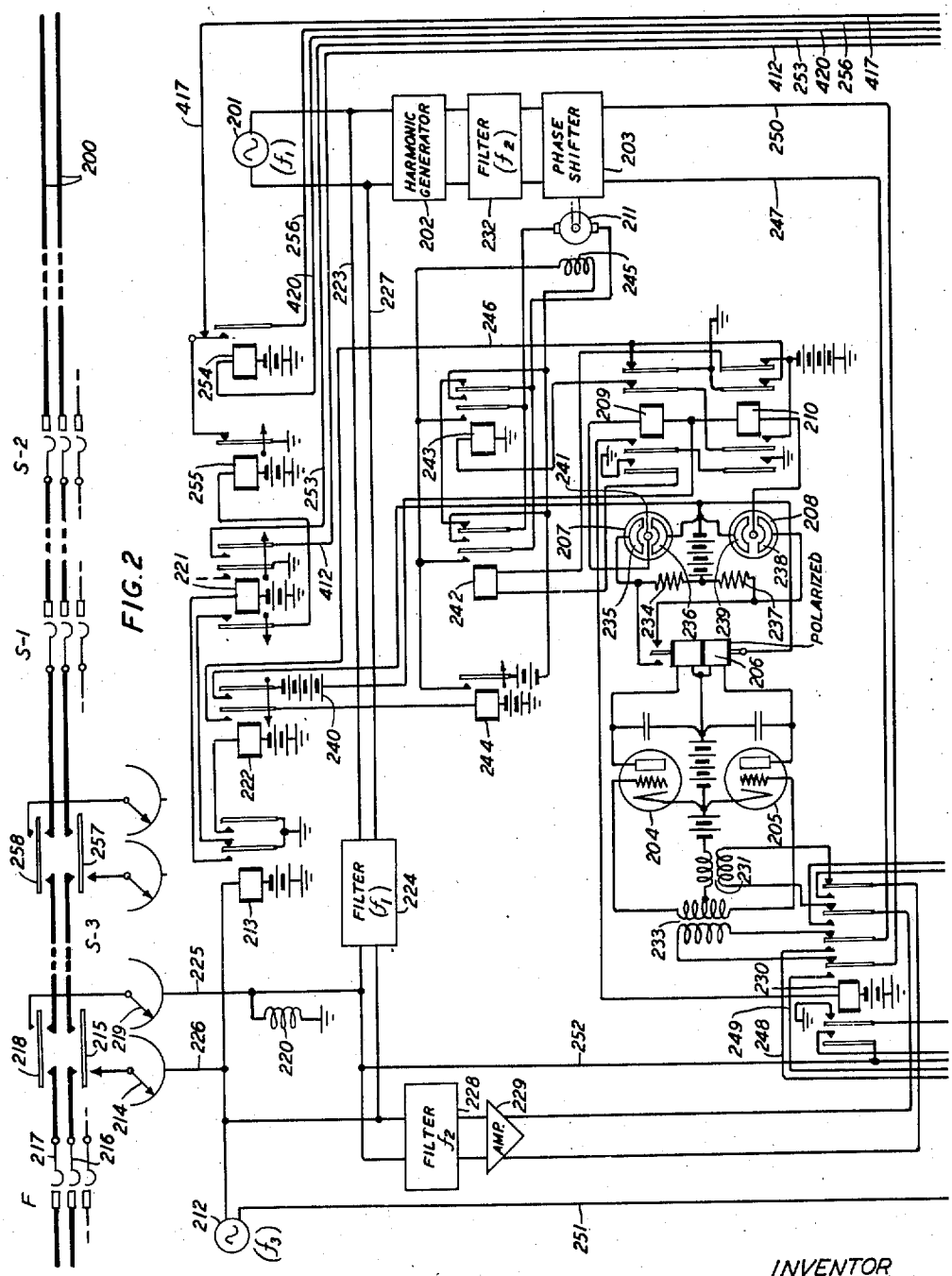

FIG. 2

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COMMUNICATION SYSTEM

Filed June 14, 1939 7 Sheets-Sheet 3

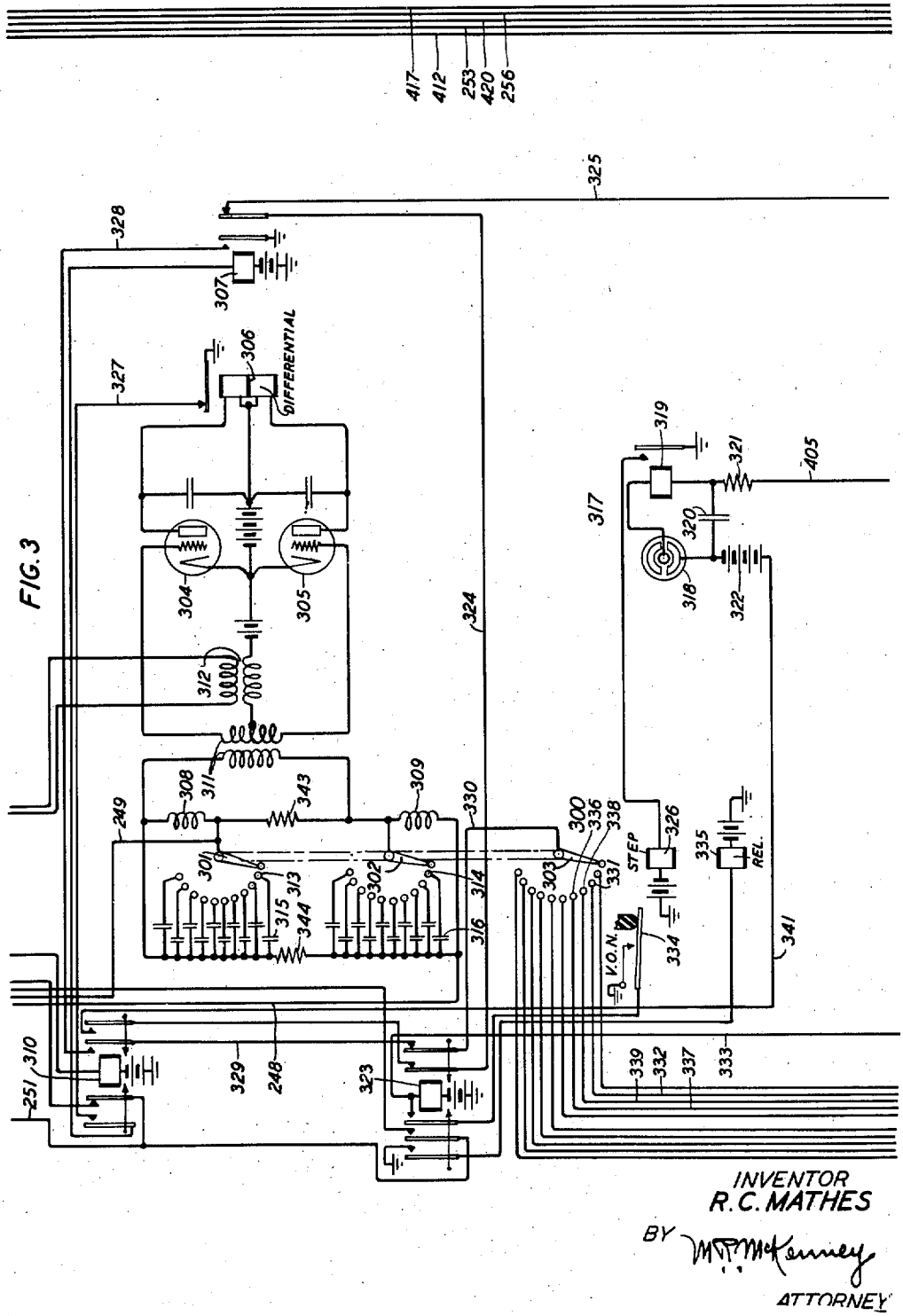

FIG. 3

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COMMUNICATION SYSTEM

Filed June 14, 1939 7 Sheets-Sheet 4

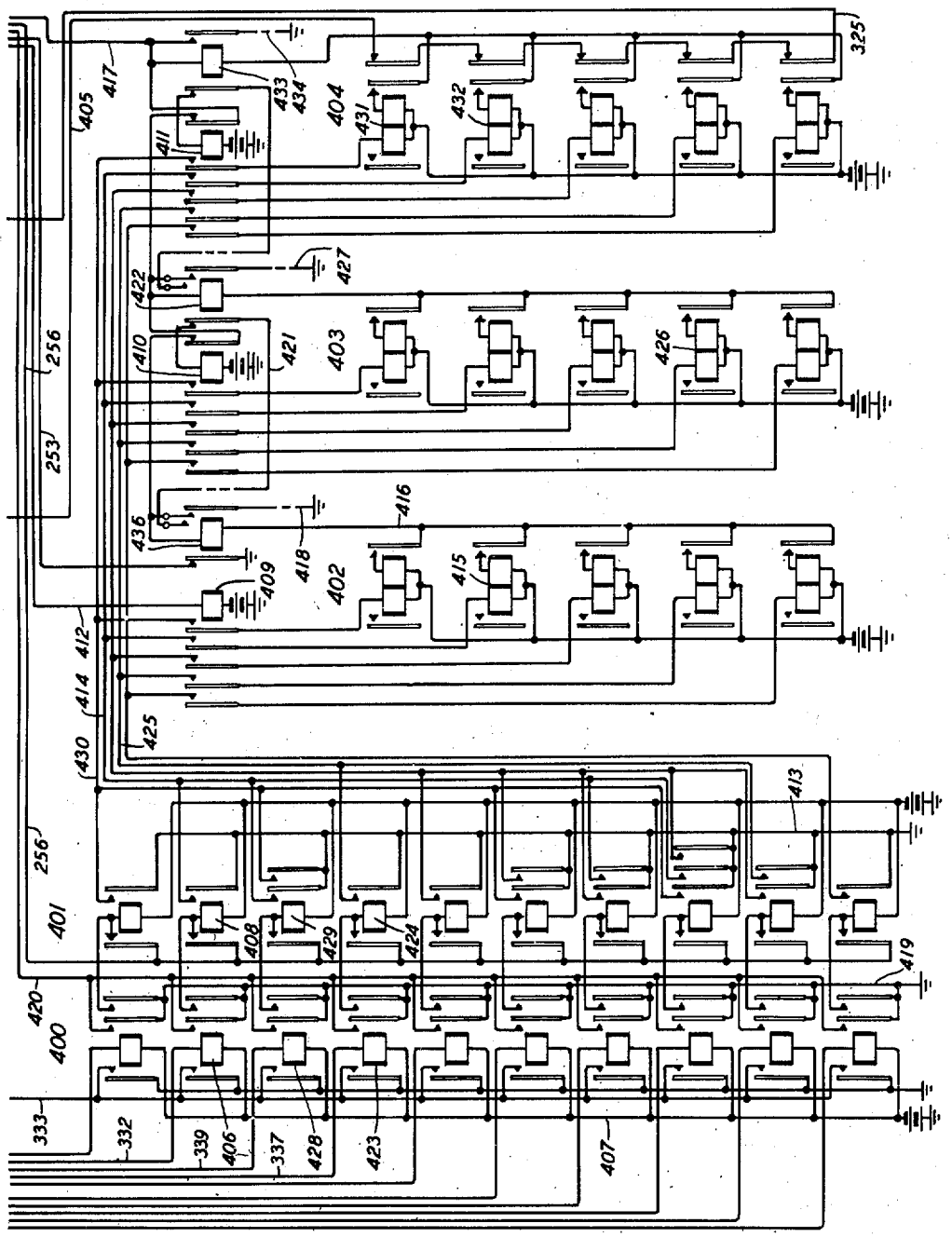

FIG. 4

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COMMUNICATION SYSTEM

Filed June 14, 1939 7 Sheets-Sheet 5

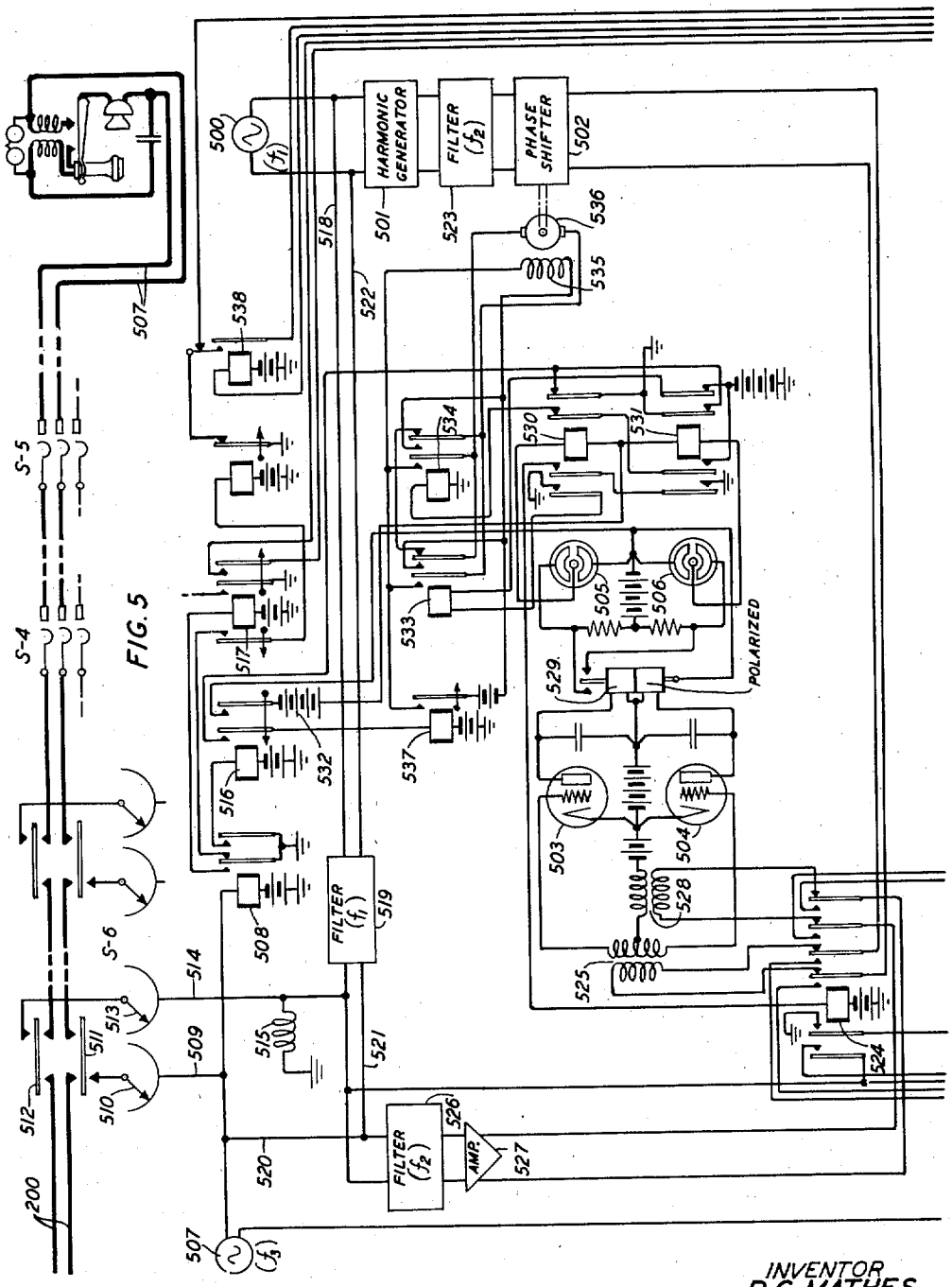

FIG. 5

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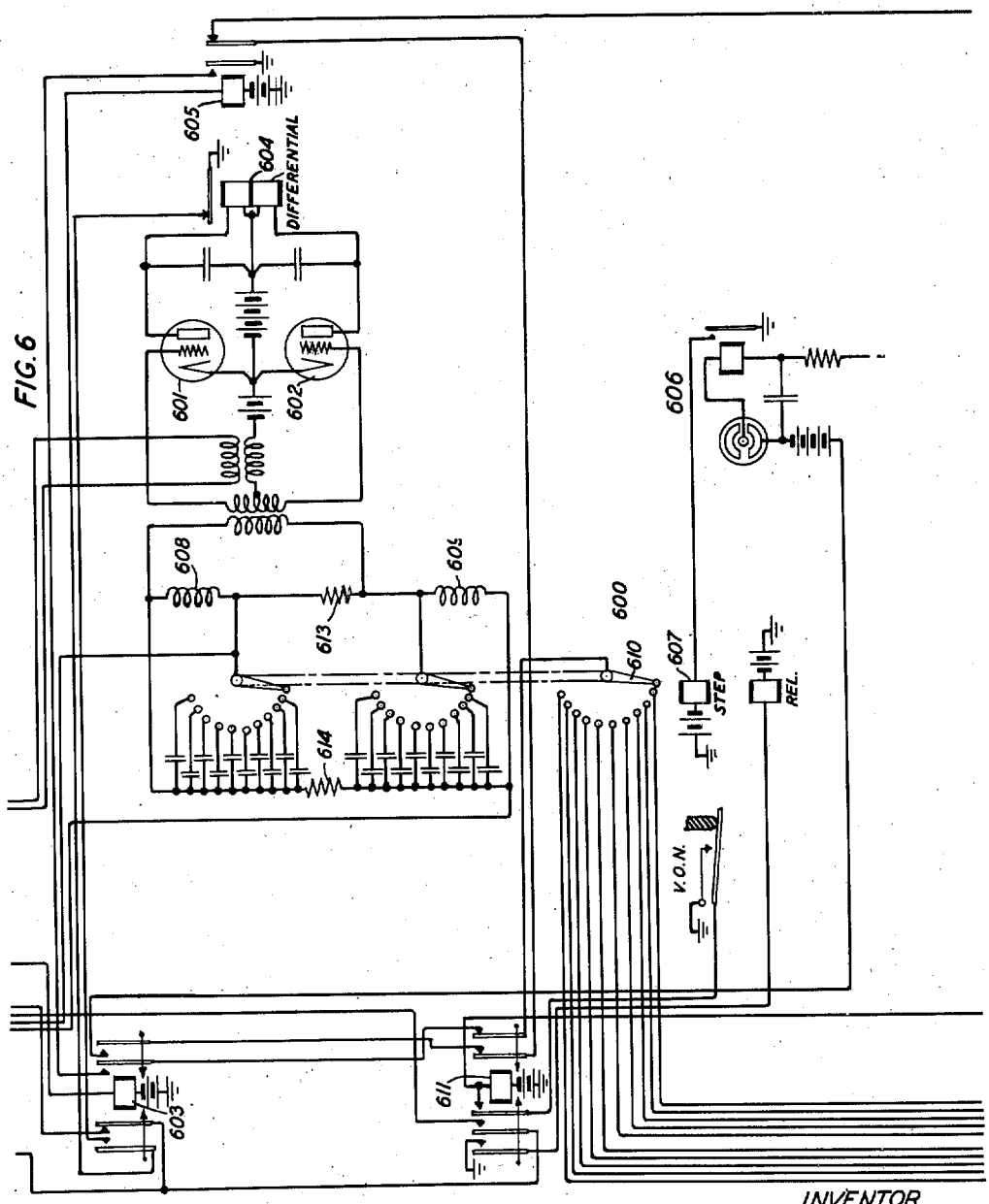
COMMUNICATION SYSTEM

Filed June 14, 1939 7 Sheets-Sheet 6

FIG. 6



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COMMUNICATION SYSTEM

Filed June 14, 1939. 7 Sheets-Sheet 7

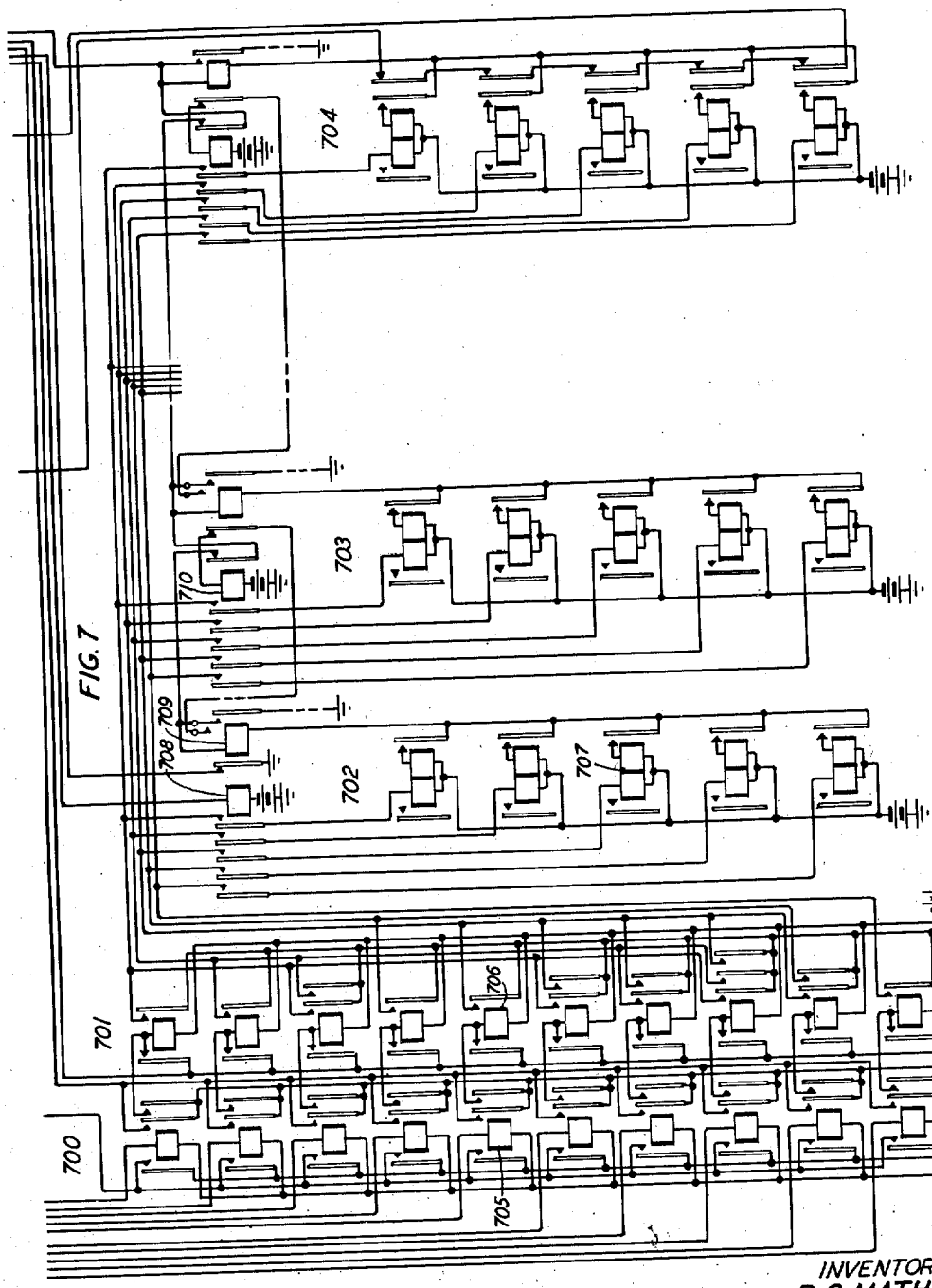

FIG. 7

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Patented Sept. 30, 1941

2,257,568

UNITED STATES PATENT OFFICE

2,257,568

COMMUNICATION SYSTEM

Robert C. Mathes, Maplewood, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 14, 1939, Serial No. 279,015

12 Claims. (Cl. 179—16)

This invention relates to communication systems and particularly to those in which connections are established automatically.

The objects of the invention are to obtain greater efficiency and increased speed in the transmission of wanted designations, such as telephone numbers; to simplify the operations necessary on the part of the subscribers and others; to reduce the holding time of the equipment at the central stations and exchanges; and otherwise to secure improvements and advantages in systems of this kind.

Systems have been proposed heretofore for transmitting telephone designations, such as the office names and numbers of subscribers' lines or the numbers of trunk circuits, from one point to another by means of currents of different frequencies, the frequencies singly or in combination serving to identify the different numerals or other characters of the designation. It has been necessary, however, with this method of signaling to provide frequency selective devices at the central office, such as selective filters or mechanically tuned elements, to discriminate between the currents of different frequencies.

According to a feature of the present invention advantages over these prior systems are realized by means of a system in which current of a single frequency is used for transmitting designations and in which the varying values of the digital characters of the designations are obtained by producing variations in the phase of the current. For example, the subscriber's substation on a telephone line is equipped with means for shifting the phase of an alternating current to characterize the successive letters or numbers in a telephone designation. At the central office means is provided for determining the amount of each shift of phase and to identify thereby the successive characters of the designation. The identified characters are then registered on relays or other suitable registering means and utilized for the purpose of selectively controlling the operation of automatic switches to establish the desired connection.

Another feature of the invention is an arrangement in which two alternating currents of the same frequency are produced, one in the subscriber's line and one at the central office, in which the current in the subscriber's line, after having its phase shifted by a given amount according to the setting of the subscriber's transmitter to characterize a designation, is transmitted to the central office, and in which means at the central office compares the two currents and measures the phase difference to identify the value of the digital character represented by the current of shifted phase received from the subscriber's line.

Another feature of the invention is a system of the foregoing character in which a preliminary adjustment is automatically made in the phase of the current produced at the central office to compensate for the shift produced in the phase of the current, flowing in the calling line, as a result of the inherent characteristics of said line. This arrangement takes into account the varying characteristics of the different subscribers' lines and makes it possible to obtain a uniform measure of the phase shift produced by any subscriber's designation transmitter unaffected by the shift resulting from the subscriber's line.

Another feature of the invention is a system in which the subscriber is able to preset his transmitter for the entire designation before any signals are sent to the central office, in which the currents of shifted phase representing the office name are first sent and registered in the originating office, in which a pause is then introduced until the switches in the originating office are set to extend the connection, either to the terminating equipment in the same office or to the terminating equipment in a distant office, according to the office designation received, and in which the numerical part of the designation preset on the subscriber's transmitter is then sent over the line and the extended connection to the called office where it is similarly identified and registered and used to control the selective switches therein to complete the desired connection.

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

The several figures of the drawings, when arranged as indicated in Fig. 8, illustrate a portion of an automatic telephone system embodying the invention.

Considering the several figures in particular:

Fig. 1 shows a subscriber's line equipped at the substation with a preset transmitter for controlling the phase of the signaling current;

Fig. 2 at the top illustrates diagrammatically the line finder and selector switches comprising the originating switching equipment in the central office to which the subscriber's line belongs;

The remainder of Fig. 2 and Figs. 3 and 4 taken together disclose one of the originating

register senders which receive the office code part of the designations transmitted from the calling lines for controlling the switches shown in Fig. 2;

Fig. 5 at the top illustrates diagrammatically the switches associated with the terminating equipment in a central office; and

The remainder of Fig. 5 and Figs. 6 and 7 taken together show one of the terminating register senders which receive the numerical part of the designations from the calling lines for controlling the selector switches shown in Fig. 5.

The invention is applicable particularly to systems in which the digital information for a call is registered in a common register sender in the central office, the registered information being utilized to control the switches in the central office to establish the desired telephone connection. To this end the system chosen to illustrate the invention is one in which the central offices are equipped with automatic switches of the well-known panel type. It will be understood, however, that other forms of switches, such as step-by-step switches and cross-bar switches, could be used to establish the connections. In the system shown in the drawings many details have been omitted, such as the structure and circuits of the selective switches, the manner in which the sender selectors seize idle senders in response to incoming calls, the manner in which the registers function to control the operation of the selector switches, and numerous other details of operation. For a better understanding of these details reference may be had to many patents in the prior art relating to systems of this general character and in particular to the following patents: Stearn et al. No. 1,395,977 of November 1, 1921; Stearn No. 1,505,171 of August 19, 1924; and Raymond et al. No. 1,862,549 of June 14, 1932.

General description

Referring to the drawings, the subscriber's line **100** is provided with the usual microphone **101**, receiver **102**, ringer **103**, induction coil **104** and switchhook **105**.

The substation is also provided with a preset designation transmitter **106** by means of which the subscriber may set up the designation before any of the signals are transmitted to the central office. The designation transmitter comprises a plurality of manually adjustable elements, one for each of the successive characters in a telephone designation. In the transmitter disclosed there are seven of these adjustable elements, assuming that the office names are expressed by the first three digits which may be letters or letters and numerals in combination, and that the numbers of the lines themselves are expressed in four digits. The first three or office code elements consist of manually rotatable shafts **107**, **108** and **109**, for selecting electrical terminals. The shaft **107** carries the two brushes or wipers **110** and **111**, each of which engages a series of ten terminals. Likewise the shaft **108** is provided with wipers **112** and **113** and the shaft **109** with wipers **114** and **115**. The shafts **107**, **108** and **109** are rotatable by the subscriber by means of knob handles **116**, **117** and **118**, respectively. The four shafts and wiper sets corresponding to the digits of the line number are similar to the three already described. Only two of these numerical designation elements are shown, namely, the one corresponding to the thousands digit, comprising shaft **119** and associated wipers **120** and **121**, and the one corresponding to the units digit comprising the shaft **122** and associated wipers **123** and **124**. These shafts are rotatable in a similar manner by means of the handles **125** and **126**, respectively.

The several contact banks of the transmitter are connected to electrical networks comprising a series of condensers of different capacities, resistance elements, and reactance coils. The purpose of these networks is to shift the phase of an alternating current flowing in the subscriber's line **100** by varying amounts according to the setting of the digital shafts **107** and **108**, etc. The alternating current which is applied to these shifting networks is derived from a current of fundamental frequency transmitted from the central office over the subscriber's line. This fundamental frequency current is applied to the harmonic generator **127** at the substation, and a suitable harmonic thereof, say the second one, is selected by filter **128** and applied to the phase shifter networks. After undergoing the phase shift the harmonic current is impressed on the line **100** and transmitted back to the central office for phase comparison. The means by which the current with its shifted phase is applied to the line for transmission to the central office comprises an escapement-driven switch **129** including a rotary shaft **130** and associated wipers **131** and **132** and an escapement mechanism **133**. This escapement switch **129** is set by the subscriber, after he has preset the transmitter, and is stepped automatically under control of the central office to cause the successive transmission over the line of the phase-shifted currents corresponding to the successive digital characters of the designation.

The subscriber's line **100** terminates at the central office in the bank of line-finder switch F. Finder F is individual to the first or district selector switch S—**1**, which has access to an office selector switch S—**2**, which in turn has access to trunks, such as the trunk **200**, extending to the selector switches comprising the terminating switching equipment either in the same or in a distant central office. The link circuit comprising the line finder F and the district selector S—**1** is provided with a sender selector switch S—**3** for seizing an idle originating sender, such as the one shown in Figs. 2, 3 and 4.

The originating sender includes a source of alternating current **201** of fundamental frequency, such as frequency f_1. Current from the source **201** is sent over the subscriber's line to the substation for producing the second harmonic frequency f_2, as explained. Also current of frequency f_1 is applied from the source **201** to a local harmonic generator **202** for producing in the central office a harmonic current of frequency f_2. Since these two harmonic currents, the one produced by the harmonic generator **127** at the substation and the one produced by the harmonic generator **202** at the central office, are derived from the same fundamental source **201**, it is possible, by bringing them together in the central office and there comparing their phases, to determine the particular phase-shifting network that the subscriber at the substation has inserted in the circuit when he set his designation transmitter. This phase comparison is made at the central office by applying the phase-shifted harmonic returned from the subscriber's station and the harmonic produced in the central office to a balancing circuit, deliberately shifting the phase of the locally produced harmonic until a balance

is attained, and measuring the amount of shift required to produce the balance. The amount of shift required to produce the balance identifies the particular shifting network inserted by the subscriber and is, therefore, an identification of the digital character set up on his transmitter. The mechanism for making this phase comparison for each of the successive digits of a designation is illustrated in Fig. 3 and will be explained presently. Before doing so, however, an explanation will be given of the compensating shift that is made in the phase of the locally produced harmonic to account for the inherent phase-shifting property of the particular calling line concerned.

The compensating phase shift is likewise performed by a balancing circuit and operates in conjunction with the phase-shifting device **203**. The balancing circuit for the compensating shift is shown in Fig. 2 and comprises vacuum tubes **204** and **205**, polarized relay **206**, gas-filled tubes **207** and **208**, relays **209** and **210** and associated circuits. By applying the harmonic received from the subscriber's station, when subjected only to the phase-shifting characteristics of the subscriber's line **100**, and the unshifted harmonic produced by the harmonic generator **202** of the central office to the input circuit of the balancing mechanism, the phase difference between these two harmonics unbalances the circuit and causes the motor **211** to rotate the phase shifter **203** in the proper direction and a sufficient amount to bring the circuit into balance. Thus the phase of the local harmonic is shifted preliminarily by an amount just sufficient to compensate for the inherent phase shift imposed by the subscriber's line upon the harmonic produced at the subscriber's station.

Thereafter the successive digits of the preset designation are transmitted and identified by applying the locally produced harmonic and the incoming phase-shifted harmonics to the balancing circuit shown in Fig. 3. This circuit includes a stepping switch **300** having wipers **301**, **302** and **303**, vacuum tubes **304** and **305** and relays **306** and **307**. The terminal banks with which wipers **301** and **302** cooperate are connected to condensers having different capacities. These condensers, and the reactances **308** and **309**, and resistances **343** and **344** form ten different electrical networks, each of which corresponds to one of the ten values of a digital character. When the incoming phase-shifted harmonic from the subscriber's line is applied to the input circuit of the tubes **304** and **305** and the locally produced harmonic is applied to the input circuit of these tubes simultaneously through the phase-shifting networks associated with switch **300**, the resulting unbalance causes the switch **300** to rotate, automatically changing the network successively and, consequently, shifting the phase of the local harmonic correspondingly, until the two harmonics are brought into a phase balancing relation. Thereupon the switch **300** stops, and the position of its wiper **303** identifies the value of the corresponding digital character. The bank of wiper **303** is wired to a chain of digital relays **400**, and a relay in this chain and a corresponding relay in the chain **401** operate to identify the particular digit. Following this the switch **300** is restored to normal, and the same operation is performed repeatedly for the succeeding digits of the designation set up at the substation. During these balancing operations, the several digit indicating elements of the subscriber's transmitter are brought successively into circuit relation with the phase balancing mechanism in the central office. This is accomplished by sending an impulse of alternating current from the source **212** over the line upon the completion of each balancing operation. These signals operate the escapement switch **129**, one step at a time, to connect the successive digital elements and their associated networks to the line. Each of the successive digits indicated on the chain relays **400** and **401** is transferred immediately and permanently registered on the registers. There are three of these registers **402**, **403** and **404** for the corresponding characters of the office designation. The register relays once operated lock and later serve to control the selective operation of the switches S—1 and S—2 to extend the calling line over a trunk **200** to the terminating equipment in the desired office.

The terminating equipment includes an incoming selector switch S—4 and a final selector switch S—5. A sender selector switch S—6 individual to the incoming trunk **200** serves to connect said trunk to an idle terminating register sender, such as the one shown in Figs. 5, 6 and 7.

The terminating register sender is substantially the same as the originating sender shown in Figs. 2, 3 and 4. It includes a source of alternating current **500** of the fundamental frequency f_1. Current from this source is supplied over the trunk **200** and thence over line **100** to the subscriber's station where it is utilized to produce the harmonic frequency f_2 for transmitting the four numerical characters of the designation. Current from the source **500** is also applied to the harmonic generator **501** to produce a local harmonic of frequency f_2 for phase comparison with the harmonic of frequency f_2 returned from the subscriber's line. The preliminary adjustment of the phase of the local harmonic f_2, to compensate for the phase-shifting properties of the subscriber's line **100** and trunk **200**, is accomplished by the motor-driven phase shifter **502** and a phase balancing circuit including vacuum tubes **503** and **504**, gas tubes **505** and **506** and associated relays. The incoming sender also includes a stepping switch **600** and associated phase-shifting networks for adjusting the phase of the locally produced harmonic f_2 to balance with the phase of the harmonic incoming from the subscriber's line. The balancing circuit includes the vacuum tubes **601** and **602** and the associated relays. For each of the balancing operations, corresponding respectively to the thousands, hundreds, tens and units digits, the incoming sender transmits an impulse of alternating current from the source **507**, of frequency f_3, back to the subscriber's station to produce the necessary stepping operation of the escapement switch **129**. The incoming sender also includes the chain relays **700** and **701** and numerical relay registers **702**, **703** and **704**. Although only three registers are shown, there are in fact four of these relay registers. Register **702** receives the thousands digits of the subscriber's number, register **703** receives the hundreds digits, an intermediate register (not shown) receives the tens digit, and register **704** receives the units digit.

A limited number of filters are disclosed diagrammatically both at the subscriber's station and in the central office. The purpose of these filters is to discriminate between the currents of different frequencies (f_1, f_2 and f_3) utilized in the operation of the system. These filters may be of any suitable and well-known design. Also the harmonic generators **127**, **202** and **501** are illus-

trated diagrammatically since these devices are well-known in the art. If desirable these generators may be of the type comprising non-linear rectifier elements, or they may be of the type making use of a saturable reactance element. A generator of the latter type is disclosed in Patent No. 2,164,335, issued July 4, 1939. The phase shifters **203** and **502** are likewise illustrated in diagrammatic manner, these devices being old and well known in the art. The details of one type of shifter suitable for this purpose are disclosed in the patent to Meacham, No. 2,004,613 of June 11, 1935.

Detailed description

The system will now be described in detail, and for this purpose it will be assumed that the subscriber of line **100** wishes to converse with the subscriber of line **507**. Assume further that line **507** terminates in a central office having the code designation CHE and the numerical designation 5678. Since the code letters C, H, and E correspond to the numerical designations 2, 4 and 3 in dialing systems using decimal impulses, it will be assumed that these letters have the same numerical values in the present system. The calling subscriber, having first determined the designation of the called line, rotates the shafts **107**, **108** and **109** to position the associated wipers on the second, fourth and third position terminals, respectively. Although not illustrated, the subscriber's transmitter would be provided with indicating means showing the positions of the various code letters and numerals to assist him in setting the contact wipers on the proper terminals. That is to say for the letter "C" he would rotate the shaft **107** to bring the wipers **110** and **111** in engagement with terminals **134** and **135**; he would rotate the shaft **108** to set the wipers **112** and **113** on terminals **136** and **137**; and he would rotate the shaft **109** to set the wipers **114** and **115** on terminals **138** and **139**, respectively. Following this he would similarly rotate the four shafts representing the numerical digits to set their wipers on the fifth, sixth, seventh and eighth position terminals, respectively. Having positioned the transmitter in accordance with the full designation, the subscriber now seizes the knob **140**, and rotates the shaft **130** of the escapement switch **129** to move the wipers **131** and **132** from their normal positions to their operated positions, at the same time tensioning the driving spring **154**. In the set or operated position of the escapement switch **129** the wipers **131** and **132** rest on terminals **141** and **142**, respectively. The escapement mechanism **133** holds the shaft in its operated position against the tension of spring **154**.

The subscriber's transmitter is now positioned ready to cooperate with the equipment at the central office to transfer the designation thereto. To effect this transfer operation the subscriber removes his receiver **102** from the switchhook and throws the key **143** to its operated position where it locks and remains locked until he restores it to normal. Operating the key **143** disconnects the subscriber's line **100** from the substation instrument and connects the line to the primary winding of the transformer **144** associated with the designation transmitter. This effects a closure of a bridge across the tip and ring conductors of the line **100** to cause the operation of the line relay at the central office. The bridging circuit may be traced from the upper conductor of line **100** through the closed switchhook contacts, left operated contacts of key **143**, conductor **145** through the primary winding of the transformer **144**, conductor **146**, through the right closed contacts of key **143** to the other side of the line **100**. The operation of the line relay (not shown) causes the finder F at the central office to find the calling line **100**. When the line is found, sender selector switch S—**3** operates to hunt for an idle originating register sender. When the selector S—**3** seizes an idle sender, which is assumed to be the one shown in Figs. 2, 3 and 4, a circuit is closed from battery through the relay **213** in the sender, conductor **226**, brush **214**, closed contacts of the spring **215** of the controlling sequence switch associated with the line finder-district selector link, through the brush **216** of finder switch F, thence over the subscriber's line **100** through the primary winding of transformer **144** and returning over the other side of the line, brush **217**, sequence switch spring **218**, selector brush **219**, conductor **225**, reactance coil **220** to ground. Relay **213** operates and closes an obvious operating circuit for slow-release relay **221**. Relay **213** also closes a circuit for relay **222**, but this latter relay, being slow to operate, does not attract its armatures until the balancing circuit has had an opportunity to become effective as will be explained presently.

At the same time that the operating circuit is completed for the relay **213**, a circuit is closed for supplying current from the source **201** to the calling subscriber's line. This circuit may be traced from the right pole of the source **201**, conductor **223**, through the filter **224**, conductor **225**, thence over the line through the primary of transformer **144** and returning over conductor **226** through the filter **224** and conductor **227** to the other pole of the source **201**. Current of frequency f_1 is induced in the secondary winding of the transformer **144** from whence it passes through the selective filter **147** to the harmonic generator **127**. Current of the frequency f_2 produced by the generator **127** is selected by filter **128** and is applied to the line **100** to be returned to the central office. Since the escapement switch **129** is standing on contacts **141** and **142**, a circuit is provided for applying the harmonic current to the line **100** free from the influence of the phase-shifting networks associated with the transmitter **106**. This circuit may be traced from the upper left pole of the harmonic generator **127** through the filter **128**, conductor **148**, conductor **149**, terminal **142** and wiper **132**, conductor **150**, through the secondary winding of the transformer **144**, thence over conductors **151** and **152**, terminal **141** and wiper **131**, conductor **153**, through the filter **128** to the lower left pole of harmonic generator **127**. Therefore, current of the frequency f_2 is induced in the primary winding of transformer **144** and flows back over the line **100** to the originating sender. Here it is applied by way of conductors **225** and **226** to the selective filter **228**. After passing the filter **228**, the harmonic current is amplified by the amplifier **229** and is then applied through the back contacts of relay **230**, to the primary winding of transformer **231** in the input circuit of the tubes **204** and **205**.

It will be noted that current from the same fundamental source **201** is applied to the harmonic generator **202**, and the second harmonic (frequency f_2) is selected by filter **232** and applied by way of phase shifter **203** and back contacts of relay **230** to the primary winding of transformer **233**. This local harmonic, which is

constantly applied to the input circuit of the tubes **204** and **205**, while the sender is in its normal condition, affects both tubes similarly with the result that the polarized relay **206** in the output circuit of the tubes maintains its neutral position. As soon, however, as the incoming harmonic from the subscriber's line is applied to the input circuit of tubes **204** and **205** by way of transformer **231**, any difference in phase, greater or less than 90 degrees, that may exist between the local harmonic and the incoming harmonic by reason of the inherent phase-shifting characteristics of the subscriber's line **100** will unbalance the tubes **204** and **205** causing relay **206** to throw its armature to one or the other of its contacts as the case may be. This effect is obtained by adjusting the bias so that the tubes operate on the non-linear portion of their characteristics.

It will also be noted that the gas-filled tubes **207** and **208** normally have their control gaps ionized. The ionizing circuit for tube **207** may be traced from the positive pole of battery through resistance **234**, control electrode **235**, cathode **236** to the opposite pole of the battery. A similar circuit for tube **208** may be traced from the positive pole of battery, resistance **237**, control electrode **238**, cathode **239** to the opposite pole of battery. The main gaps of these tubes, however, are opened at the contacts of slow-operating relay **222**. As soon as the polarized relay **206** throws its armatures to one of its contacts when the sender is seized and the tubes **204** and **205** unbalanced as above described, a circuit is closed for quenching the control gap of the corresponding gas-filled tube. Assume that the phase unbalance causes the relay **206** to close its right contacts. This closes a short circuit around the control gap of tube **208**, and this tube deionizes. When the slow-operate relay **222** closes its contacts, which does not occur until after relay **206** has had time to operate and deionize tube **208**, the anode circuit is closed for the tube **207**. This circuit may be traced from positive pole of battery **240**, winding of relay **209**, anode **241**, cathode **236**, contacts of relay **222** to the negative pole of battery **240**. The control gap of tube **207** being in an ionized condition, the main gap ionizes and relay **209** operates. Had the tubes **204** and **205** been unbalanced in the opposite sense, relay **206** would have operated to its left contact, quenching the tube **207**. This would have resulted in the firing of the main gap of tube **208** and the operation of relay **210** instead of relay **209**. When relay **209** operates, it causes the operation of relay **242** whereas the operation of relay **210** causes the operation of relay **243**. Relay **242** starts the driving motor **211** to operate the phase shifter **203** in such a direction as to bring the phase of the locally produced harmonic into quadrature with the phase of the harmonic incoming from the subscriber's line. In a similar manner relay **243** starts the motor in the opposite direction for the same purpose when the tubes are unbalanced in the opposite sense. Assuming relay **242** is the one operated, a circuit is closed as follows for exciting the field **245** of the motor: Positive pole of battery through the contact of relay **244**, through the field **245** of the motor to the opposite pole of battery. Relay **244** operated, when relay **222** energized, in a circuit through the contacts of relay **222**, conductor **246** to ground over a circuit leading through either a contact of relay **209** or a contact of relay **210**. Also the armature circuit of the motor is closed from the positive pole of battery through the contacts of relay **244**, inner contacts of relay **242** through the armature of the motor, outer front contacts of relay **242** to the opposite pole of battery. By inspection it will be found that relay **243** closes a circuit for the flow of current through the armature of the motor in the opposite direction.

The motor **211** drives the phase shifter **203** until the phase of the local harmonic applied to the transformer **233** is in quadrature with the phase of the harmonic incoming from the subscriber's line and applied to the transformer **231**. When this quadrature relation is obtained, the tubes **204** and **205** balance, relay **206** assumes its neutral position, and the control gap of the quenched tube **208** reionizes. This immediately ionizes the main gap of the tube **208**, and relay **210** operates. Since both relays **209** and **210** are now operated, relay **242** releases and opens the energizing circuit of the armature of the motor. With both relays **242** and **243** released, an obvious short circuit is closed across the armature of the motor, and, since slow-release relay **244** holds the field winding energized for a moment, the short circuit on the armature produces a dynamic braking action to stop the phase shifter accurately in its adjusted position. A moment later relay **244** releases and opens the field circuit of the motor. The phase of the locally produced harmonic has now been adjusted to compensate for the phase shifting of the calling subscriber's line **100** and may be used to measure the successive shifts produced by the different networks inserted at the subscriber's transmitter for the purpose of transmitting the several characters of the designation.

When the second one of the two relays **209** and **210** operates as the compensating balance is reached, an obvious circuit is closed for the energization of relay **230**. Relay **230** closes an energizing circuit for slow-to-operate relay **310**. Relay **310**, however, does not attract its armatures for an appreciable interval of time during which certain circuit operations, about to be described, are performed. Relay **230** at its innermost right contacts disconnects the output circuit of the phase shifter **203** from the transformer **233** and extends this circuit to the primary winding of transformer **311** through the phase-shifting networks associated with the input circuit of the balancing tubes **304** and **305**. The locally produced harmonic of frequency f_2 is thus supplied to the input circuit of the tubes **304** and **305**, the circuit therefor extending from phase shifter **203** over conductor **247**, through the right front contact of relay **230**, conductor **248**, reactance coil **309**, through the primary winding of transformer **311**, reactance coil **308**, conductor **249**, innermost right front contact of relay **230** to conductor **250**. The wipers **301** and **302** of the switch **300** serve in successive positions to connect different ones of the condensers in parallel with the coils **308** and **309**, respectively. These coils in combination with resistances **343** and **344** and with different ones of the condensers produce different amounts of shift in the phase of the harmonic f_2 flowing in the primary winding of the input transformer **311**. At the same time relay **230** at its outermost right contacts disconnects the output circuit of amplifier **229** from the transformer **231** and extends this circuit through to the primary winding of transformer **312**. Thus the harmonic f_2 incoming from the subscriber's station is applied to the input transformer **312** simultaneously with the application of the local

harmonic to the transformer **311**. The tubes **304** and **305**, which are normally balanced to maintain the armature of the differential relay **306** in its released position, will become unbalanced when these two harmonics are applied to the input circuits provided the phase difference between said harmonics is something other than 90 degrees. This result is obtained by a bias which causes the tubes to operate on the non-linear part of their characteristics.

Since the wipers **131** and **132** of the escapement switch **129** are standing on their contacts **141** and **142**, respectively, excluding the phase-shifting networks of the subscriber's transmitter, the phase shift in the harmonic f_2 transmitted from the subscriber's line to the transformer **312** is that which results only from the phase-shifting characteristics of the line. Since the wipers **301** and **302** of the phase-shifting switch **300** are assumed to be standing in their normal positions, the phase of the local harmonic f_2 applied to the transformer **311** is likewise shifted by an amount corresponding to the phase displacement produced by the subscriber's line. When, therefore, these two harmonics are applied to the balancing circuit including tubes **304** and **305**, this circuit maintains its balanced condition, and relay **306** remains deenergized. At the time relay **230** operates, a circuit is closed as follows and remains closed until relay **310** operates shortly thereafter: From the lower pole of source **212** over conductor **251**, inner left contact of relay **310**, outer left contact of relay **230**, conductor **252**, conductor **225**, thence over the subscriber's line through transformer **144** and returning to conductor **226** and the other pole of the source **212**. Current from the source **212** is induced in the secondary winding of transformer **144** at the substation, is selectively passed by the filter **155**, is rectified by the full wave rectifier **156**, and is applied to the escapement magnet **157**. Magnet **157** energizes preparatory to advancing the wipers **131** and **132** to the next set of terminals. When, following the operation of relay **230**, relay **310** attracts its armatures, it opens the circuit of the source **212**, permitting the magnet **157** at the substation to release. The escapement **133** now permits the wipers **131** and **132** to complete their advance into engagement with the next terminals **158** and **159**, respectively. The escapement switch **129** in this position includes the network, comprising reactance coils **160** and **161**, resistances **172** and **173**, and condensers **162** and **163**, corresponding to the first office code character C. The circuit, including the phase-shifting network, over which the current of harmonic frequency f_2 flows from the filter **128** to the transformer **144** may be traced from conductor **153**, reactance coil **160**, conductors **152** and **151** through the lower winding of transformer **144**, conductor **150**, reactance coil **161**, conductor **149** and conductor **148** returning to the filter **128**. It will also be seen that the resistances **172** and **173** of the networks are included in a series circuit with the transformer winding. The wiper **132** connects the condenser **163** in parallel with coil **161** over a circuit traceable from the upper terminal of said coil, wiper **132**, switch terminal **159**, wiper **111** and terminal **135**, condenser **163**, thence over conductor **149** to the lower terminal of coil **161**. Similarly wiper **131** connects condenser **162** in parallel with reactance coil **160**. Since the character C is the equivalent of the numeral **2**, the phase of the harmonic f_2 transmitted over the line to the transformer **312** is shifted by the substation transmitter network by an amount characterizing the digital numeral **2**. Consequently the phases of the two harmonics now applied to the input of the tubes **304** and **305**, one representing the numeral **2** and the other of which represents the compensation made for the subscriber's line, differ from each other such that the tubes become unbalanced, and relay **306** operates. Relay **306** opens the circuit of relay **307**, and the latter relay, if previously operated, now releases.

Relay **310** in operating as above described renders effective the relaxation oscillator **317**, comprising discharge tube **318**, relay **319**, condenser **320**, and resistance **321**, to step the switch **300** from terminal to terminal until the tubes **304** and **305** are balanced by bringing the phase of the locally produced harmonic into quadrature with the phase of the harmonic incoming from the subscriber's line. The oscillator **317** is made effective by closing the charging circuit for condenser **320**. This charging circuit may be traced from the positive pole of battery **322**, conductor **341**, through the outer right contacts of relay **310**, inner right normal contacts of relay **323**, conductor **324**, outer normal contacts of relay **307**, conductor **325**, through normal series contacts of the relays of register **404**, conductor **405**, resistance **321** to one pole of condenser **320**, the other pole of the condenser being connected to the negative pole of battery **322**. Condenser **320** charges at a rate depending upon the value of resistance **321** until it reaches the ionizing potential of the tube **318**. Thereupon the tube ionizes, and current flows through the winding of relay **319** to operate the same, and the condenser **320** discharges. Relay **319** energizes the stepping magnet **326** of switch **300**, which attracts its armature preparatory to advancing the wipers to the first position terminals. When the condenser **320** has discharged sufficiently, tube **318** deionizes, and relay **319** releases to open the circuit of the stepping magnet. The magnet thereupon releases its armature, and the wipers **301**, **302** and **303** are advanced to the first position terminals in the bank including a pair of condensers **315** and **316** in the network to change the phase of the locally produced harmonic f_2. The condenser **320** recharges and fires the tube, causing the switch **300** to take another step. This process continues, the switch **300** including successive pairs of condensers in the phase-shifting network until the phase of the local harmonic f_2 is brought into quadrature relation with the phase of the incoming harmonic from the subscriber's line. When this occurs, the tubes **304** and **305** balance, and relay **306** releases since equal currents are flowing through its differential windings. Relay **306** in releasing closes a circuit from ground through its normal contacts, conductor **327**, closed contacts of relay **310** through the winding of relay **307** to battery. Relay **307** at its outer contacts opens the charging circuit of condenser **320** to disable the oscillator **317** and prevent further stepping of the switch **300**. At its inner contacts relay **307** closes a circuit from ground over conductor **328**, closed contacts of relay **310**, conductor **329**, normal contacts of relay **323**, conductor **330** to the wiper **303** of switch **300**. Inasmuch as the movement of the switch **300** in producing a phase balance between the two harmonics of frequency f_2 is a measure of the digital character selected by the subscriber, the position of the wiper **303** in its bank of ten terminals is a direct indication of the numeral value of the character. Under the assumption that the numeral value

of the letter C is 2, the switch 300 takes two steps in the first balancing operation, and brush 303 comes to rest on terminal 331. Therefore, the circuit above traced from the grounded contact of relay 307 to the wiper 303 is further extended over terminal 331, conductor 332, through the winding of relay 406 of the chain 400 to battery over conductor 407. Relay 406 operates and closes an obvious energizing circuit for the corresponding relay 408 of the chain 401. Relay 406 also closes a circuit from battery through the winding of relay 323, conductor 333, left contact of relay 406 to ground. Relay 323, however, is slow to operate and does not attract its armatures until an interval has expired during which certain circuit operations, about to be described, are performed.

The purpose of the chain relays 400 and 401 is to take a temporary registration of the successive digits detected by the switch 300 and to transfer them to the permanent registers 402, 403 and 404. To this end the chain relays 401 are associated successively with the registers 402, 403 and 404 by the connecting relays 409, 410 and 411. The first of the connecting relays, relay 409, is already operated, having energized over a circuit from battery through its winding, conductor 412, outer contacts of relay 221, conductor 253 to ground at the normal left contact of relay 436. At the time chain relays 406 and 408 operate as above explained a circuit is closed as follows for the operation of relay 254: Battery through the winding of relay 254, conductor 420, inner right front contact of relay 406 to ground over conductor 419. Relay 254 operates and at its front contacts closes a circuit from ground through the normal contacts of relay 255, over conductor 256 through the left contact and winding of chain relay 408 to battery. Relay 408 is held in this circuit as long as relay 254 remains energized under the control of relay 406. Relay 408 in operating also closes a circuit for operating the register relay 415 of the first code register 402. This circuit may be traced from the grounded conductor 413, right front contacts of relay 408, conductor 414, through the operated contacts of relay 409 and the left winding of register relay 415 to battery.

Following the completion of these circuit operations the slow-to-operate relay 323, the circuit of which was closed by relay 406 as previously explained, attracts its armatures and locks in a circuit from battery through its winding and inner left contact to ground at the off-normal springs 334, which were closed when the switch 300 moved off normal. Relay 323 at its outer left contact closes a circuit for release magnet 335, which energizes and restores the switch 300 to normal. As the switch 300 returns to normal, contacts 334 are opened, and the locking circuit of relay 323 is severed to permit the release of this relay. The operation of relay 323 and the return of wiper 303 to normal open the energizing circuit of the chain relay 406. Relay 406 opens the operating circuit of relay 408 and the operating circuit of relay 254. Relay 254 releases, but relay 408 remains locked until the closed contacts of relay 254 are opened. However, before the closed contacts of relay 254 are opened on the release of this relay, the normal contacts of the relay are again closed, and a circuit is completed from ground over the contacts of relay 255, normal contacts of relay 254, conductor 417, through the normal contacts of relays 411 and 410 in series, winding of relay 436, right contact and right winding of the operated register relay 415 to battery. Relay 413 operates in this circuit and closes a locking circuit for itself and the operated register relay 415 to ground over control conductor 418 before the chain relay 408 has time to release following the severance of its locking circuit when the front contacts of relay 254 are finally opened upon the release of the latter relay. Relay 436 in operating releases relay 409 to disconnect the chain relays 401 from the register 402. Relay 436 also extends the grounded conductor 418 to the winding of relay 410 by way of conductor 421. Relay 410 thereupon operates and associates the chain relays 401 with the next code register 403. When relay 323 operates, as above described, in response to the operation of chain relay 406, it connects conductor 251 through its middle left contact to conductor 252, thereby completing the circuit for the transmission of current of the frequency f_3 from the source 212 over the subscriber's line to energize the escapement magnet 157. A moment later, when relay 323 releases in response to the release of the switch 300, the source 212 is disconnected from the line, magnet 157 deenergizes, and the wipers 131 and 132 advance to their third position contacts 165 and 166.

The subscriber's transmitter is now in condition to transmit the second code character H to the central office. With wipers 131 and 132 standing on terminals 165 and 166, the wipers 112 and 113 of the transmitter are effective to include the corresponding condensers in the network, resulting in a phase shift of the harmonic by an amount corresponding to the character H or its numerical equivalent 4. This harmonic flows over the subscriber's line to the transformer 312 and produces an unbalance corresponding to the numeral 4. Relay 306 operates, and relay 307 releases to render the relaxation oscillator 317 effective. The oscillator 317 steps the switch 300 from one position to another until a balance is attained, at which time relay 307 is operated to discontinue the stepping movement. Since the digit being transmitted is 4, the wiper 303 is now standing on its fourth position terminal 336, and relay 307 in operating extends ground over conductors 328, 329 and 330 through the wiper 303 and terminal 336 to conductor 337 and thence through the winding of chain relay 423 to battery. Relay 423 operates the associated chain relay 424 and also closes a circuit, previously described, for operating relay 254. Relay 424 extends the grounded conductor 413 through its right contact over conductor 425 through closed contacts of relay 410 and the left winding of register relay 426 to battery. When relay 323 subsequently operates, it releases relay 423, in turn releasing relay 254, resulting in the locking of register relay 426 and relay 422 to ground over the control conductor 427. Also relay 323 causes the release of switch 300 and causes the application of current from source 212 to the subscriber's line to energize the magnet 157 at the substation. Finally when relay 323 releases, the magnet 157 deenergizes and the escapement switch 129 advances its wipers to the fourth position terminals. Also the relay 422 in operating releases relay 419 to disconnect the register 403 and closes an obvious circuit for operating relay 411 to associate the next code register 404 with the chain relays 401.

The escapement switch 129 standing in its fourth position now associates the wipers 114 and 115 with the transmission circuit, and the

phase of the harmonic f_2 is shifted by an amount corresponding to the third code letter E or its numerical equivalent 3. At the central office the tubes **304** and **305** are unbalanced, and the switch **300** steps until the wiper **303** reaches its third position terminals **338**. The circuit is then balanced, the switch ceases stepping, and the grounded circuit previously described is extended over wiper **303** and conductor **339** to operate the chain relay **428**. Relay **428** in turn operates relay **429** and relay **254** as above described. Relay **429** applies ground from conductor **413** and its right contacts over conductors **430** and **414** through the operated contacts of relay **411** to operate register relays **431** and **432**. Following the operation of the register relays, relay **323** operates to bring about the release of switch **300** and to transmit another impulse of current from the source **212** to energize the escapement magnet **157** at the substation. Thereafter relay **323** releases causing the release of the chain relays **428** and **429**, the locking of the register relays **431** and **432** through their right windings and the winding of relay **433** to the grounded control conductor **434**. Relay **433** deenergizes relay **411** to dissociate the register **404** from the chain relays **401**. Relay **323** in releasing also removes the impulse of frequency f_3 from the subscriber's line, and magnet **157** releases to escape the wipers **131** and **132** to their fifth position terminals **167** and **168**.

It will be noted that the fifth position terminals of the escapement switch **129** lie intermediate the three positions relating to the three office code characters C, H and E and the succeeding four positions which relate to the four numerical characters 5, 6, 7, and 8 of the wanted designation. When the wipers **131** and **132** reach these intermediate terminals **167** and **168**, respectively, the phase-shifting networks associated with the subscriber's transmitter are removed from the transmission circuit, and the phase of the harmonic f_2 now transmitted over the subscriber's line to the central office is influenced only by the characteristics of the line itself. The circuit for the transmission of the harmonic f_2 from the substation, which is now free from the phase-shifting networks, may be traced from the lower left terminal of filter **128**, conductor **153**, wiper **131**, terminal **167**, conductors **152** and **151** through the lower coil of transformer **144**, conductor **150**, wiper **132**, terminal **168**, conductors **149** and **148** to the other terminal of the filter **128**. The two harmonics f_2 now produce a balanced condition of the circuit at the central office, and relay **307** is held operated to disable the relaxation oscillator **317**. Moreover, the oscillator is further disabled by the operation of any one of the relays of register **404**, severing the discharge circuit of the tube **318**.

The originating register sender having thus received the office code registration now proceeds in the well-known manner to utilize this registered information for the purpose of controlling the selective operation of the district and office switches S—1 and S—2 to seize an idle trunk **200** extending to the terminating equipment in the office containing the called subscriber's line. While the sender is controlling the selective movement of the switches the subscriber's designation transmitter remains quiescent. As soon as the trunk **200** is seized, the sender selector switch S—6 operates to find an idle one of the terminating register senders, such as the one shown in Figs. 5, 6 and 7. Having thus controlled the extension of the connection through to the terminating sender the originating sender may now be released. The specific manner in which the originating register sender proceeds through its releasing operation and the manner in which the link circuit interconnecting the finder switch F and the district selector switch S—1 is completed through to the selected trunk **200** are not shown in detail herein since these releasing and circuit controlling functions are well known to those skilled in the art. It is sufficient to note that following the control of the switches S—1 and S—2 by the originating sender the operated register relays are released by the removal of ground potential from conductors **418**, **427** and **434**, the energized relays **213**, **222**, **221**, **209** and **210** are released, the subscriber's line is disconnected from the originating sender, and the contacts of sequence switch springs **215**, **218**, **257** and **258** are closed to extend the subscriber's line through the brushes of switches S—1 and S—2 to the trunk **200**.

Upon the extension of the subscriber's line through to the terminating sender, shown in Figs. 5, 6, and 7, a circuit is closed from battery through the winding of relay **508**, conductor **509**, brush **510**, contacts of spring **511** of the sequence switch associated with the incoming selector switch S—4, thence over the lower side of the trunk **200** to the subscriber's line **100** and as previously traced through the winding of transformer **144**, and returning over the other side of the subscriber's line to the upper conductor of trunk **200**, through the contacts of sequence switch spring **512**, brush **513**, conductor **514** through the winding of reactance coil **515** to ground. Relay **508** operates and closes obvious operating circuits for relays **516** and **517**. Current of fundamental frequency f_1 is now supplied from the terminating sender over the calling subscriber's line, the same as it was from the originating sender, to energize the harmonic generator **127** at the substation for the purpose of producing thereat the harmonic frequency f_2. The circuit for supplying frequency f_1 may be traced from the right terminal of source **500**, conductor **518** through the filter **519**, thence over conductor **514** and the upper conductor of trunk **200** and line **100**, through the transformer **144** as previously traced, and returning over the lower side of the connection through conductor **509** thence over conductors **520** and **521**, through the filter **519** and conductor **522** to the other pole of the source **500**. Current from the fundamental source **500** is also applied to the harmonic generator **501** to produce a local harmonic current of frequency f_2 for purposes of comparison. Harmonic f_2 is selected by filter **523** and is applied by way of phase shifter **502** and the normal contacts of relay **524** to the primary winding of transformer **525** in the input circuit of the balancing tubes **503** and **504**. At the same time the harmonic f_2 produced by the subscriber's station is returned over the line **100** and the trunk **200** to the terminating sender where it is selected by the filter **526** and applied by way of amplifier **527** and the normal contacts of relay **524** to the transformer **528** also associated with the input circuit of the balancing tubes **503** and **504**.

It will be noted that the connection extended to the terminating sender now includes the trunk line **200** in addition to the subscriber's line **100**. This additional transmission circuit produces its effect upon the phase of the harmonic f_2 flowing from the subscriber's station, and it is now necessary to make an adjustment in the phase of the

harmonic f_2 produced locally in the terminating sender to compensate for the phase displacement produced by the entire connection, including the line 100 and the trunk 200, between the subscriber's station and the sender. This compensating adjustment, which occurs while the subscriber's transmitter is pausing between the office code and the numerical designation, is performed by the balancing circuit including the tubes 503 and 504 and the phase shifter 502 in the same manner as the compensating adjustment previously described in connection with the originating sender. Normally, that is, before the sender is seized, the tubes 503 and 504, which operate on the non-linear part of their characteristics, are in a balanced condition, and polarized relay 529 is standing with its armature in the mid-position. The control gaps of the gas-filled tubes 505 and 506 are, therefore, ionized. But the relays 530 and 531 do not operate since the anode circuits of these tubes are open at the outer right contacts of relay 516. Relay 516, being slow to operate, does not close the anode circuits of the tubes 505 and 506, following the seizure of the sender as above explained, until sufficient time has elapsed to allow the application of the local and incoming harmonics to the input circuit of the balancing tubes 503 and 504. When these harmonics are applied to the balancing tubes, an unbalance is produced, and relay 529 operates to one or the other of its contacts depending upon the sense of the unbalance. Accordingly, the relay 529 places a short circuit around the control electrodes of one of the gas-filled tubes 505 or 506, quenching the discharge of that particular tube. As soon thereafter as slow relay 516 attracts its armature, the anode circuits, including battery 532, are closed, and discharge occurs across the main gap of the tube whose control gap remains ionized. This results in the operation either of relay 530 or 531 as the case may be, causing in turn the operation of relay 533 or 534 to close the armature circuit 536 of the phase-shifting motor. The circuit for the field 535 of the motor is closed by slow-release relay 537 which also operates when relay 516 attracts its armature.

Thus the phase shifter is driven to produce a continuous change in the phase of the local harmonic applied to the input circuit of the tubes 503 and 504. When the phases of the two harmonics are brought into quadrature relation, a balanced condition results, and relay 529 returns its armature to the mid-position. This permits the other gas-filled tube to ionize whereupon the other one of the two relays 530 and 531 operates. Since both relays 530 and 531 are now operated, the operated one of relays 533, 534 releases, and the energizing circuit of the motor armature is replaced by a short circuit, thus bringing the phase shifter 502 to rest. A moment later relay 537 releases and opens the field circuit. Relay 524 also operates, extending the circuit for the local harmonic and the circuit for the incoming harmonic to the input circuit of the balancing tubes 601 and 602. Relay 524 in operating transmits an impulse of current of frequency f_3 from the source 507 back to the calling subscriber's line. The circuit may be traced from the lower terminal of source 507, normal contact of relay 603, front contacts of relay 524, conductor 514, thence over the connection through the transformer 144 at the calling station and returning to conductor 509 and the other terminal of source 507. Current from the source 507 is rectified by the rectifier 156 and energizes the escapement magnet 157 to prepare for the advance of wipers 131 and 132 to the next terminals in the bank.

The moment when slow-to-operate relay 603 operates, its circuit having been closed by relay 524, the impulse from source 507 is discontinued, and magnet 157 at the substation releases to move the wipers 131 and 132 to their sixth position terminals 169 and 170, respectively. In this position the phase-shifting network corresponding to the thousands digit 5 is included in the transmission circuit, and the phase of the harmonic f_2 now transmitted back to the terminating sender in the central office where it unbalances the tubes 601 and 602, permitting the differential relay 604 to operate and release relay 605 in case the latter relay is energized at this time. In a manner similar to that already described in connection with the originating sender, the relaxation oscillator 606 is rendered effective to operate the stepping magnet 607 to advance the switch 600 from position to position, including resistances 613 and 614 and successive condensers in shunt relation with the reactance coils 608 and 609, until the phase of the local harmonic f_2 is brought into quadrature relation with the phase of the incoming harmonic. When this occurs, relay 605 operates, and a circuit extended over wiper 610 operates the relay 705 in the chain 700. The operated relay 705 in the chain 700 operates the corresponding relay 706 in chain 701 and also operates relay 538. Relay 706 causes the operation of register relay 707 of the thousands register 702, relay 708 having previously operated at the time the sender was seized. Relay 707 locks in series with relay 709 when relay 538 releases in response to the release of relay 705, which occurs as soon as the slow-to-operate relay 611 subsequently operates, the circuit of the latter relay having been closed by the operation of chain relay 705. Relay 709 operates, releasing relay 708 and operating the next connecting relay 710 to associate the next or hundreds register 703 with the chain relays. When relay 611 operates, it causes the release of switch 600 and prepares the balancing circuit for receiving the next digit.

In a similar manner the next three digits of the number, the hundreds, tens and units digits, are transmitted from the calling subscriber's station to the incoming sender and registered on the relays of the corresponding registers. At the end of each balancing operation relay 611 operates to send an impulse from the source 507 to energize the escapement magnet 157; and upon the return of switch 600 to its normal position relay 611 releases to terminate the impulses. After all numerical digits have been received and registered on the registers 702, 703 and 704, the terminating sender proceeds in the well-known manner to control the selective operation of the incoming and final selector switches S—4 and S—5 to complete the extension of the connection through to the called subscriber's line 507. Thereupon the incoming sender, including all operated relays therein, is restored to normal condition, and the talking connection is placed under the control of the subscribers.

At the calling subscriber's station it will be noted that the escapement switch 129 returns to its normal position (indicated in the drawing) following the transmission of the final or units digit. The subscriber, observing the return of the switch 129 to its normal position, by any suitable indicating means, such as an index

pointer on the handle 140, knows that the number has been fully transmitted and that he may now disconnect the transmitter from the line. To do this he restores the key 143 to its normal condition. The restoration of the key 143 disconnects the transmitter and substitutes for the primary winding of the transformer 144 the bridge through the substation instrument. The continuity contacts of the key 143 make this substitution possible without opening the loop of the line 100 to affect the holding condition at the central office. The subscribers may now converse with each other.

When conversation is over, the subscribers release the established connection in the usual manner by replacing their receivers on the switchhooks.

Having considered this system in its details, it will be seen that it has numerous advantages over the systems of the prior art. It is possible to transmit an entire designation over a subscriber's line to a central office by using current of a single frequency, making it unnecessary to provide expensive filtering equipment at the central office; it is possible for the subscriber to set up the designation in advance on his transmitter where it remains as a record of the call that he is making and also a record of the call until the next time he wishes to use his transmitter; and it is possible to divide the designation into its code and numerical parts and to transmit each one separately to the central office, making the necessary adjustments for the line characteristics.

What is claimed is:

1. The combination in a communication system of a central office, a subscriber's line having a substation thereon and terminating in said central office, a source for producing alternating currents at the central office and for transmitting them over said line to said substation, designation means operable by the subscriber at said substation for producing predetermined variable shifts in the phase of the current flowing in the line to represent the characters of a wanted designation, means at the central office for identifying the characters of said designation by determining the amount of phase variation produced at said substation, automatic mechanisms, and means for operating said automatic mechanisms in accordance with the identified characters of said designation.

2. The combination in a telephone system of a central office, a subscriber's line terminating in said office, a source at the central office for producing alternating currents in said line, subscriber-controlled means at the substation of said line for producing variable shifts in the phase of the current flowing in the line to represent the characters of a wanted designation, means at the central office for determining the amount of phase shift produced in said currents at the substation by comparing the currents of shifted phase with the current produced by said source at the central office, means at the central office for utilizing these phase comparisons to register the characters of said wanted designation, and automatic switches controlled by said register means for extending said subscriber's line.

3. The combination in a telephone system of a central office, a subscriber's line terminating in said office, a source of alternating current of fundamental frequency at the central office, means for connecting said source to the line to transmit current thereover, means at the substation of said line for producing a harmonic of said fundamental frequency, means for varying the phase of said harmonic current to represent the characters of a wanted designation and to transmit said harmonic current back to the central office, means at the central office for determining the amount of phase variation in said harmonic current to identify the characters of said designation, and means operable in accordance with the identified characters of the designation for establishing a telephone connection.

4. The combination in a telephone system of a central office, a subscriber's line terminating therein, a source of current of fundamental frequency at the central office, means for transmitting said current over the line to the substation thereof, means at the substation for producing a harmonic of said fundamental frequency current and for transmitting it back over the line to the central office, means at the central office for producing a harmonic of the same frequency as the one produced at the substation, means for varying the phase of the harmonic produced at the substation in accordance with the digital values of a wanted designation, means at the central office for comparing the phases of the harmonic incoming over the subscriber's line with the phase of the harmonic produced locally in the central office to identify the designation, and means operable in accordance with the identified designation for establishing a telephone connection.

5. The combination in a telephone system of a central office, a subscriber's line terminating therein, a source of current of fundamental frequency at the central office, means for transmitting said current over the line to the substation thereof, means at the substation for producing a harmonic of said fundamental frequency and for transmitting it back over the line to the central office, means at the central office for producing a harmonic of the same frequency as the one produced at the substation, means for varying the phase of the harmonic produced at the substation in accordance with the digital values of a wanted designation, a phase balancing mechanism at the central office for comparing the phases of the harmonic incoming over the subscriber's line and the harmonic produced locally in the central office, means to shift the phase of the local harmonic until said mechanism balances, and means controlled by said shifting means for identifying the digital characters of said designation.

6. The combination in a telephone system of a central office, a line terminating in said office, means at the substation of said line for producing current of a given frequency, means at the central office for producing current of said frequency, means including networks selectable by the subscriber for causing variable shifts in the phase of the current produced at the substation to characterize the digits of a telephone designation and for transmitting it over said line to the central office, networks at the central office for varying the phase of the current produced at the central office until a definite phase relation with the current incoming over said line is reached, means at the central office for identifying the digits of said designation by measuring the amount of phase shift required at the central office to reach said definite relation, and means controlled in accordance with the

designation identified for establishing a telephone connection.

7. The combination in a telephone system of a telephone line having a substation thereon, a designation transmitter at said substation and means for variably presetting it in accordance with the successive characters of a designation, networks of different values selected by said transmitter in its preset position to represent the successive characters of the designation, a source of current of a given frequency, means for subjecting said current to the selected networks successively to produce corresponding shifts in the phase thereof and for applying said current to said line, and means associated with said line for determining the amount of the successive shifts produced in the current flowing in said line to identify the characters of the designation preset on said transmitter.

8. In combination, a subscriber's line having a designation transmitter for sending designations comprising a plurality of successive digital characters, means for presetting said transmitter in accordance with an entire designation, means for producing an alternating current in said line, means for causing a partial operation of said preset transmitter to produce successive shifts in the phase of said current to represent a portion of the digital characters of said designation, means for detecting said shifts of phase to identify the particular characters represented, automatic switches controlled in accordance with the digital characters identified for partially extending said line, means for thereupon causing said transmitter to complete its operation to produce further shifts in the phase of the current in said line to represent the remaining characters of said designation, means for detecting said further phase shifts to identify the characters involved, and other automatic switches operated in accordance with the characters so identified for further extending said line.

9. The combination in a telephone system of an originating office, a subscriber's line terminating therein, a terminating office, a trunk line interconnecting said offices, a source in the originating office for producing alternating currents in said subscriber's line, means at the subscriber's station for varying the phase of currents flowing in the subscriber's line to represent the code and numerical portions of a wanted designation, means at the originating office for measuring the phase variations representing the code part of the designation to cause the registration in the originating office of said code, automatic switches in the originating office controlled by the registered code designation for extending said subscriber's line over said trunk to the terminating office, a source in the terminating office for producing alternating currents in the extended connection including said subscriber's line, means in the terminating office for measuring the phase variations produced in said subscriber's line representing the numerical part of said designation and for causing the registration of said numerical designation in said terminating office, and automatic switches in said terminating office controlled by said numerical registration for further extending said connection.

10. In a telephone system, a central office, a subscriber's line terminating therein, means at the substation of said line for producing a current of a given frequency and for transmitting it over said line to the central office, means at the central office for producing a current of the same frequency, means at said substation for varying the phase of said first current to characterize a designation, means at the central office for comparing the phases of said first and second currents to identify said designation, and means for producing an adjustment in the phase of said current produced at the central office to compensate for the shift produced by said line in the phase of the current flowing thereover from the substation.

11. In a telephone system, a central office, a subscriber's line terminating in said office, means for producing a first current of a given frequency and for transmitting it from the substation over said line to the central office, means in the central office for producing current of the same frequency, means for adjusting the phase of the central office current to compensate for the shift produced by said line in the phase of said first current, means at the substation for varying the phase of said first current to characterize a designation, means for comparing the phases of said first current and said central office current to identify a portion of said designation, automatic switches controlled in accordance with the identified portions of the designation for extending a connection from said line, means for adjusting the phase of the central office current to compensate for the shift produced by said extended connection in the phase of said first current, means for comparing the phases of said first current and said central office current to identify the remainder of said designation, and other automatic switches controlled in accordance with the remainder of the identified designation for further extending said connection.

12. The combination in a telephone system of a central office, a telephone line terminating in said office, a station on said line, a source of alternating current at the central office, means for connecting said source to the line to transmit current thereover, means at said station responsive to the current in said line for producing alternating current of a particular frequency differing from the frequency of said source, means for varying the phase of the current of said particular frequency to represent the characters of a telephone designation and to transmit the same back to the central office, means at the central office for determining the amount of phase variation in the current of said particular frequency to identify the characters of said designation, and means operable in accordance with the identified characters for establishing a telephone connection.

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