May 1, 1945. H. E. VAUGHAN 2,375,053

SIGNALING SYSTEM

Filed Aug. 19, 1943 3 Sheets-Sheet 1

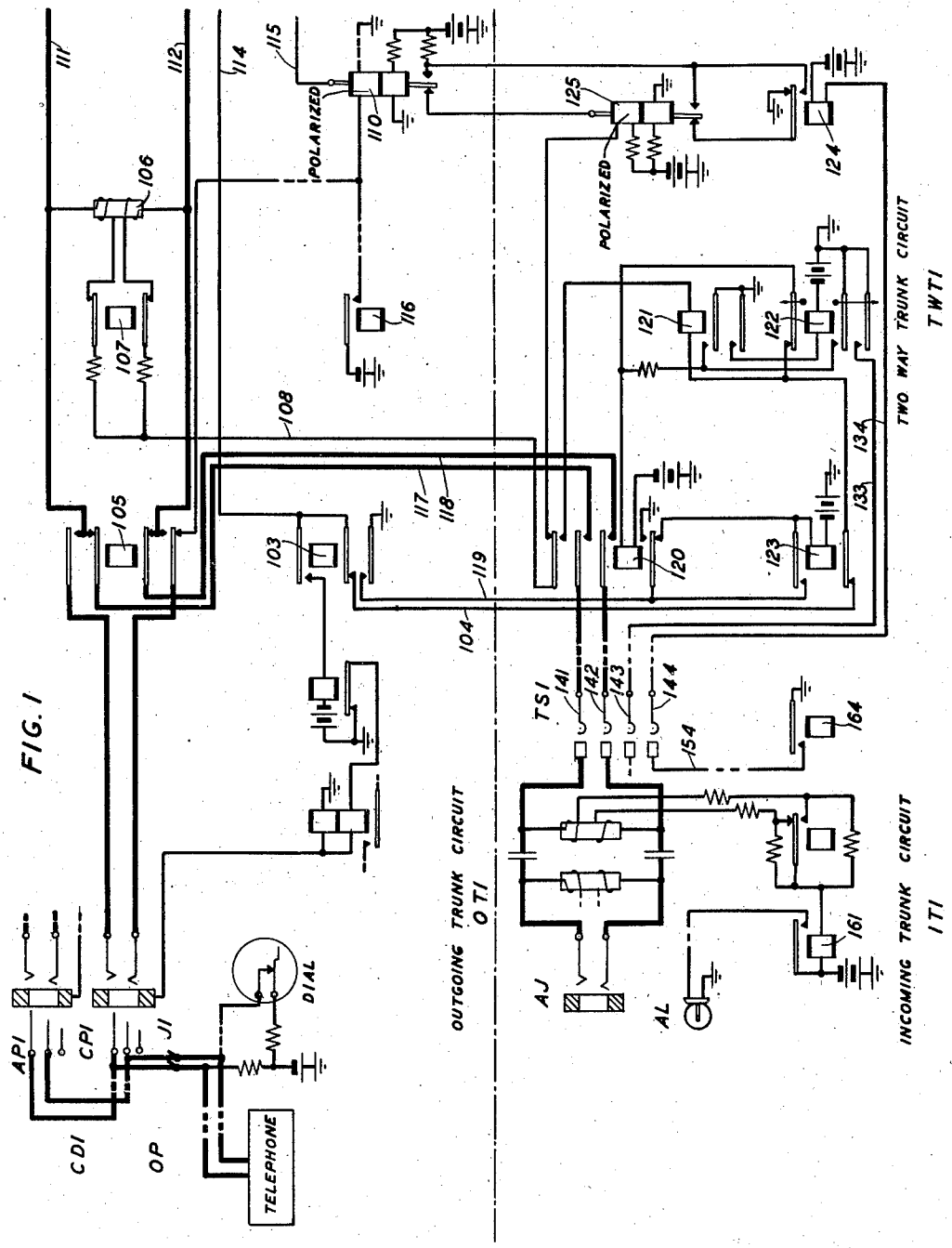

FIG. 1

INVENTOR
H.E. VAUGHAN
BY
R.O. Covell
ATTORNEY

May 1, 1945. H. E. VAUGHAN 2,375,053

SIGNALING SYSTEM

Filed Aug. 19, 1943 3 Sheets-Sheet 2

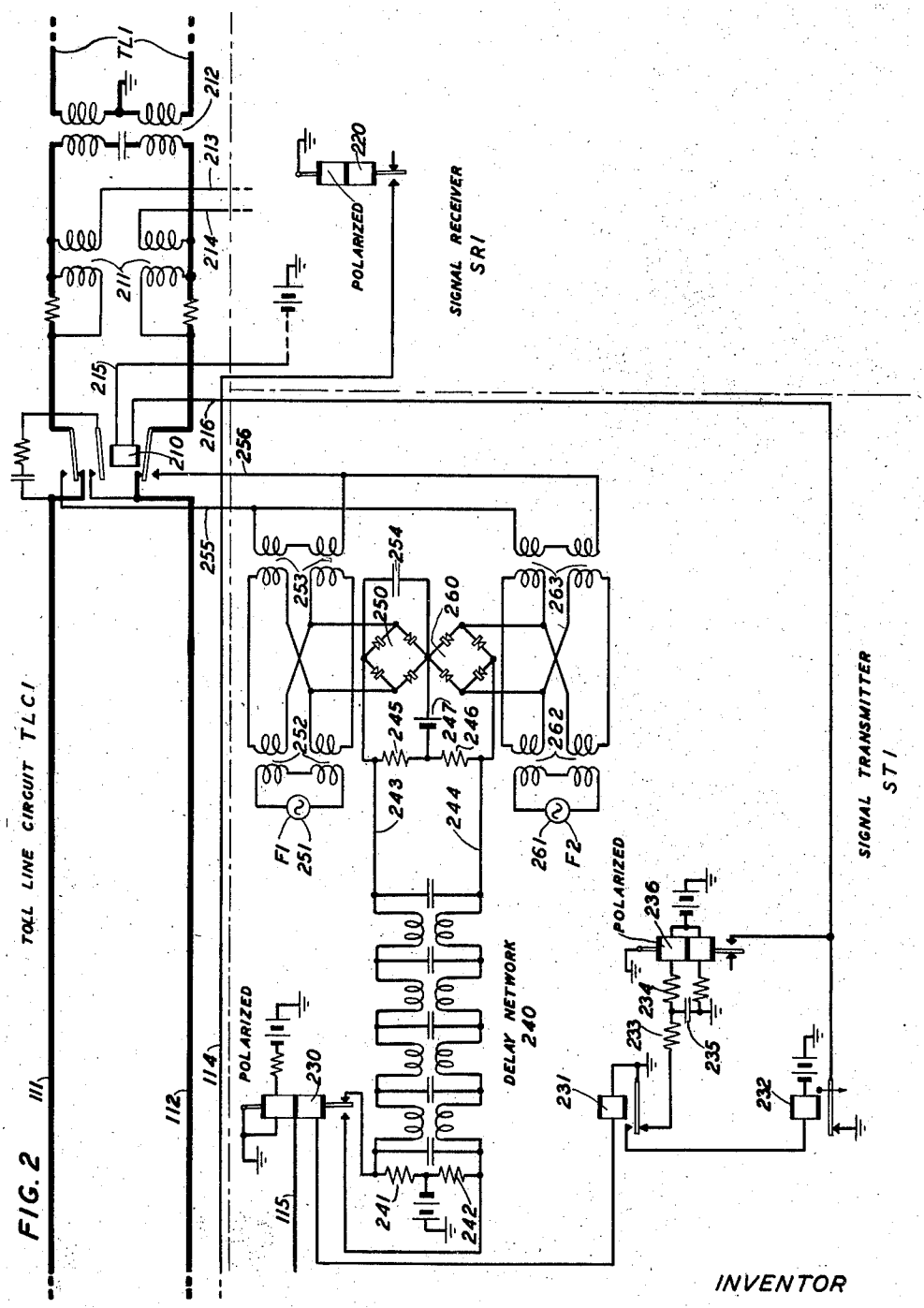

FIG. 2

INVENTOR
H.E. VAUGHAN
BY
R.O. Covell
ATTORNEY

May 1, 1945. H. E. VAUGHAN 2,375,053

SIGNALING SYSTEM

Filed Aug. 19, 1943 3 Sheets-Sheet 3

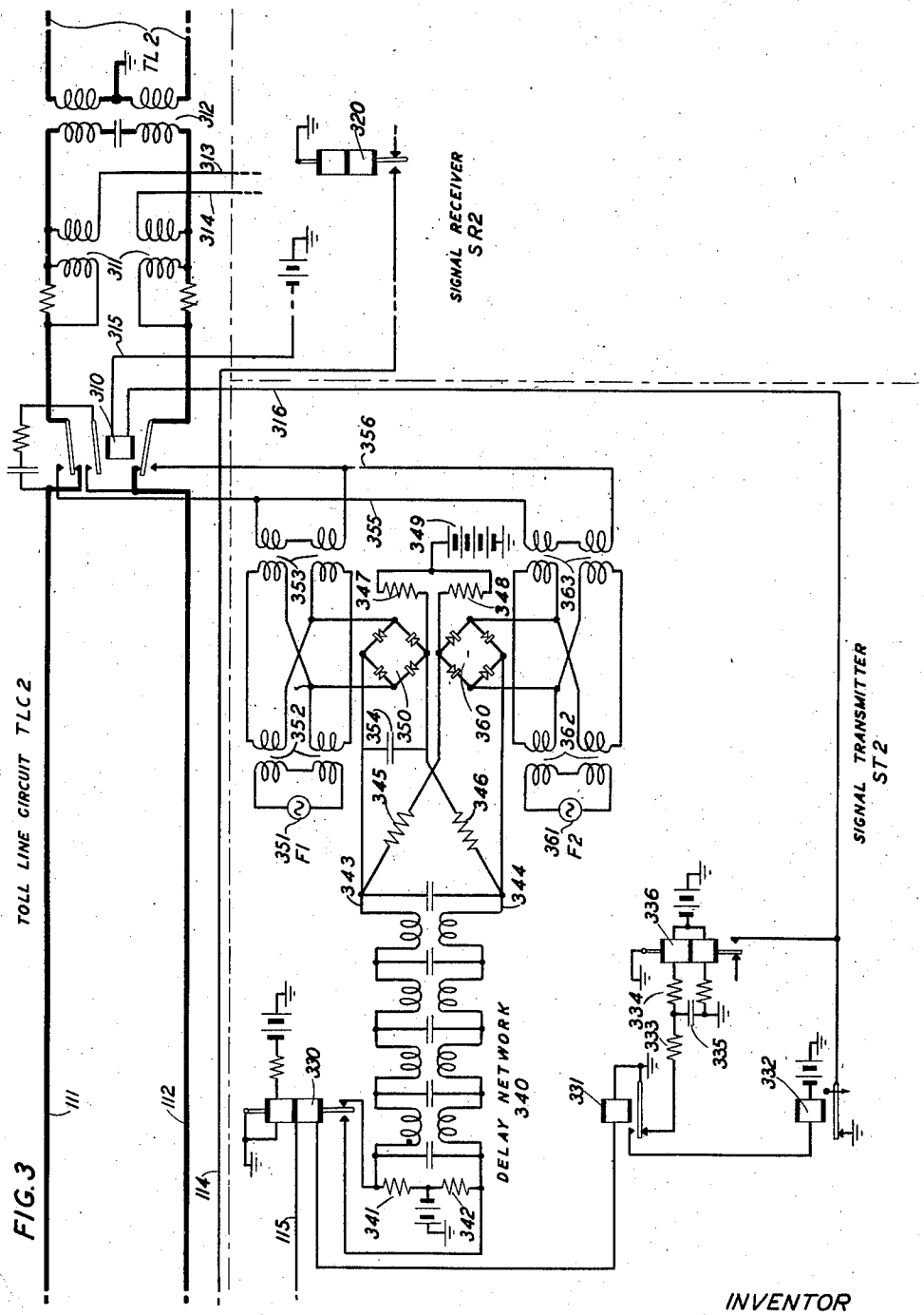

FIG. 3

INVENTOR
H. E. VAUGHAN

BY
R. O. Covell
ATTORNEY

Patented May 1, 1945

2,375,053

UNITED STATES PATENT OFFICE

2,375,053

SIGNALING SYSTEM

Henry E. Vaughan, Valley Stream, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 19, 1943, Serial No. 499,185

13 Claims. (Cl. 179—27)

This invention relates to signaling systems and particularly to telephone systems in which voice frequency currents are used for transmitting signals.

Objects of the invention are the provision of more reliable signal transmitting means in systems employing voice frequency signals and particularly the provision of improved signal transmitters arranged to transmit signals consisting of impulses of current of different frequencies in succession. Other objects of the invention are a minimization of transient effects, a reduction of the time required for changing from one frequency to another, compensation for delay distortion in the line, and the modification of the per cent break of outgoing dial impulse signals to compensate for signal distortion.

This invention is an improved signaling system comprising a signal transmitting circuit arrangement adapted to transmit signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of a corresponding plurality of signaling frequencies; in which system, according to one feature of the invention, the necessary timing for the transmission of dial impulses is obtained by the use of a low-pass delay network and in which, according to another feature, varistor bridges effect the starting and stopping of the current impulses and the low-pass network is effective to shape the envelopes of the signal impulses to minimize the production of transients at the beginning and end of each signal impulse. Other features are the use of crossed coils in combination with the varistor bridges for connecting the sources of signaling current to the line over which signals are to be transmitted, the biasing of the bridges to control the time required for transition from one frequency to the other, the provision of means for delaying an impulse of one frequency more than an impulse of the other frequency so as to modify the time relationship of the envelopes of the signal impulses to compensate for delay distortion in the line, and the provision of means for modifying the per cent break of the dial impulse signals.

The invention and its various features will be further described by considering the specific embodiments of the invention shown in the drawings which form a part of this specification. The invention is not limited in its application to the particular system shown but is applicable generally to any telephone or other signaling system employing voice frequency currents for signaling.

Referring to the drawings:

Figs. 1 and 2 show in a toll office an operator's position OP, an outgoing trunk circuit OT1, a two-way trunk circuit TWT1, a toll selector TS1, a signal transmitter ST1, a signal receiver SR1, and a toll line circuit TLC1, all individually associated with an intertoll trunk line TL1; Fig. 1 further shows an incoming trunk circuit IT1 connected to a set of terminals in the bank of toll selector TS1; and

Fig. 3 shows another toll line circuit TLC2, a signal transmitter ST2 and signal receiver SR2 individually associated with an intertoll trunk line TL2 and adapted for use with the trunk and selector circuits shown in Fig. 1.

The system represented in the drawings includes a plurality of toll offices, each of which comprises a toll board with operator's positions and cords for answering calls incoming from local, manual and dial offices, from toll subscribers' lines, and from other toll offices, and for extending incoming calls to switching trunks leading to called local manual and dial offices, to intertoll trunks and to toll subscribers' lines. Outgoing jacks are connected to trunks to local offices, to toll subscribers' lines and to intertoll trunks. Answering jacks are directly connected to recording trunks, to toll subscribers' lines, to intertoll trunks and to incoming trunk circuits terminating in the banks of toll route selectors. Toll route selectors and auxiliary toll route selectors are provided for use on calls incoming over intertoll trunks to extend connections to called toll, local or community dial offices.

Reference may be had to the patent to R. E. King et al., No. 2,209,777, granted July 30, 1940, for a detailed disclosure of the cord and operator's position circuits provided in each of the toll offices for interconnecting calling and called lines and trunks and controlling the completion of toll calls. The outgoing trunk circuit OT1, incoming trunk circuit IT1, two-way trunk circuit TWT1, and toll selector TS1 are all similar to corresponding circuits disclosed in the aforementioned King et al. patent. The operators' positions are provided with dials for use in controlling the operation of incoming and auxiliary toll route selectors in other toll offices and for controlling the operation of selector and connector switches in local or community dial offices.

The toll line circuit TLC1 comprises a repeating coil 212, directionally selective coils 211, and

a cut-off relay 210 for disconnecting the talking conductors of outgoing trunk circuit OT1 from, and connecting the associated signal transmitter ST1 to, the intertoll trunk line TL1. The directionally selective coils 211 transmit signaling current incoming over line TL1 through conductors 213 and 214 to the signal receiver SR1 without substantial attenuation and transmit voice currents and signaling current from signal transmitter ST1 to the repeating coil 212 without substantial attenuation. The coils 211 reduce the portion of the signal energy transmitted by the transmitter ST1 which passes into the signal receiver SR1, thereby to reduce the possibility of false operations and reduce interference with the response of the signal receiver SR1 to incoming signals.

The signal transmitters ST1 and ST2 are arranged to transmit seizure, selective, ringing and disconnect signals on outgoing calls and to transmit off-hook, all-trunks-busy, called-line-busy and on-hook supervisory signals on incoming calls.

The signal transmitter ST1 comprises relays 230 and 231 which are operatively controlled by relay 110 of the outgoing trunk circuit OT1 on outgoing calls and controlled by relay 124 of two-way trunk circuit TWT1 on incoming calls. The signal transmitter ST1 further comprises relays 232 and 236 controlled by relay 231, a delay network 240 connecting the contacts of relay 230 to varistor bridges 250 and 260, a source 251 of current of frequency F1 and a source 261 of current of frequency F2. Relays 232 and 236 control the operating circuit of cut-off relay 210 of toll line circuit TLC1. Relay 232 is a slow-to-release relay which is operated responsive to the seizure of trunk circuit OT1 and line TL1 and remains operated until the line TL1 is released. The transmission of signaling current from source 251 through transformers 252 and 253 is controlled by varistor bridge 250 and the transmission of signaling current from source 261 through transformers 262 and 263 is controlled by varistor bridge 260. The rectifiers of bridge 250 are so poled that the direct current therethrough is of the required polarity and amplitude necessary to effect a substantial reduction in the resistance of the bridge only when relay 230 is normal; and the rectifiers of bridge 260 are so poled that the direct current therethrough is of the required polarity and amplitude necessary to effect a substantial reduction in the resistance of the bridge only when relay 230 is operated. Each operation and each release of relay 230 is effective to reverse the current through the windings of the network 240 to control the resistance of the bridges 250 and 260. When the bridge 250 is low in resistance, due to relay 230 being normal, and relay 210 is released as hereinafter described, signal energy from source 251 is transmitted through transformers 252 and 253 and bridge 250 to intertoll line TL1; and when the bridge 260 is low in resistance, due to relay 230 being operated, and relay 210 is released, signal energy from source 261 is transmitted through transformers 262 and 263 and bridge 260 to line TL1. The low-pass network 240 delays the change in the resistance of bridges 250 and 260 under the control of relay 230 for about .035 second.

The sending of the voice frequency current impulses by means of varistor bridges, the resistance of each of which is controlled by a direct current circuit which includes a low-pass delay network, is effective to shape the envelope of the impulses and thereby minimize the production of transients at the beginning and end of each impulse. Since the directionally selective coils 211 do allow some energy to pass from the signal transmitter ST1 to the signal receiver SR1, it has heretofore been known to insert a band-pass filter between the transmitter and the directionally selective coils and to insert a band-pass filter between the directionally selective coils and the signal receiver. The use of a low-pass network in the direct current circuit which controls the resistance of the varistor bridges is effective to delay the build-up and decay of the current through the bridges thereby to shape the envelope of the alternating current impulses transmitted over the line TL1. The reduction in the transients produced at the beginning and at the end of a voice frequency signal impulse, due to the shaping effected by the low-pass network, gives about the same protection against false operation of the signal receiver and against interference with the response of the signal receiver to incoming signals as is obtained by the use of a band-pass filter between the signal transmitter and the directionally selective coils. The use of varistors in place of relay contacts eliminates the possibility of failure to transmit the current impulses, which possibility exists when relay contacts are used to transmit the impulses, and makes possible the elimination of any interval between the end of an impulse of current of one frequency and the beginning of the succeeding impulse of another frequency. The interval of time between such impulses is herein referred to as travel time even though relay contacts are not used to control the current impulses. By introducing a biasing voltage, for instance a battery 247, in series with the bridges 250 and 260, succeeding impulses of the two frequencies may be overlapped to eliminate all travel time; or, if the biasing voltage is of opposite polarity, the travel time may be increased. If the character of the line is such that considerable delay distortion is produced, the impulses of different frequencies will overlap if sent out in one order and will be separated by an interval if sent out in the reverse order. The overlap is the equivalent of a gap if the signal receiver makes use of volume limiting to protect against operation in response to speech currents; and any gap is undesirable because it requires a longer enablement or preparatory signal. To avoid these difficulties, a condenser such as the condenser 254 may be connected in parallel with the bridge through which one of the frequencies is transmitted. When the polarity of the voltage applied across the bridge changes in one direction, the charging of the condenser delays the reduction of the resistance of the bridge for a desired interval; and when the polarity of the voltage changes in the opposite direction, the discharge of the condenser delays the increase in the resistance of the bridge. Thus, the impulse of this frequency is delayed without distorting its length or its shape.

By changing the relative value of the resistors 241 and 242 at the input end of the delay network 240, the relative duration of the impulses of the two frequencies is changed a definite amount, the change in the percentage break depending upon the dial speed. For instance, if resistors 241 and 242 are 1,600 ohms each in one case and are 1,000 ohms and 800 ohms, respectively, in another case, the impulse of one frequency may be lengthened .005 second and the impulse of the other frequency shortened .005 second; if the dial speed is 10 impulses per second, this change in the per

cent break is 5 per cent, but if the dial speed is 20 impulses per second, this change in the per-cent break is 10 per cent.

The signal transmitter ST2 is similar to the signal transmitter ST1 except that the resistances of bridges 350 and 360 are controlled by a direct current network which includes a biasing battery 349 and the associated resistors 347 and 348. The resistance of each of resistors 347 and 348 is high so that these resistors do not constitute a substantial load across the output of network 340. Like elements in the transmitters ST1 and ST2 are identified by reference characters having the same tens and units digits.

The signal receivers SR1 and SR2 may be similar to those disclosed and described in detail in the patent to J. G. Walsh, No. 2,306,236, granted December 22, 1942.

When relay 110 is operated responsive to insertion of the calling plug CP1 of a cord CD1 into jack J1 of outgoing trunk circuit AT1, as described in detail in the aforementioned King et al. patent, it closes a circuit through conductor 115 for operating relays 230 and 231 of signal-transmitter ST1. The operation of relay 231 opens the normally closed circuit through the upper winding of relay 236 and closes a circuit for operating the slow-to-release relay 232. Relay 236 is held normal by current charging condenser 235 for about .1 second after relay 231 operates. The operation of relay 232 opens the normally closed circuit for operating the cut-off relay 210 of line circuit TLC1. The release of relay 210 initiates the transmission of current of frequency F1 from source 251 through transformer 252, bridge 250, transformer 253, conductors 255 and 256, back contacts of relay 210, coils 211 and repeating coil 212 to toll line TL1. When the resistance of bridge 250 has been substantially increased and the resistance of bridge 260 has been substantially decreased due to the delayed reversal of the direct current through conductors 243 and 244 responsive to the operation of relay 230, the transmission of current of frequency F1 is ended; and the transmission of current of frequency F2 from source 261, through transformer 262, bridge 260 and transformer 263 to toll line TL1 is initiated. When relay 236 operates about .1 second after relay 231 operates, it connects ground to conductor 216 to effect the reoperation of relay 210, thereby ending the transmission of current of frequency F2 over toll line TL1. Thus a signal consisting of an impulse of current of frequency F1 for about .025 second followed by an impulse of current of frequency F2 for about .050 second is transmitted over toll line TL1 as a seizure signal responsive to insertion of plug CP1 in jack J1 of outgoing trunk circuit OT1.

When the calling operator dials the various digits of a called toll route code, the digits of a called local office code, and the digits of a called subscriber's number on calls to local or community dial offices, relay 110 is alternately released and reoperated responsive to each dial impulse, thereby causing like operations of relays 230 and 231. The release of relay 230 effects the delayed reversal of the current through conductors 243 and 244 and the release of relay 231 causes the release of relay 236. The release of relay 236 causes the release of cutoff relay 210, thereby to initiate the transmission of current of frequency F2 over toll line TL1. When the resistance of bridge 260 is increased and the resistance of bridge 250 is decreased by a reversal of the current through conductors 243 and 244 about .035 second after relay 230 releases, the transmission of current of frequency F2 ends and the transmission of current of frequency F1 is initiated. The reoperation of relay 231 at the end of the first dial impulse of a digit closes the circuit for maintaining the operative energization of slow-to-release relay 232 and again opens the circuit through the upper winding of relay 236. Since the deenergization of the upper winding of relay 236 responsive to each operation of relay 231 is delayed for about .1 second by current charging condenser 235; relay 236 remains normal following its release responsive to the first dial impulse of a digit until relay 231 has remained operated for about .1 second at the end of the last dial impulse of the digit. The reoperation of relay 230 at the end of each dial impulse effects the delayed reversal of current through conductors 243 and 244 thereby to end the transmission of current of frequency F1 and initiate the transmission of current of frequency F2. Thus, an impulse of current of frequency F1 is transmitted for the duration of each dial impulse and an impulse of current of frequency F2 is transmitted for the duration of the interval between successive dial impulses and for about .050 second at the end of the last dial impulse of a digit, this impulse of current of frequency F2 being terminated by the reoperation of relay 210 responsive to the reoperation of relay 236.

The momentary release of relay 110 of outgoing trunk circuit OT1 responsive to an operation of the ringing key (not shown) associated with cord CD1 causes a corresponding momentary release of relays 230 and 231, thereby causing the transmission of a ringing signal, which is the same as that transmitted responsive to the dialing of the digit 1.

The release of relay 110, responsive to disconnection of cord CD1 from jack J1, causes the release of relays 230 and 231. The release of relay 231 causes the release of relay 236 thereby to release the cut-off relay 210 to initiate the transmission of current of frequency F2. The release of relay 231 also opens the circuit energizing the winding of relay 232, but relay 232 remains operated for about .6 second. The release of relay 230 causes the delayed reversal of the current through conductors 243 and 244, whereby the transmission of current of frequency F2 is ended about .035 second after relay 230 releases and the transmission of current of frequency F1 initiated. Since relays 230 and 231 do not reoperate, the release of relay 232 at the end of an interval of about .6 second causes the reoperation of relay 210 thereby terminating the transmission of current of frequency F1 over toll line TL1.

Assume now that the toll line TL1 has been seized at its distant end and that the signal receiver has responded to the seizure signal to operate relay 220 and thereby connect ground to conductor 114 to cause the operation of relays 120, 121 and 122 of two-way trunk circuit TWT1 in the manner set forth in the aforementioned King et al. patent. When dial impulses are received, the selector TS1 is operated to select an idle set of terminals in a selected level. Assuming selection of the terminals connected to the incoming trunk circuit IT1, the line relay 161 is operated and answering lamp AL energized in the manner set forth in the aforementioned King et al. patent. When the call is answered, relay 164 is operated as described in the King et al. patent to connect ground to con-

ductor 154 thereby to operate relay 124 of the two-way trunk circuit TWT1. The operation of relay 124 closes a circuit for operating relays 230 and 231 of signal transmitter ST1, whereby an off-hook supervisory signal is transmitted over line TL1 in the same manner as a seizure signal on an outgoing call. When the answering operator disconnects, relay 164 is released causing the release of relays 124, 230 and 231, whereby an on-hook signal is transmitted over toll line TL1, this signal being the same as a disconnect signal on an outgoing call. If the selector TS1 encounters an all-trunks-busy condition or if a called line in a local office is busy, the alternate operation and release of relay 124 are effected as described in the King et al. patent; and the resulting alternate operation and release of relays 230 and 231 of signal transmitter ST1 effect the alternate transmission of off-hook and on-hook signals over toll line TL1.

The signal transmitter ST2 shown in Fig. 3 differs from the signal transmitter ST1 in that the biasing of the bridges 350 and 360 is effected by connecting the biasing battery 349 through resistors 347 and 348 to the inner ends of the bridges 350 and 360 and through resistors 345 and 346 to the opposite sides of the delay network 340.

What is claimed is:

1. In a signaling system, a signal transmitter adapted to transmit signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, means comprising a pair of crossed coils and one of said bridges connecting one of said sources to the line over which signals are to be transmitted, means comprising another pair of crossed coils and the other of said bridges connecting the other of said sources to the line over which the signals are to be transmitted, and means including a delay network and the contacts of said relay for varying the resistances of said varistor bridges to effect the transmission of signal impulses over said line.

2. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, and means for rendering the resistance of one of the bridges low while said signal responsive relay is normal and for rendering the resistance of the other of the bridges low while said signal responsive relay is operated.

3. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, and means including a low-pass network connecting the contacts of said relay to said bridges for rendering the resistance of one of said bridges low when said signal responsive relay is normal and for rendering the resistance of the other of said bridges low when said signal responsive relay is operated, said network being effective to delay the change in the resistance of said bridges for a predetermined interval of time.

4. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, means including a low-pass network connecting the contacts of said relay to said bridges for rendering the resistance of one of said bridges low when said signal responsive relay is normal and for rendering the resistance of the other of said bridges low when said signal responsive relay is operated, said network being effective to delay the change in the resistance of said bridges for a predetermined interval of time, and means comprising a condenser connected across one of said bridges for increasing the delay in the change in the resistance of said one of the bridges.

5. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit cur-

rent from the associated source to said line only when the resistance of said bridge is low, means for rendering the resistance of one of the bridges low while said signal responsive relay is normal and for rendering the resistance of the other of the bridges low while said signal responsive relay is operated, and means for biasing said bridges to decrease the overlap in the transmission of an impulse of current of one frequency and the transmission of an impulse of current of the other frequency thereby to reduce the interval between the effective portions of said impulses.

6. In a signaling system, a line and a signal transmitter adapted to transmit signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, means for rendering the resistance of one of the bridges low while said signal responsive relay is normal and for rendering the resistance of the other of the bridges low while said signal responsive relay is operated, and means for biasing said bridges to increase the overlap in the transmission of an impulse of current of one frequency and the transmission of an impulse of current of the other frequency thereby to increase the interval between the effective portions of said impulses.

7. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, means including a low-pass network connecting the contacts of said relay to said bridges for rendering the resistance of one of said bridges low when said signal responsive relay is normal and for rendering the resistance of the other of said bridges low when said signal responsive relay is operated, said network being effective to delay the change in the resistance of said bridges for a predetermined interval of time, means comprising a condenser connected across one of said bridges for increasing the delay in the change in the resistance of said one of the bridges, and means for biasing said bridges to change the overlap in the transmission of current of one frequency and the transmission of an impulse of current of the other frequency.

8. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, means including a low-pass network connecting the contacts of said relay to said bridges for rendering the resistance of one of said bridges low when said signal responsive relay is normal and for rendering the resistance of the other of said bridges low when said signal responsive relay is operated, said network being effective to delay the change in the resistance of said bridges for a predetermined interval of time, a resistor connected in series with the coils of said delay network when said relay is normal, and a resistor connected in series with the coils of said network when said relay is operated, the delay in changing the resistance of each of said bridges responsive to the operation and release of said relay being dependent upon the value of the resistance which is connected in series with said coils.

9. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, means including a low-pass network connecting the contacts of said relay to said bridges for rendering the resistance of one of said bridges low when said signal responsive relay is normal and for rendering the resistance of the other of said bridges low when said signal responsive relay is operated, said network being effective to delay the change in the resistance of said bridges for a predetermined interval of time, a resistor connected in series with the coils of said delay network when said relay is normal, a resistor connected in series with the coils of said network when said relay is operated, the delay in changing the resistance of each of said bridges responsive to the operation and release of said relay being dependent upon the value of the resistance which is connected in series with said coils, and means comprising a condenser connected across one of said bridges for increasing

the delay in the change in the resistance of said one of the bridges.

10. In a signaling system, a line and a signal transmitter adapted to transmit over said line signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, means for rendering the resistance of one of the bridges low while said signal responsive relay is normal and for rendering the resistance of the other of the bridges low while said signal responsive relay is operated, and means for biasing said bridges to introduce a desired interval of time between the end of an impulse of current of one frequency and the beginning of an impulse of current of the other frequency.

11. In a signaling system, a line and a signal transmitter adapted to transmit signals consisting of a plurality of impulses of current in succession, each impulse consisting of current of only one of two signaling frequencies, said transmitter comprising a signal responsive relay, a source of current of one of said frequencies, a source of current of the other of said frequencies, two varistor bridges, two pairs of transformers, means comprising one of said bridges and one of said pairs of transformers connecting one of said sources to said line, means comprising the other of said bridges and the other pair of transformers connecting the other of said sources to said line, the connection between each pair of transformers and the associated bridge being effective to transmit current from the associated source to said line only when the resistance of said bridge is low, means for rendering the resistance of one of the bridges low while said signal responsive relay is normal and for rendering the resistance of the other of the bridges low while said signal responsive relay is operated, and means for biasing said bridges to initiate the transmission of an impulse of current of one frequency a desired interval of time prior to the ending of an impulse of current of the other frequency.

12. In a signaling system, a signal transmitter adapted to transmit signals consisting of a plurality of impulses of current in succession, each of said impulses consisting of current of only one of a plurality of signaling frequencies, said transmitter comprising a signal responsive relay, sources of current, each of said sources being of a different one of said signaling frequencies, varistor bridges one for each of said sources, means including said bridges connecting said sources to the line over which signals are to be transmitted, each of said bridges being adapted to transmit a signal impulse from the associated source to said line when the resistance of the bridge is low and to prevent the transmission of a signal impulse from the associated source to said line when the resistance of said bridge is high, means comprising said signal responsive relay for controlling the resistance of each of said bridges to render each of said bridges low in resistance one at a time, and means comprising a low-pass network connected in series with each of said bridges for shaping the envelope of the impulses of current of each of said frequencies thereby to minimize the production of transients at the beginning and end of each impulse.

13. In a signaling system, a signal transmitter adapted to transmit signals consisting of a plurality of impulses of current in succession, each of said impulses consisting of current of only one of a plurality of signaling frequencies, said transmitter comprising a signal responsive relay, sources of current, each of said sources being of a different one of said signaling frequencies, varistor bridges one for each of said sources, means including said bridges connecting said sources to the line over which signals are to be transmitted, each of said bridges being adapted to transmit a signal impulse from the associated source to said line when the resistance of the bridge is low and to prevent the transmission of a signal impulse from the associated source to said line when the resistance of said bridge is high, means comprising said signal responsive relay for controlling the resistance of each of said bridges to render each of said bridges low in resistance one at a time, and means comprising a low-pass network connected in series with each of said bridges for delaying the change in resistance of said bridges a desired interval of time and for shaping the envelope of the impulses of current of each of said frequencies thereby to minimize the production of transients at the beginning and end of each impulse.

HENRY E. VAUGHAN.