June 6, 1944. N. D. NEWBY 2,350,917

SIGNALING SYSTEM

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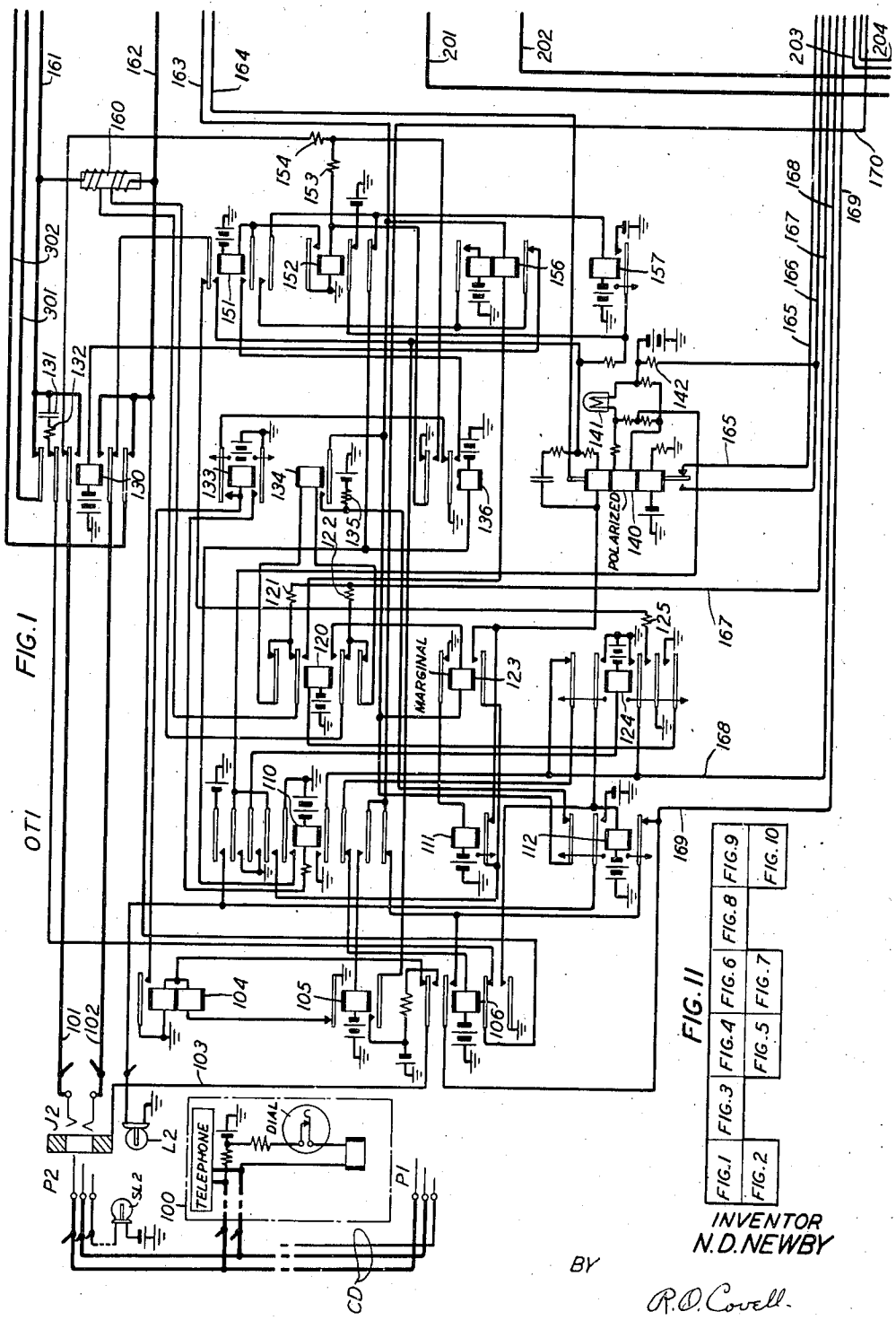

FIG. 1

FIG. 11

FIG. 1	FIG. 2		
FIG. 3	FIG. 4	FIG. 5	FIG. 6	FIG. 7	FIG. 8	FIG. 9	FIG. 10

INVENTOR
N. D. NEWBY

BY
R. D. Covell.
ATTORNEY

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SIGNALING SYSTEM

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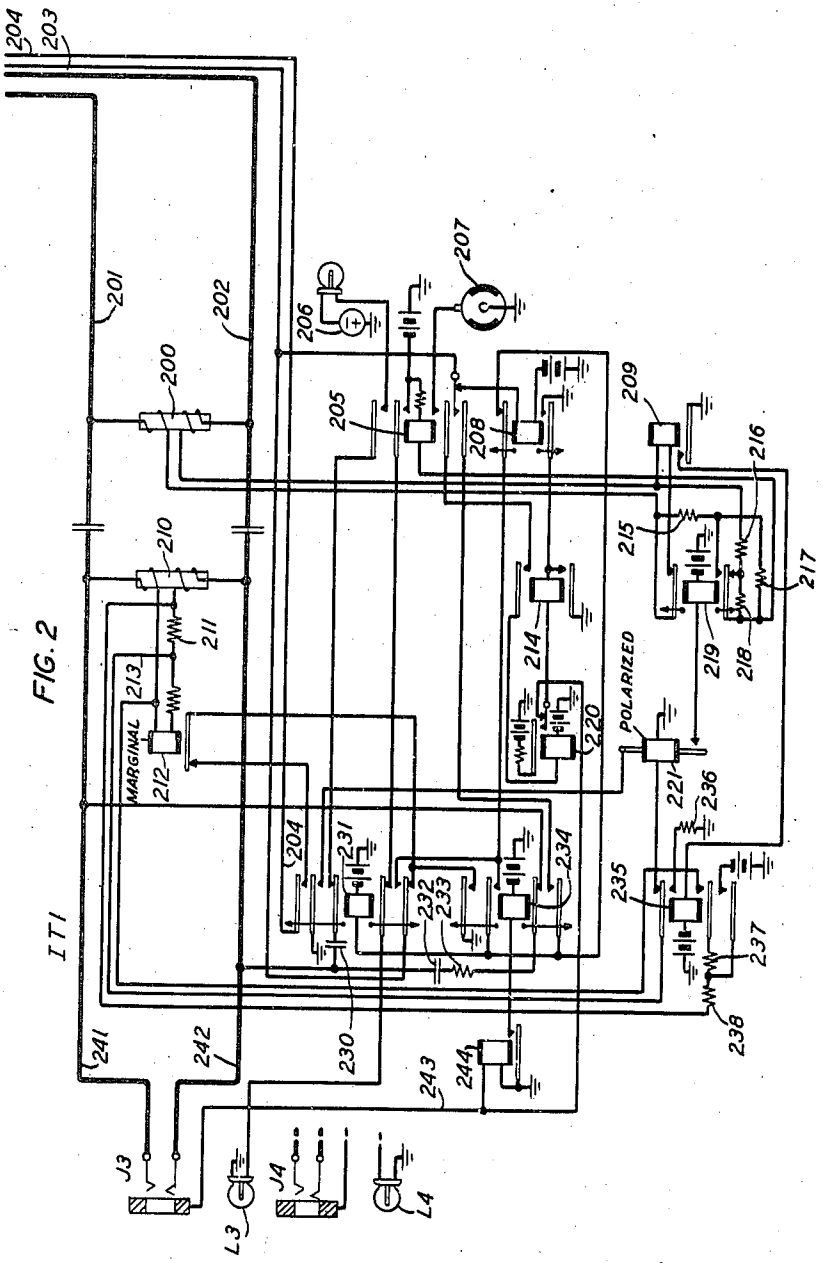

FIG. 2

IT1

INVENTOR
N. D. NEWBY

BY R. O. Covell

ATTORNEY

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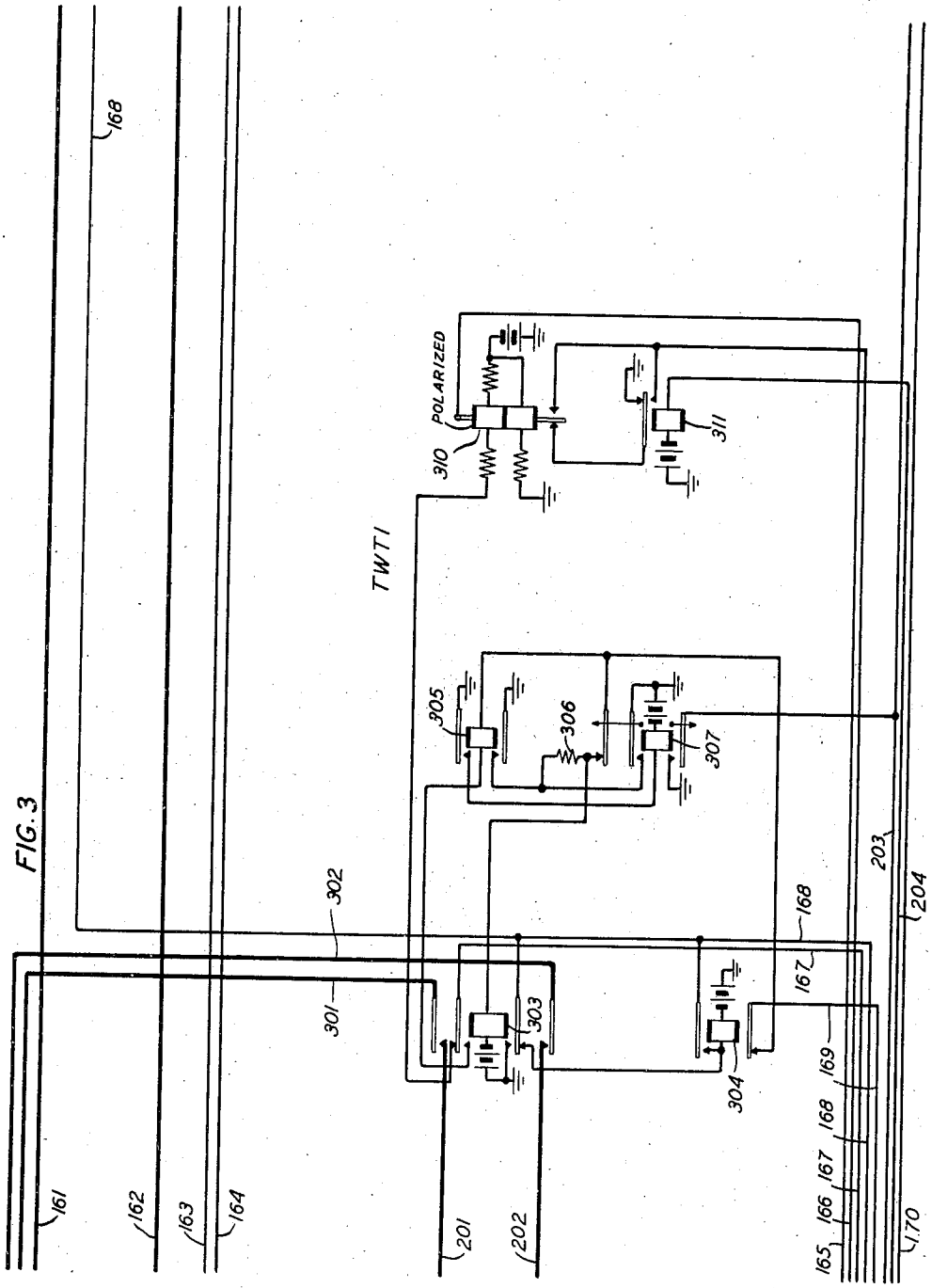

FIG. 3

INVENTOR
N.D. NEWBY

BY

R. O. Covell

ATTORNEY

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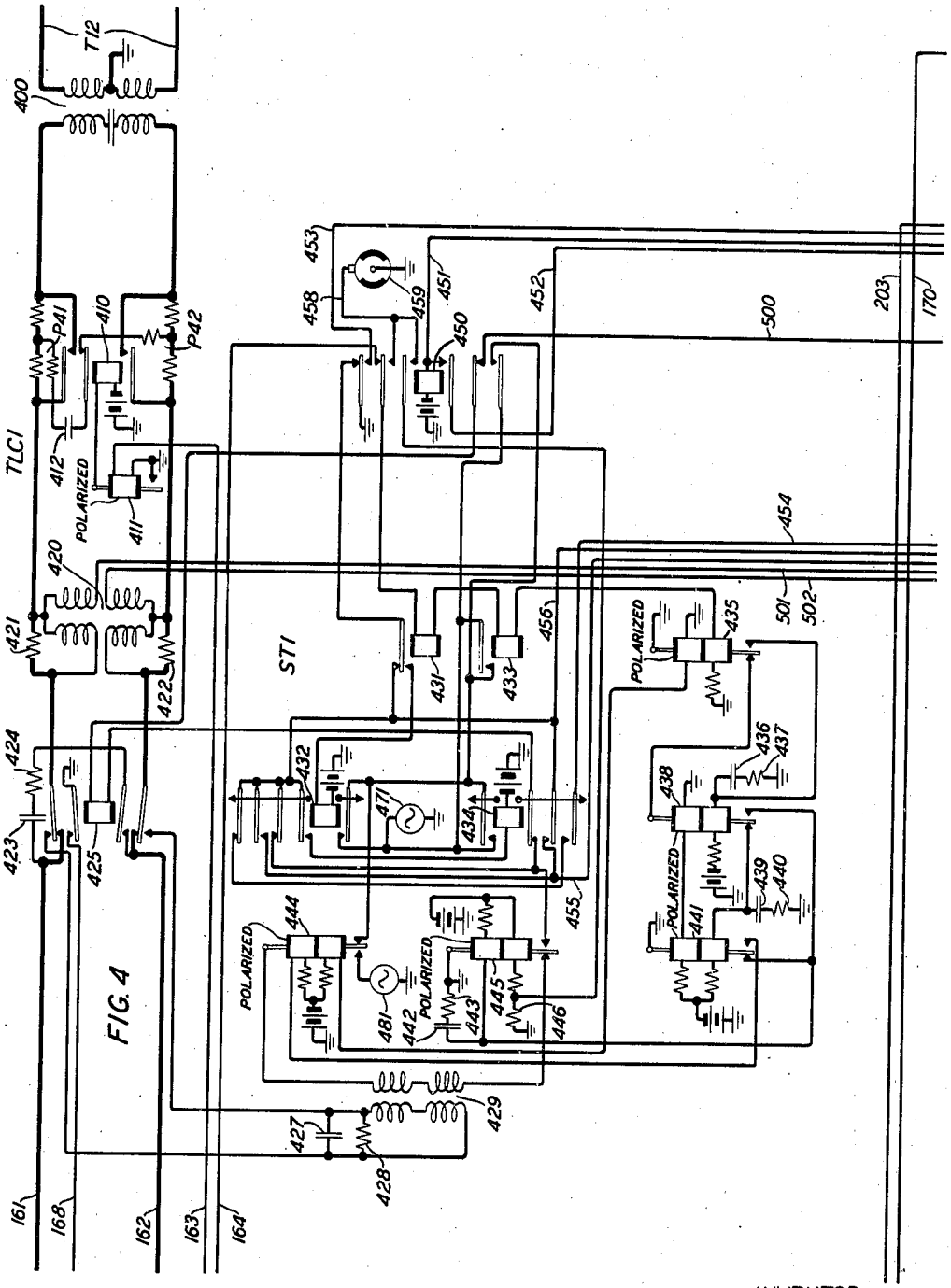

FIG. 4

INVENTOR
N.D.NEWBY
BY
R. O. Covell
ATTORNEY

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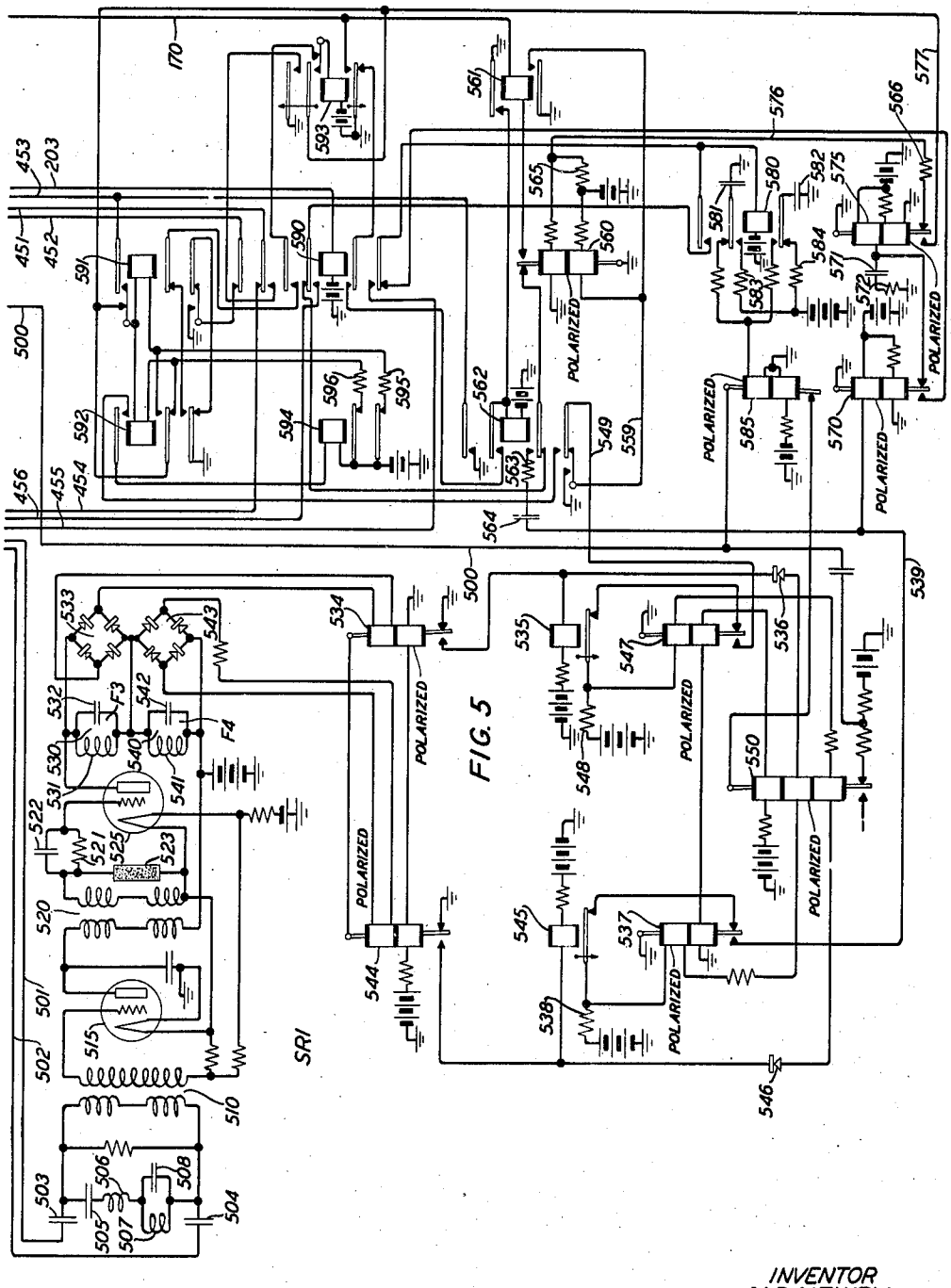

FIG. 5

INVENTOR
N.D.NEWBY
BY
R. O. Covell
ATTORNEY

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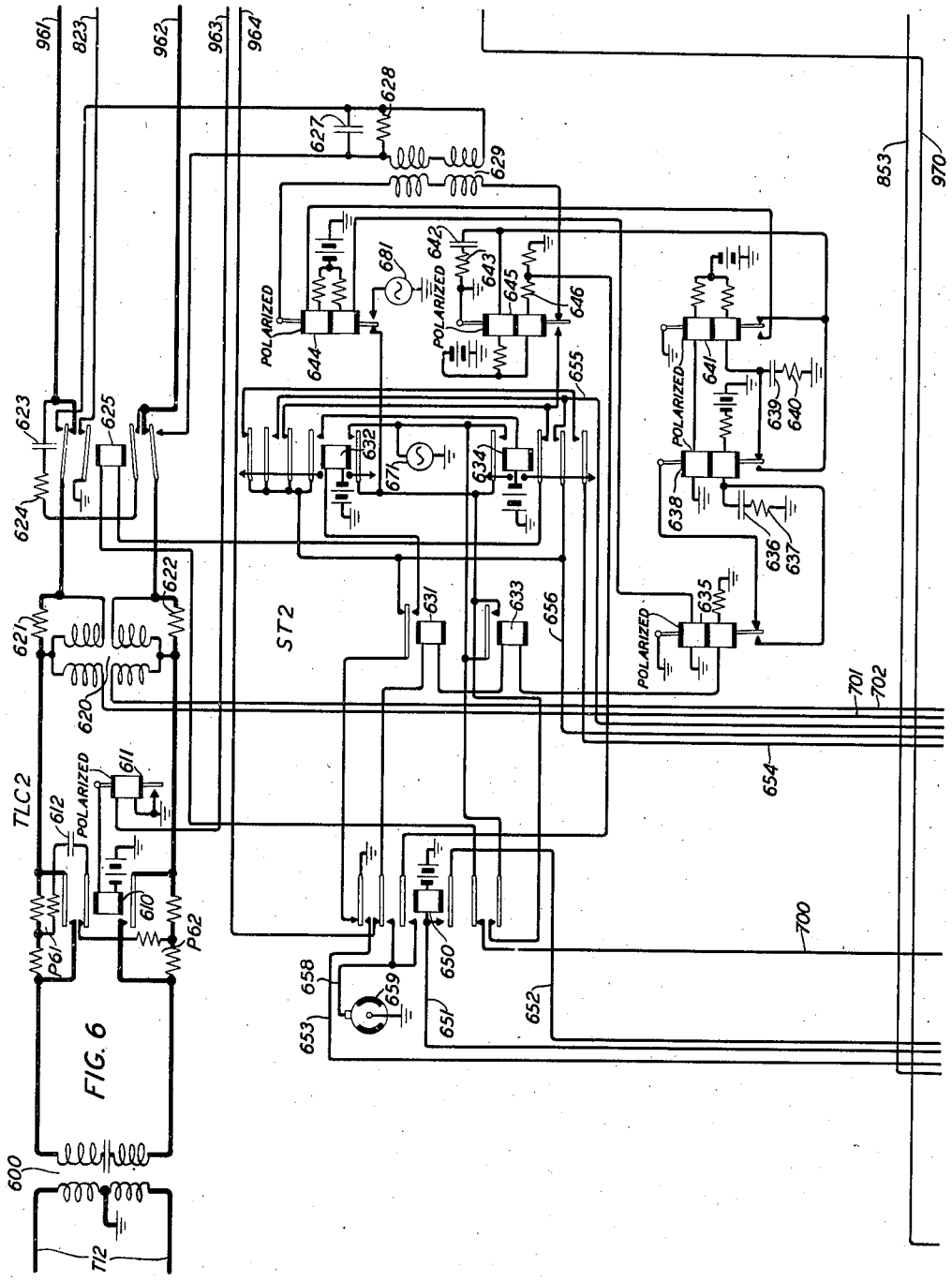

FIG. 6

INVENTOR
N.D.NEWBY
BY
R. O. Covell
ATTORNEY

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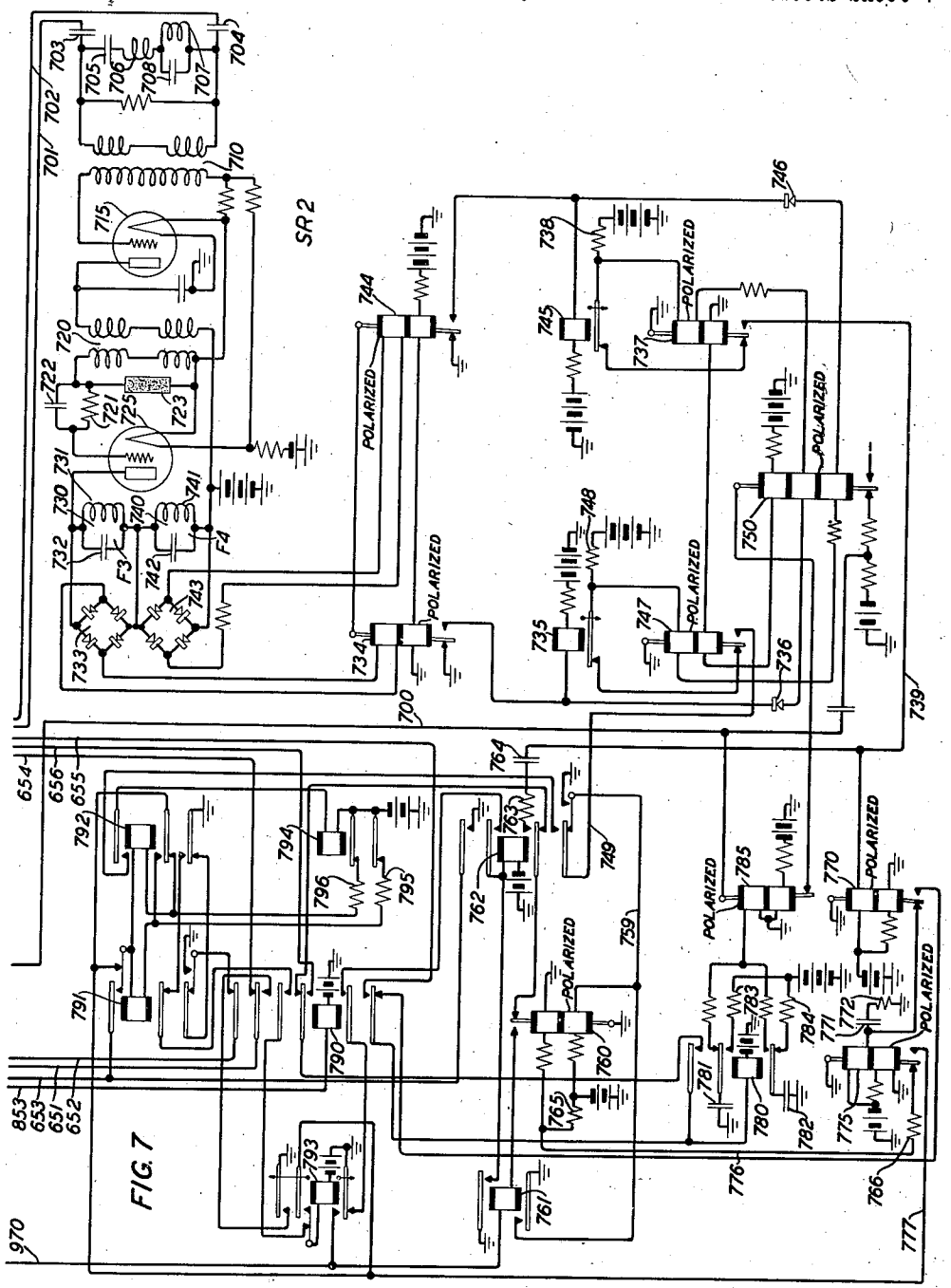

FIG. 7

INVENTOR
N. D. NEWBY
BY
R. O. Covell
ATTORNEY

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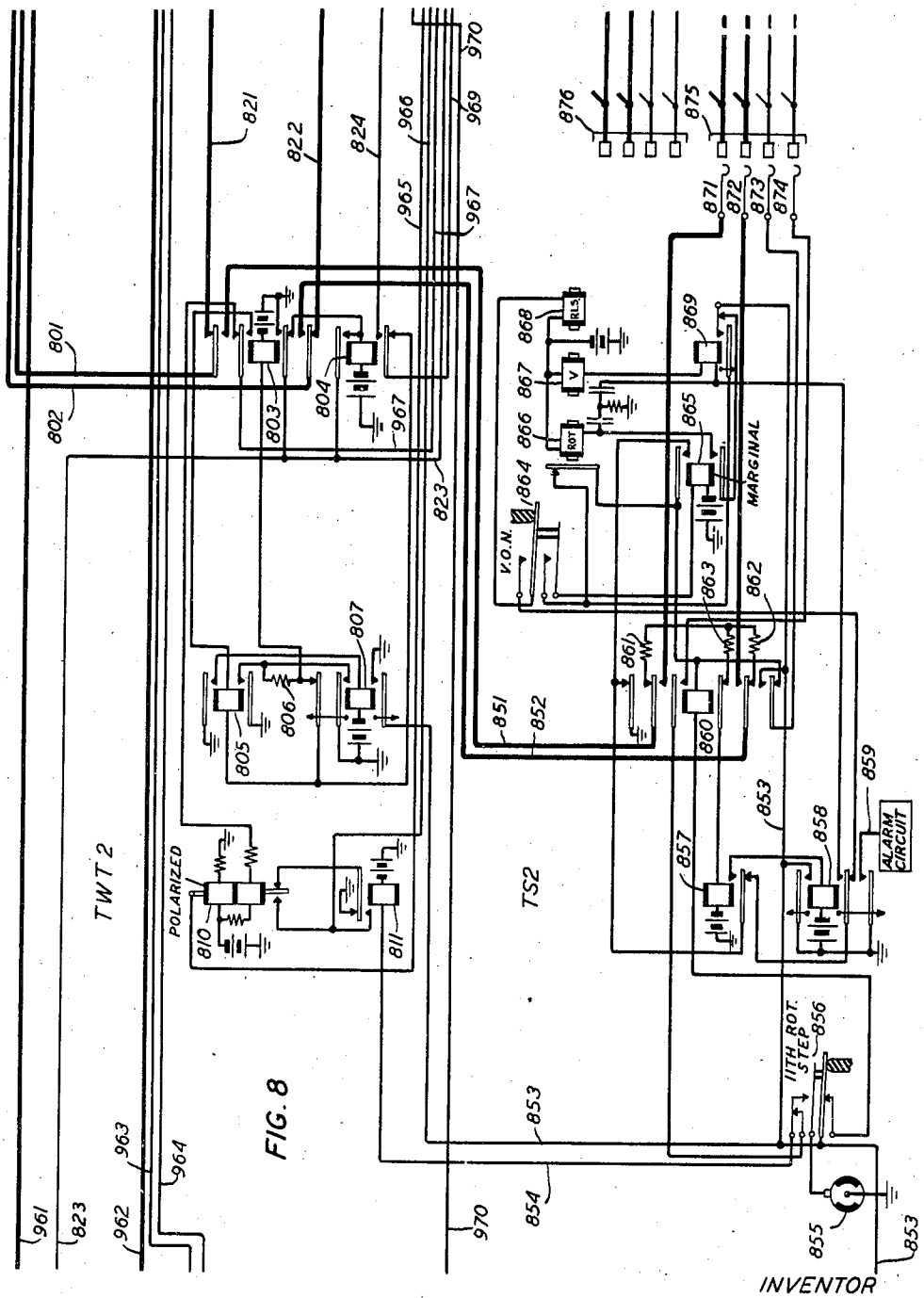

FIG. 8

INVENTOR
N.D. NEWBY

BY
R. O. Covell
ATTORNEY

June 6, 1944. N. D. NEWBY 2,350,917

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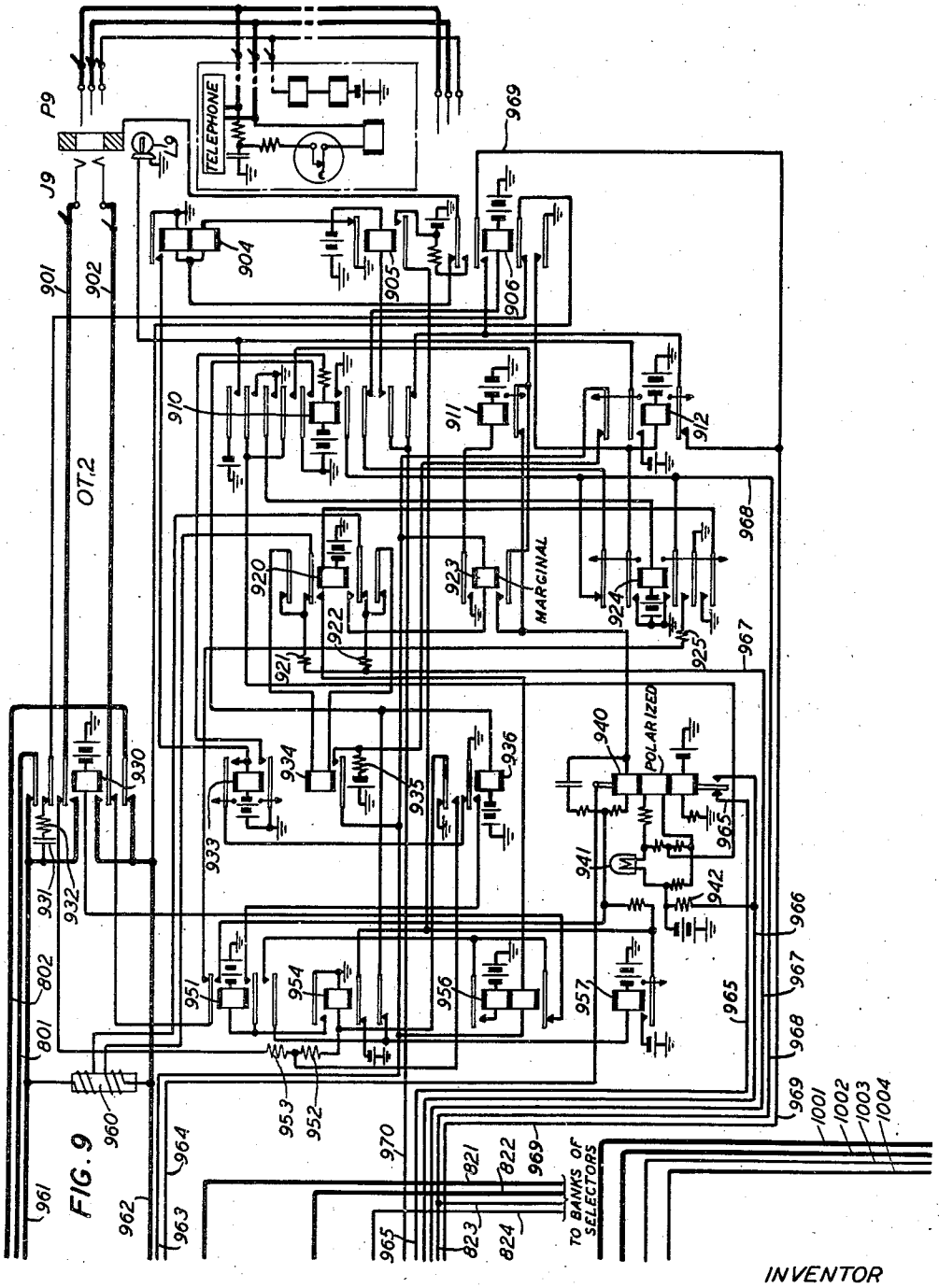

FIG. 9

INVENTOR
N.D.NEWBY

BY

R. O. Covell

ATTORNEY

June 6, 1944. N. D. NEWBY 2,350,917

SIGNALING SYSTEM

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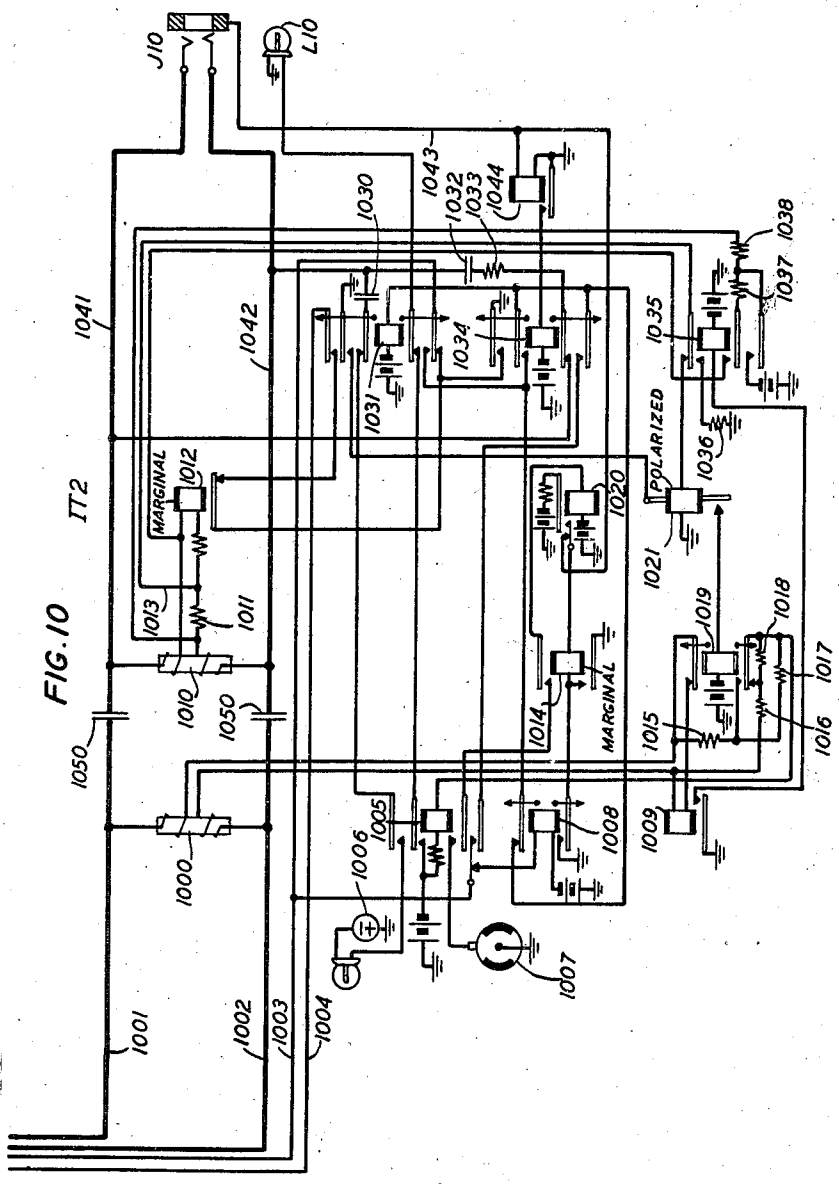

FIG. 10

INVENTOR
N. D. NEWBY

BY R. O. Covell
ATTORNEY

Patented June 6, 1944

2,350,917

UNITED STATES PATENT OFFICE

2,350,917

SIGNALING SYSTEM

Neal D. Newby, Leonia, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application July 17, 1942, Serial No. 451,304

9 Claims. (Cl. 179—84)

This invention relates to signaling systems and particularly to telephone systems in which voice frequency signaling currents are employed.

Objects of the invention are the provision of more reliable signal transmitting and receiving means in systems employing voice frequency signaling and the prevention of false operation in response to voice currents or other interfering currents.

This invention is a signaling system comprising means for transmitting signals comprising current of a first frequency followed by current of a second frequency or for transmitting signals comprising current of the second frequency followed by current of the first frequency, and means for responding to such signals without responding to voice currents or other interfering currents. Similar transmitting and receiving means are connected to both ends of a toll telephone line, different frequencies being used for signaling in each direction thereover. Means are provided for opening the talking connection over the associated toll telephone line whenever signals are being transmitted or received thereover, the connection opening means being non-responsive to voice currents or other interfering currents having a signaling frequency component.

A feature of the invention is the provision of means for repeatedly transmitting the disconnect signal over a toll line until an acknowledgment signal is received from the other end of the line. Another feature is the provision of means for transmitting an acknowledgment signal over a toll line, responsive to a disconnect signal from the other end of the line, and for terminating the transmission of the acknowledgment signal when the disconnect signal ends.

In signaling systems in which one type of signal consists of an impulse of current of a first frequency characteristic followed by an impulse of current of a second frequency characteristic and another type of signal consists of an impulse of current of the second frequency characteristic followed by an impulse of current of the first frequency characteristic, it is necessary to introduce an interval of time between the transmission of a signal of one type and another signal of the same type in order to distinguish from a signal of one type immediately followed by a signal of the other type. Other features of the invention are the provision of signal transmitting means arranged to introduce a predetermined minimum interval of time between successive like signals and the provision of signal receiving means arranged to test for said predetermined interval between successive signals of like type, thereby to distinguish between a signal of one type followed by a signal of the other type and a signal of one type followed by a signal of the same type.

A clear and complete understanding of the invention will be facilitated by considering a system embodying the invention and its features, one such system being represented schematically in the drawings which form a part of this specification. The invention is not limited in its application to the particular system and circuit arrangements shown in the drawings but is applicable generally to any voice frequency signaling system.

Referring to the drawings:

Figs. 1 to 5, inclusive, represent a first toll office comprising an operator's position, an outgoing trunk circuit OT1, an incoming trunk circuit IT1, a two-way trunk circuit TWT1, a toll line circuit TLC1, a signal transmitting circuit ST1 and a signal receiving circuit SR1;

Figs. 6 to 10, inclusive, represent another toll office comprising toll line circuit TLC2, signal transmitting circuit ST2, signal receiving circuit SR2, two-way trunk circuit TWT2, outgoing trunk circuit OT2, toll route selector TS2, and an incoming trunk circuit IT2;

Fig. 11 shows the relative position of Figs. 1 to 10, inclusive, to form an operative arrangement.

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 two toll offices for interconnecting calling and called lines and trunks and controlling the completion of toll calls. The outgoing trunk circuits OT1 and OT2, incoming trunk circuits IT1 and IT2, the two-way trunk circuits TWT1 and TWT2, and the toll route selector circuit TS2 are all similar to corresponding circuits in the aforementioned King et al. patent.

The toll line circuits TLC1 and TLC2, and the associated signal transmitting and receiving circuits, ST1 and ST2 and SR1 and SR2, are arranged for voice frequency signaling over the associated toll lines; whereas in the aforementioned King et al. patent, composite signaling circuits are associated with the toll lines. The toll line circuit TLC1 comprises a repeating coil 400, attenuation pads P41 and P42, pad control relays 410 and 411, a directionally selective coil 420, a cut-off relay 425, and a repeater termination consisting of condenser 423 and resistor 424 in series. The directionally selective coil 420 permits signal-

ing current incoming over toll line T12 to pass to the signal receiver SR1 and permits signaling current from transmitter ST1 to pass out over line T12, but coil 420 prevents the passing of any substantial portion of the signaling current outgoing from transmitter ST1 into the signal receiver SR1. The normally operated cut-off relay 425 is released to open the talking connection between toll line T12 and the trunk circuits OT1 and IT1 whenever signals are being sent out by transmitter ST1 or received by the signal receiver SR1.

The toll line circuit TLC2 is similar to the circuit TLC1, the reference characters of like elements in these circuits having the same tens and units digits.

The signal transmitter ST1 comprises relays 431, 433 and 435 connected in series for control by seizure, selective and supervisory direct current signals transmitted by signal relay 140 of the outgoing trunk circuit OT1. Relays 432, 434, 438, 441, 444 and 445 are controlled by relays 431, 433 and 435 to transmit signals consisting of current of one of two signaling frequencies either followed or preceded by current of the other frequency for required intervals of time. Each of relays 435, 438 and 444 is a polarized relay having a normally energized biasing winding for normally holding the contacts in the position shown in the drawings. Each of relays 441 and 445 has a normally energized operating winding which normally maintains the contacts in the position shown in the drawings; and has a normally energized biasing winding which is effective to move the contacts to their alternate position when the circuit through the operating winding is opened. The tone supply sources 471 and 481 may be oscillators of known design, one generating oscillations at one of the two signaling frequencies and the other generating oscillations at the other of the two signaling frequencies employed for transmitting signals over toll line T12 to the second toll office. Relay 450 and interrupter 459 are effective on outgoing calls to cause the repeated transmission of the disconnect signal and on incoming calls to cause the repeated transmission of a disconnect acknowledgment signal. The signal transmitter circuit ST2 is similar to the transmitter circuit ST1, the reference characters of like elements in these circuits having the same tens and units digits. The two frequencies used for transmitting signals over toll line T12 in one direction are different from the two frequencies used for transmitting signals over toll line T12 in the other direction; for instance, the frequencies 680 cycles per second and 1615 cycles per second may be used in one direction and the frequencies 850 cycles per second and 1870 cycles per second may be used in the other direction.

The signal receiver circuit SR1 comprises an input transformer 510, an amplifier comprising vacuum tube 515, transformer 520, a peak limiting amplifier comprising vacuum tube 525, tuned networks 530 and 540, rectifiers 533 and 543, relay 534 for response to current of one of the two frequencies used for transmitting signals over toll line T12 from the second toll office, and relay 544 for response to current of the other of these two frequencies. Although the directionally selective coil 420 prevents the passing of a large portion of signaling currents from transmitter ST1 to receiver SR1, further protection against response to outgoing signaling currents is provided by a suppression network tuned to the outgoing signaling frequencies connected across the left windings of transformer 510. This network comprises condenser 505 and inductor 506 in series with a filter consisting of inductor 507 and condenser 508 in parallel. In order to secure a signal response, it is necessary that the signaling current of each frequency comprising a voice frequency signal incoming to the signal receiver be somewhat stronger than the sum of all other currents present at the time, and that current of the second of the two frequencies constituting a signal follow the current of the first frequency within a predetermined interval of time. Only if both of these conditions exist, will a signal operation be effected; and for this reason voice currents or other interfering currents will not effect a signal operation. A high resistance element 521, shunted by a small condenser 522, is connected in series with the grid of tube 525 and a non-linear impedance element 523, for instance, a piece of silicon carbide, is connected across the right windings of transformer 520 to limit the voltage impressed on the grid circuit of tube 525. If the desired limiting action is obtainable by the use of the resistor 521 and condenser 522 alone, the element 523 may be omitted; or if the desired limiting action is obtainable by the use of the non-linear impedance element alone, the resistor 521 and condenser 522 may be omitted. Although the plate current of tube 525 never exceeds a definite limiting value, the relative proportion of the various energy components in the output is at all times the same as that of these components in the input. In the plate circuit of tube 525, the network 530 offers substantially infinite impedance to current of one of the two signaling frequencies and the network 540 offers substantially infinite impedance to current of the other of the two frequencies so that relay 534 is energized only by current which is of the one signaling frequency and relay 544 is energized only by current which is of the other signaling frequency. Furthermore, relays 534 and 544 are each adjusted to be operatively responsive to a current equal in value to somewhat more than half the maximum output of tube 525. In other words, the energy of signaling frequency F1 must exceed the sum of all other energy components in the plate circuit to effect the operation of relay 534; and the energy of signaling frequency F2 must exceed the sum of all other energy components to effect the operation of relay 535; and, therefore, both of these relays cannot be operated at the same time. Relays 535, 537, 545, 547, 550, 560, 561, 562, 570, 575, 580, 585, 590, 591, 592, 593 and 594 convert the incoming voice frequency signals into direct current seizure, selective and supervisory signals which effect desired operations in establishing, maintaining, and releasing desired connections. Relays 535 and 545 are slow-to-release relays which are directly controlled by relays 534 and 544. If relays 534 and 535 are operated responsive to current of signaling frequency F1, relay 535 remains operated for a predetermined interval of time after relay 534 releases; and signaling current of frequency F2 must be received before relay 535 releases in order that a signal operation result from the successive operation of relays 534 and 544. Likewise if relays 544 and 545 are operated responsive to current of signaling frequency F2, relay 545 remains operated for a predetermined interval of time after relay 544 releases; and signaling current of frequency F1 must be received before relay 545 releases in order that a signal operation

result from the successive operations of relays 544 and 534. These protections against false signal operation will be further explained in describing the operations involved on calls over toll line T12. Each of relays 534, 544, 537, 547, 550, 560, 570 and 585 is a polarized relay which has a normally energized biasing winding for normally maintaining the contacts in the position shown in the drawings. Relay 575 is a polarized relay having a normally energized operating winding which normally maintains the contacts in the position shown in the drawings and which has a normally energized biasing winding which effects the operation of the contacts to their alternate position when the circuit through the operating winding is opened. Relays 580 and 585 are provided for holding the cut-off relay 425 released for about .550 second after the end of each incoming signal, this arrangement being necessary, in case the toll line T12 is connected by a cord CD to another toll line arranged for voice frequency signaling, to prevent false signal operations at the distant end of the other toll line. The delay in the reoperation of relay 425 also prevents interference with disconnect signals. Relays 591, 592, 593 and 594 are provided for checking incoming disconnect or disconnect acknowledgment signals as hereinafter described. On outgoing calls relay 590 is not operated and the operation and locking of relay 580 is controlled by relays 560 and 570; but on incoming calls relay 590 is operated to place the operation and locking of relay 580 under the control of relays 431, 432 and 434 of the signal transmitting circuit ST1. With relay 590 normal, the operation of relay 450 of signal transmitting circuit ST1 is under the control of relays 431, 432 and 434 and the locking of relay 450 is under the control of relays 591 and 592 of the signal receiver SR1; but with relay 590 operated, the operation of relay 450 is under the control of relays 591, 592 and 593 and relay 450 has no locking circuit. The signal receiving circuit SR2 is similar to the circuit SR1, the reference characters of like elements in these circuits having the same tens and units digits.

The above-mentioned network comprising condensers 505 and 508 and inductors 506 and 507 suppresses the outgoing signaling frequencies but transients produced at the beginning and the end of a signal impulse may be passed to the receiver and tend to cause false operation and interference with response to incoming signals. By using a band-pass filter tuned to the incoming signaling frequencies in place of the band suppression filter, the outgoing signaling currents could not cause false operation of the receiver. While the transients produced in an arrangement using a band-pass filter are not as high as those produced by the suppression network, they are of longer duration. Thus, in either case the transients may be high enough and long enough to cause interference unless the transients are reduced. Such a reduction may be effected by signal wave shaping or by adding a band-pass filter tuned to the outgoing signaling frequencies inserted between the secondary winding of transformer 429 and the back contacts of the cut-off relay 425 of the signal transmitter ST1. If the filter between the directionally selective coil 429 and the signal receiver SR1 is a band elimination filter, the signaling frequencies passed by the sending band-pass filter will be entirely rejected if the band width of the band-pass filter is equal to or less than the band width of the elimination filter. If the filter between the coil 429 and the signal receiver SR1 is a band-pass filter, as above suggested, all frequencies within the pass band of the receiving filter are attenuated by the sending band-pass filter thereby preventing false operation and interference with the receiver.

Further explanation of the invention will be facilitated by describing in detail the circuit operations involved on a call over toll line T12. Assume first that the plug P2 of a cord CD is inserted in jack J2 of the trunk circuit OT1 in Fig. 1, thereby closing a circuit from battery in the operator's position circuit, through the sleeve conductor of the cord CD, as fully described in the aforementioned patent to King et al., through the sleeve conductor of jack J2, a back contact of relay 106 of trunk circuit OT1, and through the upper winding of relay 104 to ground. Relay 104 operates and closes a circuit for operating relay 133. Relay 133 locks under control of relay 136 and closes a circuit for operating relay 110. Relay 110 closes a circuit for lighting the busy lamp L2 associated with jack J2, closes circuits for operating relays 124, 136 and 157; closes a circuit including the inner lower contact of relay 152 for operatively energizing the upper winding of relay 140; closes a circuit through the middle biasing winding of relay 140 in series with ballast lamp 141; connects ground to conductor 168 and disconnects the winding of relay 106 from conductor 168; disconnects conductor 170 from conductor 169 and the windings of relays 303 and 305 of the two-way trunk circuit TWT1; and connects conductor 170 to the winding of relay 105. The operation of relay 124 closes circuits for operating relays 112 and 120, connects ground to conductor 168 and connects ground through its middle lower front contact, resistor 125, back contacts of relays 151 and 130, conductor 102, through the ring conductors of jack J2, plug P2 and cord CD to operate a relay in the operator's position circuit. The connection of ground to conductor 168 operates relay 304. Relay 304 locks to this ground and disconnects the windings of relays 305 and 303 from conductor 169. The operation of relay 136 opens the locking circuit of relay 133, but relay 133 holds under control of relay 104. Relay 133 is slow to release and relay 136 is slow to operate so as to prevent the momentary release of relay 140 if relay 140 operates before the plug P2 is fully seated in jack J2. The operation of relay 140 closes a circuit from battery through resistor 142, front contact of relay 140, conductor 164, a back contact of relay 450, through the windings of relays 431, 433 and 435 of signal transmitting circuit ST1 to initiate the transmission of a seizure signal over toll line T12. The operation of relay 112 opens the normally closed circuit for operating pad control relay 411, closes a circuit for holding the busy lamp L2 lighted, and further opens the connection between conductors 169 and 170. The operation of relay 120 disconnects relay 134 and conductor 167 from the windings of retard coil 160 and conductors 161 and 162 and connects these conductors through the windings of relays 123 and 156 and conductor 163 to the winding of pad control relay 411. The operation of relay 136 opens a normally closed short circuit around the winding of relay 152 and closes a short circuit around resistor 153. Relay 152 is thereupon operated in a circuit through resistor 154, inner upper back contact of relay 139, conductor 191, through the tip conductor of jack J2 and plug P2, thence to battery in the operator's position

circuit as described in the aforementioned King et al. patent. The operation of relay 152 closes a circuit for operating relay 151 and opens the operating circuit of relay 157. Relay 151 locks under control of relay 136 and connects the operating, upper winding of relay 140 through a back contact of relay 130, conductor 102, the ring conductors of jack J2, plug P2 and cord CD to battery in the operator's position circuit. When the dial key (not shown) is operated, the impulse contacts of the dial are connected in series with the operating winding of relay 140 as described in detail in the aforementioned King et al. patent; and, when the called toll route number is dialed, the impulse relay 140 operates and releases in response to each dial impulse to repeat the impulses to the signal transmitter ST1 as hereinafter described.

The aforementioned closing of the circuit through the front contact of relay 140 and windings of relays 431, 433 and 435, in response to insertion of plug P2 in jack J2, causes the operation of these relays. Relay 431 closes a circuit for operating the slow-to-release relay 432, and causes the release of the normally operated cut-off relay 425. The circuit in which relay 425 is normally operated is traced from ground at a back contact of relay 450, the back contact of relay 431, through back contacts of relays 432 and 434, winding of relay 425, another back contact of relay 450, conductor 500, and through back contacts of relays 585 and 550, to battery. The release of relay 425 opens the connection between the talking conductors 161 and 162 of outgoing trunk circuit OT1 and repeating coil 400, and connects the left windings of repeating coil 429 to the repeating coil 400. The operation of relay 433 closes a circuit from ground through the left contact of relay 445, right windings of repeating coil 429, back contact of relay 444, front contact of relay 433, and through the tone source 471 to ground. The operation of relay 432 connects tone source 471 to the back contact of relay 444, the front contacts of relays 432 and 433 being connected in parallel. The alternating potential of frequency F1 generated by the tone source 471 initiates signaling current of frequency F1 through repeating coils 429 and 400, to transmit the first part of a seizure signal over toll line T12 to the signal receiver SR2 in the second toll office. The aforementioned operation of relay 435 closes a circuit for energizing the lower winding of relay 438 and opens the normally closed circuit through the lower winding of relay 441. Upon energization of its lower winding, relay 438 opens its left contact and closes its right contact. When the circuit through the lower winding of relay 441 is opened by the operation of either or both of relays 435 and 438, condenser 439 is charged in series with resistor 440, the charging current being effective to hold relay 441 operated and thereby delay the operation of relay 444 for about .030 second after the operation of relay 433 initiates the signaling current of frequency F1. When the charging current is no longer sufficient to maintain the operative energization of the lower winding of relay 441, the normally energized upper winding of relay 441 effects the opening of the left contact and the closing of the right contact of this relay, thereby opening the energizing circuit through the upper winding of relay 445 and closing an operating circuit through the upper winding of relay 444. The operation of relay 444 disconnects the right windings of repeating coil 429 from tone source 471, and connects the right windings of repeating coil 429 to tone source 481. Since the closing of the operating circuit of relay 444 is delayed by the charging of condenser 439, the current of frequency F1 through coils 429 and 400 and toll line T12 continues for a minimum of .030 second before the operation of relay 444 terminates the signaling current of frequency F1 and initiates a signaling current of frequency F2. The upper winding of relay 445 continues to be energized, after the operation of relay 441, by current charging condenser 442 in series with resistor 443. The opening of the left contact and closing of the right contact of relay 445 is thereby delayed for an interval of approximately .050 second, during which interval there is a current of frequency F2 through coils 429 and 400 and toll line T12. The opening of the left contact of relay 445 ends the signaling current of frequency F2, and the closing of the right contact of relay 445 closes a circuit, including a back contact of relay 434, for energizing the winding of the cut-off relay 425. Reoperation of relay 425 disconnects repeating coil 429 from repeating coil 400 and reconnects coil 400 to conductors 161 and 162.

Thus a seizure signal, consisting of current of frequency of F1 for an interval of not less than .030 second followed immediately by current of frequency F2 for an interval of about .050 second, is transmitted over toll line T12 to the second toll office, through repeating coil 600, pads P61 and P62, the left windings of directionally selective coil 620, conductors 701 and 702, condensers 703 and 704 and the right windings of transformer 710. The signal energy is applied through transformer 710 to the grid of amplifying tube 715, is amplified by tube 715, and is applied through transformer 720 to the grid of tube 725. The resistor 721 in the grid circuit of tube 725 effects a drop in potential which limits the amplitude of the output voltage. The network 730 offers substantially infinite impedance to current of frequency F1, so that the signaling current of this frequency in the plate circuit of tube 725 is applied to and rectified by the full-wave rectifier 733; and the rectified current operatively energizes the upper winding of relay 734. When the signaling current of frequency F1 ceases, relay 734 releases. The network 740 offers substantially infinite impedance to current of frequency F2; and the signaling current of this frequency in the plate circuit of tube 725, immediately following the current of frequency F2, is applied to and rectified by the rectifier 743; and the rectified current operatively energizes the upper winding of relay 744. When the current of frequency F2 ceases, relay 744 releases. Since the current in the plate circuit of tube 725 is limited to a value which is sufficient for operating relay 734 only when substantially all of the current in line T12 is of frequency F1 and which is sufficient for operating relay 744 only when substantially all of the current in line L1 is of frequency F2, the operation of either of these relays, when voice or other interfering currents are present, is prevented. The operation of relay 734 in response to the impulse of current of frequency F1 closes a circuit for operating relay 735 and closes a circuit through rectifier 736, the middle winding of relay 750, upper winding of relay 737 and resistor 738, to battery. Since ground is normally connected through back contacts of relays 737 and 745, to resistor 738, the operation of relay 734 is ineffective to energize the middle winding of relay 750 and upper winding of

relay 737. When the current of frequency F1 ceases, relay 734 releases but relay 735 is a slow-to-release relay and remains operated for approximately .020 second after the release of relay 734. The operation of relay 744, in response to signaling current of frequency F2, immediately following the current of frequency F1, closes a circuit for operating relay 745 and closes a circuit through rectifier 746, the lower winding of relay 750, the upper winding of relay 747 and resistor 748. Since the operation of relay 744, in response to a seizure signal, occurs before relay 735 has released, the current in the circuit through rectifier 746 effects the operation of relays 747 and 750. The operation of relay 750 opens the normally closed energizing circuit of cut-off relay 625, this circuit being traced through back contacts of relays 750 and 785, conductor 700, a back contact of relay 650, winding of relay 625, and through back contacts of relays 634, 632 and 631, to ground at another back contact of relay 650. The operation of relay 747 prevents the connection of a short-circuiting ground to resistor 748 when relay 735 releases, and closes a circuit from ground through conductor 749, a back contact of relay 762, conductor 759 and the lower winding of relay 760 to battery. Relay 760 operates, closing a circuit from ground through its left contact, winding of relay 761, conductor 970, lowermost back contact of relay 910 of outgoing trunk circuit OT2, lower back contact of relay 912, conductor 969, back contact of relay 804 of two-way trunk circuit TWT2, back contact of relay 807, and through the winding of relay 803 to battery. Relays 761 and 803 are operated by the current in this circuit. The operation of relay 761 closes a circuit for operating relay 762 and connects ground to conductor 759 to maintain the energization of the lower winding of relay 760. Relay 762 locks under control of relays 790 and 793, connects ground to conductor 759, and connects the right contact of relay 760 through resistor 763 and condenser 764 to conductor 739 in preparation for the receiving of succeeding signals. When the current of frequency F2 ends, relay 744 releases, causing the release of relays 745, 747 and 750, the release of relay 745 occurring about .020 second after the release of relay 744. The release of relay 750 closes the circuit for operating cut-off relay 625; and relay 625 closes the talking connection between toll line T12 and conductors 961 and 962.

The aforementioned operation of relay 803, in response to the seizure signal, connects ground to conductor 823 to mark the two-way trunk circuit TWT2 and associated toll line T12 busy in the banks of the toll route selectors. This ground potential is further connected through conductors 823 and 968, back contacts of relays 924 and 910 of the outgoing trunk circuit OT2 to the winding of relay 906. Relay 906 operates, connects battery to the sleeve of jack J9 as a busy indication, and closes a circuit for operating relay 912. Relay 912 closes a circuit for lighting busy lamp L9 and opens the normally closed circuit for operating pad control relay 611. The aforementioned operation of relay 803 disconnects conductors 801 and 802 from conductors 821 and 822 leading to terminals in the banks of toll route selectors, and closes a circuit for operating relay 805 of trunk circuit TWT2 and line relay 857 of toll selector TS2. This circuit is traced from ground through the front contact of relay 760, winding of relay 761, conductor 970, back contact of relay 910, front contact of relay 906, conductor 969, back contact of relay 804, winding of relay 805, inner upper front contact of relay 803, conductor 967, thence in simplex through resistors 921 and 922, inner back contacts of relay 920, windings of retard coil 960, outer back contacts of relay 930, conductors 801 and 802, outer front contacts of relay 803, conductors 851 and 852, back contacts of relay 860 of selector TS2, resistors 861 and 862, to and through resistor 863 and another back contact of relay 860, through the winding of relay 857 to battery. The operation of relay 805 closes a circuit through resistor 806 for holding relay 803 and closes a circuit for operating relay 807. Relay 807 closes a holding circuit for relay 803 and connects ground to conductor 853 thereby operating relay 790 of signal receiver SR2. Relay 790 disconnects the winding of relay 780 from the contact of relay 770, to prevent the operation of relay 780 in response to signals incoming over line T12, closes a locking circuit for relay 762 to ground at a back contact of relay 793, and connects relay 780 to conductor 655 for operation as hereinafter described during the transmission of signals over line T12 to the calling office. Relay 807 is a slow-to-release relay in order to maintain the connection of ground to conductor 853 during the response of relay 805 to dial impulses as hereinafter described. The operation of relay 857 closes a circuit for operating the slow-to-release relay 858. Relay 858 connects ground to conductor 853, and connects ground to conductor 859 leading to the alarm circuit which operates in usual manner to operate an alarm device if the selector TS2 fails to complete its selective operations within a predetermined interval of time.

No further operations take place until the calling operator dials the desired toll route number and also the called subscriber's number if the called line is in an automatic office. Relay 140 of outgoing trunk circuit OT1 responds to the dial impulses, opening and closing the circuit through conductor 164 and the windings of relays 431, 433 and 435 in response to each opening and closing of the impulse contacts of the dial. The release of relay 431 opens the operating circuit of relay 432, but relay 432 is slow in releasing and remains operated during the transmission of dial impulses. With relay 431 released and relay 432 operated, a circuit is closed in response to the first impulse of each train for operating relay 434; and since relay 434 is slow in releasing, it remains operated until relay 433 reoperates, after receiving the last impulse of the train. The operation of relay 434 causes the release of the cut-off relay 425 to disconnect coil 400 from conductors 161 and 162 during the transmission of dial impulses. The release of relay 435 opens the circuit through the lower winding of relay 438 and closes a circuit including the right contact of relay 438 for energizing the upper winding of relay 445. Relay 438 is held operated, after relay 435 releases, by current charging condenser 436. The energization of the upper winding of relay 445 effects the closing of its left contact; and, since relay 434 is operated and the right contact of relay 444 is closed, the right windings of coil 429 are connected to tone source 481 to initiate a current of frequency F2 in line T12. As soon as the current charging condenser 436 is no longer sufficient to maintain the closure of the right contact of relay 438, (about .030 second after relay 435 releases), the lower winding of relay 441 is again energized through the left contacts of relays 438 and 435.

Relay 441 thereupon closes its left contact to maintain the energization of the upper winding of relay 445, the energization of this winding being maintained by current charging condenser 442 after relay 438 releases and before relay 441 operates. The opening of the right contact of relay 441 deenergizes the upper winding of relay 444; so that relay 444 opens its left contact to disconnect tone source 481 from coil 429 and closes its right contact to connect tone source 471 thereto, thereby ending the current of frequency F2 through coils 429 and 400 and toll line T12 and starting current of frequency F1. When relay 435 reoperates, at the end of the first dial impulse, it opens the circuit for energizing the lower winding of relay 441 and closes the circuit for energizing the lower winding of relay 438. Relay 438 immediately actuates its contacts but the actuation of the contacts of relay 441 is delayed while condenser 439 is charging. When relay 441 actuates its contacts, about .030 second after relay 435 reoperates, the upper winding of relay 444 is energized; and the coil 429 is disconnected from tone source 471 and again connected to tone source 481, thereby ending the current of frequency F1 and initiating current of frequency F2. Each release and reoperation of relay 435 in response to succeeding dial impulses in the same train effects the above-described cycle of operations whereby an impulse of current of frequency F2 is transmitted, followed by an impulse of current of frequency F1, through coils 429 and 400 and toll line T12 for each dial impulse. At the end of the last impulse of the train, the current of frequency F2 continues for about .050 second while condenser 442 is being charged, whereupon the contacts of relay 445 are actuated to open the circuit through the right windings of coil 429. Relay 434 releases when relay 431 remains operated at the end of a train of impulses, thereby causing the reoperation of cut-off relay 425.

Dialing may start within .080 second after the plug P2 is inserted in jack J2. In this case, relay 445 has not been operated to end the current of frequency F2 of the seizure signal, the release of relay 431 and operation of relay 434 maintain the deenergization of relay 425, and the release of relay 435 prevents the deenergization of the upper winding of relay 445, for about .030 second while condenser 436 is charging and until relay 438 opens its right contact. Thus there is no interval between the current of frequency F2 of the seizure signal and the current of frequency F2 for the first dial impulse.

Each succeeding train of dial impulses effects the operation of the signal transmitter ST1 in like manner to transmit voice frequency impulses over toll line T12 to the receiver SR2 in the second toll office. The signal receiver SR2 responds to each train of dial impulses, the first train being effective to control the selective operation of selector TS2. The current of frequency F2, responsive to the first opening of the impulse contacts of the dial, causes the operation of relay 744. Relay 744 closes a circuit for operating relay 745 and closes a circuit through rectifier 746 and windings of relays 747 and 750. Since relay 735 is not then operated, the windings of relays 747 and 750 are short-circuited through back contacts of relays 735 and 747. When the current of frequency F2 through toll line T12 ceases and current of frequency F1 begins, relay 744 releases and relay 734 operates. Being slow in releasing, relay 745 remains operated for about .020 second after relay 744 releases; and the operation of relay 734, while relay 745 is operated, effects the operation of relays 735, 737 and 750. The operation of relay 750 causes the release of cut-off relay 625 to disconnect coils 600 and 620 from talking conductors 961 and 962; and the operation of relay 737 prevents the short-circuiting of its upper winding, when relay 745 releases, and connects ground to conductor 739, thereby energizing the upper winding of relay 770. The energization of the upper winding of relay 770 effects the opening of its left contact and the closing of its right contact. The closing of the front contact of relay 770 is without effect, since relay 790 is operated; but the opening of the left contact of relay 770 opens the circuit through the upper winding of the normally operated relay 775, the deenergization of this winding being delayed for about .030 second while condenser 771 is being charged in series with resistor 772. The deenergization of the upper winding of relay 775 causes the opening of the left contact and closing of the right contact of this relay; whereby ground is disconnected from conductor 776 and connected to conductor 777. The disconnection of ground from conductor 776 effects an increase in the current through the upper winding of relay 760 to cause relay 760 to open its left contact to release relays 761, 805 and 857 and close its right contact to discharge condenser 764. The connection of ground to conductor 777 operatively energizes the winding of relay 791; but relay 792 is not energized since its winding is short-circuited through its own inner lower back contact. Relay 791 locks under control of relay 762. When the current of frequency F1 ends, relays 734, 735 and 737 release, the release of relay 735 being delayed for .020 second. The release of relay 737 disconnects ground from conductor 739 but the upper winding of relay 770 remains energized for about .030 second while condenser 764 is being charged in series with resistor 763. When the charging current is no longer effective to operatively energize the upper winding of relay 770, the biasing winding effects the opening of the right contact and closing of the left contact of this relay. The upper winding of relay 775 is thereby energized to effect the disconnection of ground from conductor 777 by the opening of the right contact of relay 775 and the reconnection of ground to conductor 776 by the closing of the left contact of relay 775. The disconnection of ground from conductor 777 opens the short circuit around the winding of relay 792, whereupon this winding is energized in series with resistor 796, through the locking contact of relay 791 to ground at a front contact of relay 762. The reconnection of ground to conductor 776 decreases the current through the upper winding of relay 760 to cause the closing of the left contact of relay 760 and thereby reoperate relays 761, 805 and 857. The current of frequency F2, immediately following the current of frequency F1 in line T12, causes the successive operations of relays 744 and 745. Since relay 735 has not yet released, the operation of relay 744 causes the operation of relay 747 and holds relay 750; and the operation of relay 747 connects ground to conductor 749 thereby causing the operative energization of relay 794. The operation of relay 794, in response to the current of frequency F2 following each dial impulse signal, causes the release of relays 791 and 792, thereby preventing two succeeding dial impulse signals from being recognized as a disconnect sig-

nal. Since relay 762 is locked under control of relay 793, it remains operated during the response of relays 770 and 775 to dial impulses and maintains the connection of ground to conductor 759. Each succeeding dial impulse in the train effects the reoperation of the relays of the receiver SR2 to effect a release and reoperation of relays 761, 805 and 857. When the current of frequency F2, following the last impulse of the train ceases, the release of relay 744 causes the release of relays 745 and 750. The release of relay 750 closes the circuit for operating cut-off relay 625 to reconnect coils 600 and 620 to talking conductors 961 and 962. Relay 760 now maintains the connection of ground through the winding of relay 761 to conductor 970 to hold relay 805 of the two-way trunk circuit TWT2 and to hold the line relay 857 of selector TS2 until an idle trunk is seized in the level corresponding to the first digit dialed by the calling operator.

Since relay 807 of two-way trunk circuit TWT2 and relay 858 of selector TS2 are slow in releasing, these relays remain operated during the response of relays 805 and 857 to dial impulses. The release of relay 857 in response to the first impulse incoming over toll line T12 closes a circuit for operating the vertical stepping magnet 867 and the slow-to-release relay 869 in series. The operation of magnet 867 steps the brushes 871, 872, 873 and 874 up the first level of the terminal bank. The vertical off-normal springs 864 are actuated when the shaft is moved out of normal position, closing a circuit including the front contact of relay 869 and conductor 853 for operating relay 865. Relay 865 locks, through the back contact of rotary stepping magnet 866 and a front contact of relay 865, to ground at a back contact of relay 860. When relay 857 reoperates at the end of the first impulse, magnet 867 releases but relay 869 is slow in releasing and remains operated until all of the impulses in the train created by the dialing of the first digit have been received by relay 857. Relay 858 is also slow in releasing and remains operated during the response of relay 857 to dial impulses. Each succeeding release and reoperation of relay 857 causes the operation and release of magnet 867, stepping the brushes of the selector up to the level corresponding to the digit dialed. When relay 869 releases, after all of the impulses in the train have been received, it closes a circuit for operating the rotary stepping magnet 866. This circuit is traced from battery through the winding of magnet 866, lower front contact of relay 865, back contact of relay 869, conductor 853, to ground at the upper front contact of relay 858. The operation of magnet 866 rotates the brushes one step, into engagement with the first set of terminals in the selected level. When magnet 866 opens its back contact, relay 865 releases. The release of relay 865 causes the release of magnet 866. If the terminal, with which test brush 873 is in engagement, is guarded by a ground potential, relay 865 reoperates when magnet 866 releases; the operating circuit being traced through the lower front contact of springs 864, back contact of magnet 866, lowermost back contact of relay 860 and test brush 873. The reoperation of relay 865 causes the operation of the rotary stepping magnet 866, thereby advancing the brushes to the next set of terminals. The operation of magnet 866 releases relay 865; and the release of relay 865 releases magnet 866. Relay 865 and magnet 866 repeat this cycle of operations, to advance the brushes step by step, until brush 873 encounters a terminal not marked by ground potential; whereupon, relay 860 is operated to seize the idle set of terminals. The circuit for operating relay 860 is traced from battery through the winding of relay 865, front contact of the vertical off-normal springs 864, back contact of magnet 866, winding of relay 860, lower back contact of the 11th rotary step springs 856, through conductor 853 to ground at the upper front contact of relay 858. Relay 865 is marginal and does not reoperate in series with the winding of relay 860. Relay 860 disconnects the winding of relay 857 from conductors 851 and 852 and connects these conductors to brushes 871 and 872 thence to the trunk or selector circuit connected to the selected set of terminals. The release of relay 857 causes the release of relay 858 but ground is not thereby disconnected from conductor 853 since this conductor is connected to ground at the lower front contact of relay 807.

Assume first that the call is routed to an operator in the second toll office, that the terminals, in the level selected in response to the first digit dialed by the calling operator, are connected to incoming trunk circuits and that the terminals 876, connected to the trunk circuit IT2, are selected by the trunk hunting operation of the selector TS2. In this case, the operation of relay 860 closes a circuit for operating the line relay 1005 of trunk circuit IT2. This circuit is traced from battery through the winding of relay 1005, thence in simplex through resistors 1015, 1016 and 1017, the windings of retard coil 1000, conductors 1001 and 1002, brushes 871 and 872, front contacts of relay 860, conductors 851 and 852, front contacts of relay 803, conductors 801 and 802, back contacts of relay 930, windings of retard coil 960, back contacts of relay 920, through resistors 921 and 922, thence through conductor 967, inner upper front contact of relay 803, winding of relay 805, back contact of relay 804, conductor 969, a front contact of relay 906, lowermost back contact of relay 910, conductor 970, winding of relay 761, to ground at the left contact of relay 760 of signal receiver SR2. Relays 761 and 805 are thereby held operated in series with relay 1005. With relay 1019 non-operated, resistor 1018 is short-circuited; and, since the resistance of resistors 1015 and 1017 together is equal to that of resistor 1016, the simplex is balanced so that pad control relay 934 of outgoing trunk circuit OT2 remains non-operated. In the incoming trunk IT2 the winding of pad control relay 1009 is bridged across the end of the simplex path; but this relay does not operate since the simplex circuit is balanced when an intertoll trunk, such as toll line T12, is connected to the incoming trunk circuit IT2. The aforementioned operation of relay 1005 closes a circuit for lighting the answering lamp L10 and connects the source of ringing current 1006 through a back contact of relay 1031 and condenser 1030 to talking conductor 1042 to transmit a ringing tone to the calling operator to indicate that the toll operator in the called toll office is being signaled. The calling operator having completed dialing restores the dialing key to normal, thereby reconnecting the operator's telephone through plug P2 and jack J2 to the outgoing trunk circuit OT1 and effecting the operation of relay 130 in the manner described in the aforementioned King et al. patent.

When the call is answered by insertion of the plug of a cord in jack J10, relay 1044 is operated in a circuit through conductor 1043 and the sleeve

conductor of jack J10, to battery in the answering operator's position circuit. Relay 1044 closes a circuit for operating relay 1034. Relay 1034 opens the repeater termination, comprising resistor 1033 and condenser 1032 normally bridged across the talking conductors 1041 and 1042, and closes a circuit for operating relay 1031. This circuit is traced through the lower front contact of relay 1034, front contact of relay 1005, conductor 1003, brush 873, lowermost front contact of relay 860, conductor 853, to ground at the lower front contact of relay 807. Relay 1031 locks under control of relay 1008 through conductor 1003, independent of relay 1034. Relay 1031 extinguishes lamp L10, opens the connection through ringing tone condenser 1030 and closes a circuit for operating relay 811 of two-way trunk circuit TWT2. This circuit is traced from ground, through the outer upper front contact of relay 1034, back contact of relay 1012, front contact of relay 1031, conductor 1004, brush 874, a front contact of relay 860, a back contact of the 11th rotary step springs 856 of selector TS2, and through conductor 854 to the winding of relay 811. Relay 811 closes a circuit from battery through resistor 942 of outgoing trunk circuit OT2, conductor 966, front contact of relay 811, back contact of relay 810, conductor 965, back contact of relay 940, conductor 964 through the windings of relays 631, 633 and 635, in series, to ground. Relay 631 closes a circuit for operating the slow-to-release relay 632 and causes the release of the normally operated cut-off relay 625. The release of relay 625 opens the connection between the talking conductors 961 and 962 and repeating coil 600 and connects the right windings of repeating coil 629 to the repeating coil 600. The operation of relay 633 closes a circuit from ground through the right contact of relay 645, left windings of repeating coil 629, back contact of relay 644, front contact of relay 633, and through the tone source 671 to ground. The operation of relay 632 connects tone source 671 to the back contact of relay 644, the lower front contact of relay 632 and front contacts of relays 633 and 634 being connected in parallel. The alternating potential of frequency F3 generated by the tone source 671 initiates signaling current of frequency F3 through repeating coils 629 and 600 to transmit the first part of an answering supervisory signal over toll line T12 to signal receiver SR1. The operation of relay 635 closes a circuit for energizing the lower winding of relay 638 and opens a circuit including the right contact of relay 638 and the lower winding of relay 641. Upon energization of its lower winding, relay 638 opens its right contact and closes its left contact. When the circuit through the lower winding of relay 641 is opened by the operation of either or both of relays 635 and 638, condenser 639 is charged in series with resistor 640, the charging current being effective to hold relay 641 operated and thereby delay the operation of relay 644 for about .030 second after the operation of relay 633 initiates the signaling current of frequency F3. When the charging current is no longer sufficient to maintain the operative energization of the lower winding of relay 641, the normally energized upper winding of relay 641 effects the opening of the right contact of this relay thereby opening the energizing circuit through the upper winding of relay 645 and closing an operating circuit through the upper winding of relay 644. The operation of relay 644 disconnects the left windings of repeating coil 629 from tone source 671 and connects the left windings of repeating coil 629 to tone source 681. Since the closing of the operating circuit of relay 644 is delayed by the charging of condenser 639, the current of frequency F3 through coils 629 and 600 and toll line T12 continues for a minimum of .030 second before the operation of relay 644 terminates the signaling current of frequency F3 and initiates a signaling current of frequency F4. The upper winding of relay 645 continues to be energized, after the operation of relay 641, by current charging condenser 642 in series with resistor 643. The opening of the right contact and closing of the left contact of relay 645 is thereby delayed for an interval of approximately .050 second, during which interval there is a current of frequency F4 through coils 629 and 600 and toll line T12. The opening of the right contact of relay 645 ends the signaling current of frequency F4 and the closing of the left contact of relay 645 closes a circuit including a back contact of relay 634 for energizing the winding of the cut-off relay 625. The reoperation of relay 625 disconnects repeating coil 629 from repeating coil 600 and reconnects coil 600 to talking conductors 961 and 962.

Thus an answering or "off-hook" signal, consisting of current of frequency F3 for an interval of about .030 second followed immediately by current of frequency F4 for an interval of about .050 second, is transmitted over toll line T12 to the calling office, through repeating coil 400, pads P41 and P42, the right windings of directionally selective coil 420, conductors 501 and 502, condensers 503 and 504 and the left windings of transformer 510. The signal energy is applied through transformer 510 to the grid of amplifier tube 515, is amplified by tube 515, and is applied through transformer 520 to the grid of tube 525. The resistor 521 in the grid circuit of tube 525 effects a drop in potential which limits the amplitude of the output voltage. The network 530 offers substantially infinite impedance to current of frequency F3 so that the signaling current of this frequency in the plate circuit of tube 525 is applied to and rectified by the full wave rectifier 533; and the rectified current operatively energizes the upper winding of relay 534. When the signaling current of frequency F3 ends, relay 534 releases. The network 540 offers substantially infinite impedance to current of frequency F4; and the current of this frequency in the plate circuit of tube 525, immediately following the current of frequency F3, is applied to and rectified by the rectifier 543; and the rectified current operatively energizes the upper winding of relay 544. When the current of frequency F4 ceases, relay 544 releases. Since the current in the plate circuit of tube 525 is limited to a value which is sufficient for operating relay 534 only when substantially all of the current incoming in line T12 is of frequency F3 and which is sufficient for operating relay 544 only when substantially all of the current in line T12 is of frequency F4, the operation of either of these relays, when voice or other interfering currents are present, is prevented. The operation of relay 534, in response to current of frequency F3, closes a circuit for operating relay 535 and closes a circuit through rectifier 536, the middle winding of relay 550, upper winding of relay 537 and resistor 538 to battery. Since ground is normally connected through back contacts of relays 537 and 545 to resistor 538, the operation of relay 534 is inef-

fective to energize the middle winding of relay 550 and upper winding of relay 537. When the current of frequency F3 ceases, relay 534 releases but relay 535 is a slow-to-release relay and remains operated for approximately .020 second after the release of relay 534. The operation of relay 544, in response to signaling current of frequency F4 immediately following the current of frequency F3, closes a circuit for operating relay 545 and closes a circuit through rectifier 546, the lower winding of relay 550, the upper winding of relay 547 and resistor 548. Since the operation of relay 544, in response to the answering signal, occurs before relay 535 has released, the current in this circuit effects the operation of relays 547 and 550. The operation of relay 550 causes the release of the cut-off relay 425. The operation of relay 547 prevents the connection of a short-circuiting ground to resistor 548 when relay 535 releases, and closes a circuit from ground through conductor 549, a back contact of relay 562, conductor 559 and the lower winding of relay 560 to battery. Relay 560 operates closing a circuit from ground through its right contact, winding of relay 561, conductor 170, a front contact of relay 110, and through the winding of relay 105. Relays 561 and 105 are operated by the current in this circuit. The operation of relay 561 closes a circuit for operating relay 562 and connects ground to conductor 559 to maintain the energization of the lower winding of relay 560. Relay 562 connects ground to conductor 559 and connects the left contact of relay 560 through resistor 563 and condenser 564 to conductor 539 in preparation for the receiving of succeeding signals. Relay 562 does not lock operated since relay 590 is not operated. When the current of frequency F4 ends, relay 544 releases causing the release of relays 545, 547 and 550, the release of relay 545 occurring about .020 second after the release of relay 544. The release of relay 550 closes the circuit for operating cut-off relay 425 to close the connection between coil 400 and talking conductors 161 and 162. The aforementioned operation of relay 105 opens the circuit through the lower winding of relay 104 thereby leaving the high resistance upper winding of relay 104 in series with the sleeve conductor of jack J2 and plug P2 so as to extinguish the operator's supervisory lamp SL2 as an answering or "off-hook" signal.

While the answering operator's telephone set is connected to trunk IT2, battery is connected through jack J10 to both of conductors 1041 and 1042, thence through the windings of retard coil 1010, through resistor 1011 and relay 1012, conductor 1013, through the upper back contact of relay 1035 and winding of relay 1021 to ground. Relay 1021 operates closing a circuit for operating relay 1019. Relay 1019 disconnects pad control relay 1009 and opens the short circuit around resistor 1018 and short-circuits resistor 1017 to unbalance the simplex circuit through conductors 1001 and 1002 so as to effect the operation of pad control relay 934 of outgoing trunk circuit OT2. Relay 934 closes a circuit through conductor 963 for operating relay 611. Relay 611 opens the circuit for operating relay 610; and with relay 610 released, pads P61 and P62 are included in the talking circuit. After the operator's telephone set is disconnected from trunk IT2 and this trunk is connected through the cord to another trunk or toll line, relay 1021 is held operated if this other trunk or toll line is a switching trunk or tributary line but is released if it is a toll line or intertoll trunk. The release of relay 1021 causes the successive release of relays 1019, 934 and 611 and the operation of relay 610 to short-circuit the pads P61 and P62. If the intertoll trunk associated with the outgoing trunk circuit OT2 is one which is not provided with transmission pads, relay 934 is not provided. If the intertoll trunk associated with the outgoing trunk circuit OT2 is one which does not require the short-circuiting of the pads of a line or trunk to which the incoming trunk circuit IT2 is connected by the answering operator's cord, resistors 921 and 922 of the outgoing trunk circuit OT2 would be of such value as to unbalance the simplex circuit and thereby cause the operation of relay 1009 of the incoming trunk circuit IT2. The operation of relay 1009 closes a circuit for operating relay 1035. Relay 1035 disconnects relay 1021 from conductors 1041 and 1042 and connects battery through resistors 1037 and 1038 to conductors 1041 and 1042 to hold operated the pad control relay of the trunk or line to which the trunk circuit IT2 is connected by the answering operator's cord.

The talking connection between outgoing trunk circuit OT1 and incoming trunk circuit IT2 includes conductors 101 and 102, front contacts of relay 130, conductors 161 and 162, front contacts of relay 425, resistors 421 and 422, repeating coil 400, toll line T12, repeating coil 600, resistors 621 and 622, front contacts of relay 625, conductors 961 and 962, back contacts of relay 930, conductors 8T01 and 802, front contacts of relay 803, conductors 851 and 852, front contacts of relay 860, brushes 871 and 872, conductors 1001 and 1002, condensers 1050 and conductors 1041 and 1042.

If the answering operator disconnects cord CD2 from jack J10, relay 1044 releases causing the release of relay 1034 to disconnect ground from conductor 1004 and effect the release of relay 811. The release of relay 811 causes the release of relays 631, 633 and 635 of signal transmitter ST2, thereby effecting the transmission of an "on-hook" signal consisting of current of frequency F4 followed by current of frequency F3. The release of relay 631 closes a circuit for operating relay 634 and closes a circuit for operating relay 780. The circuit for operating relay 780 is traced from the winding of relay 780, through a front contact of relay 790, conductor 655, a front contact of relay 632, and through the back contact of relay 631 to ground at a back contact of relay 650. Relay 780 locks under control of relays 631 and 650 but independent of relay 632; and closes a circuit for operatively energizing the upper winding of relay 785 for an interval of .550 second while condenser 782 is charging. The operation of relay 634 opens the circuit for operating relay 625 and so also does the operation of relay 785. The release of relay 625 opens the talking connection between toll line T12 and talking conductors 961 and 962. The release of relay 635 opens the circuit through the lower winding of relay 638 and closes a circuit including the left contact of relay 638 for energizing the upper winding of relay 645. Relay 638 is held operated for about .030 second after relay 635 releases, by current charging condenser 636. The energization of the upper winding of relay 645 effects the closing of its right contact; and, since relay 634 is operated and the right contact of relay 644 is closed, the left windings of coil 629 are connected to tone source 681 to initiate an impulse of current of frequency F4

in line T12. When the current charging condenser 636 is no longer effective to maintain the operative energization of the lower winding of relay 638, the circuit through the upper winding of relay 645 is opened at the left contact of relay 638; and the lower winding of relay 641 is again energized in the circuit including the right contacts of relays 638 and 635, the contacts of relay 641 being thereby restored to normal. After relay 638 releases and until relay 641 releases, the energization of the upper winding of relay 645 is maintained by current charging condenser 642. When relay 641 releases, the opening of the left contact of this relay deenergizes the upper winding of relay 644 and the closing of the right contact maintains the energization of the upper winding of relay 645. Relay 644 opens its right contact and closes its left contact thereby disconnecting the left windings of coil 629 from tone source 681 to end the impulse of current of frequency F4 and connecting these windings to tone source 671 to start an impulse of current of frequency F3 through coils 629 and 600 and toll line T12. When relay 632 releases, it causes the release of relay 634, the current of frequency F3 being maintained for about .750 second before the release of relay 634 disconnects coil 629 from tone source 671. Relay 780 remains operated, since it is locked under control of relays 631 and 650. When relay 634 releases, it closes the circuit for operating relay 625, relay 785 having released at the end of an interval of .550 second after relay 780 was operated; and the reoperation of relay 625 closes the connection between line T12 and talking conductors 961 and 962.

In response to the "on-hook" signal transmitted over line T12 to the signal receiver SR1, relay 544 is operated by the current of frequency F4 and relay 534 is operated by the current of frequency F3. Relay 544 closes a circuit for operating relay 545 which remains operated until relay 534 closes circuits for operating relays 535, 537 and 550. The operation of relay 550 causes the release of cut-off relay 425; and the operation of relay 537 connects ground to conductor 539 to energize the upper winding of relay 570. Relay 570 opens the normally closed circuit through the upper winding of relay 575 and closes a circuit for operating relay 580. Relay 580 closes a circuit for operatively energizing the upper winding of relay 585 for about .550 second, while condenser 582 is discharging. About .030 second after relay 570 operates, the current charging condenser 571 is no longer effective to maintain the operative energization of the upper winding of relay 575, the opening of the right contact of relay 575 causing an increase in the current through the upper winding of relay 560 to cause the release of relay 560; and the closing of the left contact of relay 575 being effective to cause the operation of relay 591. Relay 592 does not operate at this time because its winding is short-circuited by its own inner lower back contact. Relay 591 locks under control of relay 562. The opening of the right contact of relay 560 causes the release of relays 561 and 105. Since relay 534 is held operated for about .750 second, relay 570 is operated and relay 575 released long enough to cause the release of relay 562. The release of relay 562 causes the release of relay 591. The release of relay 105 connects ground to the lower winding of relay 104, to decrease the resistance in the circuit through conductor 103 to cause the lighting of the supervisory lamp SL2 associated with plug P2 of cord CD1 in the manner described in the aforementioned King et al. patent. The calling operator is thus given an "on-hook" signal. When relay 534 releases at the end of the current of frequency F3, relays 535, 537 and 550 release. The release of relay 537 releases relay 570; and the release of relay 570 causes the release of relay 580 and reoperation of relay 575. With both of relays 561 and 562 released, and relay 547 being normal, relay 560 cannot reoperate when relay 575 releases; and, therefore, relays 561 and 105 are not reoperated at the end of the signal. The release of relay 580 connects condenser 581 in series with the winding of relay 585 to reoperate relay 585 for about .550 second; and the operation of relay 585 maintains the release of cut-off relay 425 for about .550 second after the "on-hook" signal ends.

When the calling operator disconnects plug P2 from jack J2 to release the connection, relay 104 releases causing the successive release of relays 133 and 110. Relay 110 releases relays 140, 124 and 136 and also releases relays 105 and 157, if operated. Relay 124 releases relays 112 and 120. Relay 136 releases relay 151 and also relay 152, if operated. The release of relay 112 extinguishes the busy lamp L2; and the release of relay 120 reconnects the signaling conductor 167 through resistors 121 and 122 to the windings of retard coil 160. The release of relay 140 causes the release of relays 431, 433 and 435 of signal transmitter ST1. The release of relay 431 opens the operating circuit of slow-to-release relay 432 and closes a circuit for operating relay 434, this circuit being opened when relay 432 releases. The operation of relay 434 causes the release of cut-off relay 425 to open the connection between line T12 and talking conductors 161 and 162. The release of relay 435 closes a circuit including the right contact of relay 438 for energizing the upper winding of relay 445. Relay 445 thereupon reoperates, restoring its contacts to normal position to initiate an impulse of current of frequency F2 through the coils 429, 400 and toll line T12. The release of relay 435 opens the circuit through the lower winding of relay 438, the release of relay 438 being delayed for about .030 second while condenser 436 is charging. When relay 438 releases, it opens the circuit through the upper winding of relay 445 and closes the circuit for energizing the lower winding of relay 441 to restore the contacts of relay 441 to normal position. After relay 438 releases and until relay 441 closes its left contact, the energization of the upper winding of relay 445 is maintained by current charging condenser 442. When relay 441 operates, the opening of the right contact of relay 441 deenergizes the upper winding of relay 444; and the closing of the left contact of relay 441 maintains the operative energization of the upper winding of relay 445. The deenergization of the upper winding of relay 444 disconnects tone source 481 from the right windings of coil 429, to end the current of frequency F2; and connects tone source 471 to those windings, to initiate an impulse of current of frequency F1. When the slow-to-release relay 432 releases, it opens the operating circuit of slow-to-release relay 434 and closes a circuit for operating relay 450, this circuit being traced from the winding of relay 450 through a back contact of relay 590, conductor 454, a front contact of relay 434, a back contact of relay 432, back contact of relay 431, to ground at a back contact of relay 450. Relay 450 closes

a locking circuit through conductor 452, a back contact of relay 590, a back contact of relay 591, to ground at a back contact of relay 592; so that relay 450 is held operated after relay 434 releases. Relay 450 disconnects ground from the armature of relay 431, connects ground to conductor 453, connects tone source 471 to the right contact of relay 444, disconnects conductor 500 from the winding of relay 425 to hold the operating circuit of relay 425 open while repeated disconnect signals are being transmitted over toll line T12, disconnects conductor 164 from the winding of relay 431, and connects the winding of relay 431 to the brush of interrupter 459 so that relays 431, 433 and 435 are now operated ten times per second under the control of interrupter 459. As soon after relay 450 operates as interrupter 459 next connects ground to conductor 458, relays 431, 433 and 435 are reoperated and resistor 446 is short-circuited to cause the immediate release of relay 445 and thereby end the current of frequency F1 by disconnecting ground from the right windings of coil 429. Since relay 450 is operated, the reoperation of relay 431 does not cause the reoperation of relay 432. The operation of relay 433 connects tone source 471 to the right contact of relay 444, a parallel connection being traced through a front contact of relay 450. The operation of relay 435 effects the reoperation of relay 438 and release of relay 441 at the end of .030 second thereby causing the operation of relay 444 to disconnect tone source 471 from and connect tone source 481 to, the right windings of coil 429; but with relay 445 released the circuit through these windings of coil 429 is open and there is no current through coil 429 until relay 445 is reoperated to close its left contact. When the interrupter 459 next disconnects ground from conductor 458, relays 431, 433 and 435 release. The release of relay 435 causes the reoperation of relay 445 and holds relay 445 operated while relay 438 releases. The release of relay 438 reoperates relay 441 and thereby maintains the operation of relay 445, relay 445 having been held operated, after relay 438 releases and until relay 441 reoperates, by current charging condenser 442. The reoperation of relay 441 causes the release of relay 444, relay 444 having been held operated by relay 441 for about .030 second while condenser 436 is charging before relay 438 effects the reoperation of relay 441. Thus, there is an impulse of current of frequency F2 for about .030 second in coils 429 and 400 and line T12 after relay 445 reoperates before relay 444 releases. When relay 444 releases, due to the reoperation of relay 441, coil 429 is disconnected from tone source 481 and connected to tone source 471 thereby starting an impulse of current of frequency F1 through coils 429 and 400 and toll line T12, this impulse continuing until relays 431, 433, 435 and 445 are reoperated under the control of interrupter 459. Thus, a disconnect signal consisting of current of frequency F2 followed by current of frequency F1 is transmitted ten times per second, under the control of interrupter 459, over line T12 to the signal receiver SR2, with an interval of about .050 second between the end of one signal and the beginning of the next.

In the signal receiver SR2, the current of frequency F2 effects the operation of relay 744. The operation of relay 744 causes the operation of relay 745; but relay 735 being normal, relays 747 and 750 do not operate. When the current of frequency F2 ends, relay 744 releases, relay 745 remaining operated for about .020 second. The current of frequency F1 causes the operation of relay 734. The operation of relay 734 causes the operation of relay 735; and, since relay 745 has not yet released, it also causes the operation of relays 737 and 750. The operation of relay 750 causes the release of relay 625. Relay 737 connects ground to conductor 739, thereby causing the energization of the upper winding of relay 770. Relay 770 opens the circuit through the upper winding of relay 775, the deenergization of this winding being delayed for about .020 second while condenser 771 is being charged. Relay 775 disconnects ground from conductor 776 to effect the release of relay 760 and connects ground to conductor 777 to operate relay 791. Relay 760 opens the circuit through relay 761, conductor 970, relays 805 and 1005 causing the release of relays 761, 805 and 1005. Relay 762 does not release at this time since it is locked to ground at the back contact of relay 793. When the current of frequency F1 ceases, relay 734 releases causing the release of relays 735, 737 and 750. The release of relay 737 disconnects ground from conductor 739, causing the release of relay 770 and operation of relay 775. The operation of relay 775 disconnects ground from conductor 777 to cause the operation of relay 792; and reconnects ground to conductor 776 causing the reoperation of relays 760, 761, 805 and 1005. The operation of relay 792 connects the winding of relay 791 to conductor 777 in preparation for the next disconnect signal, and connects the winding of relay 794 to conductor 749. If a signal consisting of current of frequency F1 followed by current of frequency F2 follows the disconnect signal, or if a current of frequency F2 immediately follows the disconnect signal, the connection of ground to conductor 749 by the operation of relay 747 causes the operation of relay 794; and the operation of relay 794 causes the release of relays 791 and 792. If, however, the first disconnect signal is followed by a second disconnect signal, the operation of relay 737 again connects ground to conductor 739 reoperating relay 770 and releasing relay 775. The release of relay 775 again disconnects ground from conductor 776, releasing relay 760; and connects ground to conductor 777, thereby short-circuiting the winding of relay 791. The release of relay 791 closes a circuit for operating relay 793. Relay 793 locks to ground at the front contact of relay 775, closes a circuit for operating relay 650, opens the locking circuit of relay 762, and connects ground to conductor 970. Relay 793 is slow in releasing so that the intermittent connection of ground to conductor 777 by succeeding release operations of relay 775 will hold relay 793 operated as long as the disconnect signal is repeated.

The operation of relay 650 connects interrupter 659 to the windings of relays 631, 633 and 635 and to the lower winding of relay 645. Each time the interrupter connects ground to conductor 658, the operation of relays 631 and 635 causes the transmission of an acknowledgment signal, over toll line T12 consisting of current of frequency F4 followed by current of frequency F3 in similar manner to that in which disconnect signals are transmitted from the calling end of toll line T12, as above described. The acknowledgment signal effects the operation of the signal receiver SR1, in like manner to that in which the disconnect signal effects the operation of signal receiver SR2, to cause the operation of relays 591, 592 and 593. When the first acknowledgment

signal is transmitted, relays 560, 561 and 562 may be either operated or released depending upon whether an "on-hook" or an "off-hook" signal condition exists at the time the acknowledgment signal is started. If these relays are operated, the first acknowledgment signal causes the operation of relay 537 thereby connecting ground to conductor 539 to operate relay 570. The operation of relay 570 causes the release of relay 575. The release of relay 575 disconnects ground from conductor 576 to release relays 560, 561 and 562; and connects ground to conductor 577 to operate relay 591. When relay 575 reoperates at the end of the signal, relay 592 operates. When the next acknowledgment signal is received, the release of relay 575 causes the release of relay 591, thereby releasing relay 450 to end the transmission of disconnect signals. If a signal consisting of current of frequency F3 followed by current of frequency F4 is received between two acknowledgment signals, the operation of relay 594 causes the release of relays 591 and 592.

When relay 793 operates as above described, it opens the locking circuit of relay 762, and connects ground to conductor 970 to short-circuit the winding and prevent the reoperation of relay 761. Therefore, relays 761 and 762 release, disconnecting ground from conductor 759 so that relay 760 is not reoperated when relay 775 reoperates at the end of the last disconnect signal incoming over toll line T12. After receiving the last disconnect signal, relay 775 remains operated and therefore relay 793 releases. The release of relay 793 causes the release of relay 650, to end the transmission of the acknowledgment signal and effect the reoperation of relay 625; and disconnects ground from conductor 970 thereby causing the continued release of relay 805 of two-way trunk circuit TWT2 and the continued release of relay 1005 of trunk circuit IT2. The continued release of relay 805 causes the release of slow-to-release relay 807; and the release of relay 807 disconnects ground from conductor 853 to release relay 799. The release of relay 799 restores the signal receiver SR2 to normal.

The aforementioned release of relay 807 of two-way trunk circuit TWT2 causes the release of relay 803 and the release of relay 860 of selector TS2. The release of relay 860 closes a circuit for operating release magnet 868; and selector TS2 is thereupon restored to normal in well-known manner. The release of relay 803 completes the return of trunk circuit TWT2 to normal, disconnecting ground from conductors 823 and 968 to terminate the guarding of the terminals to which trunk circuit TWT2 is connected in the banks of toll selectors and to cause the release of relay 906. The release of relay 906 disconnects battery from the sleeve of jack J9 and causes the release of relay 912. The release of relay 912 extinguishes busy lamp L9 and completes the return of the outgoing trunk circuit OT2 to normal.

The aforementioned release of relay 1005 connects relay 1008 to conductor 1003, relay 1008 closes the circuit for operating relay 1014, and relay 1014 locks. Relay 1008 releases as soon as ground is disconnected from conductor 1003 by the aforementioned release of relay 807; and, since relay 1005 does not reoperate, the supervisory lamp (not shown) of the cord connected to jack J10 lights as a disconnect signal. The aforementioned disconnection of ground from conductor 1003 also causes the release of the slow-to-release relay 1031. When relay 1031 releases, and if the answering operator has not disconnected from jack J10, conductor 1003 is connected to ground at the uppermost front contact of relay 1034 to prevent the reseizure of trunk circuit IT2. When the answering cord is disconnected from jack J10, relays 1044 and 1014 release. The release of relay 1034 completes the return of trunk circuit IT2 to normal.

The above described arrangement insures release of a connection in response to a disconnect signal, the transmission of busy tone on calls to local dial offices being ineffective to prevent disconnect since the silent interval between the tone intervals is long enough for one or more disconnect signals to be received, the first one being effective to release the cut-off relay and thereby prevent the next tone impulse from interfering with the operation of the signal receiver in response to the second disconnect signal.

It is to be noted that the use of alternating current of two frequencies in sequence to constitute a signal is a case of frequency modulation in which the carrier is suppressed when there is no signal and in which the frequency of the signaling current is increased proportional to the amplitude of a positive direct current potential and is decreased proportional to the amplitude of a negative direct current potential. For instance, with a carrier of 1500 cycles per second, the signaling current transmitted responsive to the positive part of a direct current signal might be 1800 cycles per second and the signaling current transmitted responsive to the negative part of the direct current signal might be 1200 cycles per second. The signals thus transmitted effect the desired operations of the signal receiver with protection against operation by voice currents or other interference currents as above described.

What is claimed is:

1. In a telephone system, a trunk, means at one end of said trunk for transmitting over said trunk signals of a first type and signals of a second type, signal receiving means at the other end of said trunk for operatively responding to said signals, means at said one end of the trunk for causing the repeated transmission of a signal of said second type over said trunk, and means associated with said signal receiving means responsive to two signals of said second type in succession but non-responsive to two signals of said second type if a signal of said first type is interposed between the two signals of said second type.

2. In a telephone system, a trunk, means at one end of said trunk for transmitting over the trunk signals of a first type and signals of a second type, each signal of said first type consisting of an impulse of current of a first frequency characteristic within the voice frequency band followed by an impulse of current of a second frequency characteristic within the voice frequency band, each signal of said second type consisting of an impulse of current of said second characteristic followed by an impulse of current of said first characteristic, signal receiving means at the other end of said trunk for operatively responding to said signals, means at said one end of the trunk for causing the repeated transmission of a signal of said second type over said trunk, and means associated with said signal receiving means for distinguishing between successive signals of like type from successive signals alternating in type.

3. In a telephone system, a trunk, means at one end of said trunk for transmitting over the trunk signals of a first type and signals of a

second type, each signal of said first type consisting of an impulse of current of a first frequency characteristic within the voice frequency band followed by an impulse of current of a second frequency characteristic within the voice frequency band, each signal of said second type consisting of an impulse of current of said second characteristic followed by an impulse of current of said first characteristic, signal receiving means at the other end of said trunk for operatively responding to said signals, means at said one end of the trunk for causing the repeated transmission of a signal of said second type over said trunk, and means associated with the signal receiving means at said other end of the trunk for determining whether successive signals are of like or unlike type.

4. In a telephone system, a trunk, means at one end of said trunk for transmitting over the trunk signals of a first type and signals of a second type, each signal of said first type consisting of an impulse of current of a first frequency characteristic within the voice frequency band followed by an impulse of current of a second frequency characteristic within the voice frequency band, each signal of said second type consisting of an impulse of current of said second characteristic followed by an impulse of current of said first characteristic, signal receiving means at the other end of said trunk for operatively responding to said signals, means at said one end of the trunk for causing the repeated transmission of a signal of said second type over said trunk, and means associated with the signal receiving means at said other end of the trunk operated only if successive signals are of like type.

5. In a telephone system, a trunk, means at one end of said trunk for transmitting over the trunk signals of a first type and signals of a second type, each signal of said first type consisting of an impulse of current of a first frequency characteristic within the voice frequency band followed by an impulse of current of a second frequency characteristic within the voice frequency band, each signal of said second type consisting of an impulse of current of said second characteristic followed by an impulse of current of said first characteristic, signal receiving means at the other end of said trunk for operatively responding to said signals, means at said one end of the trunk for causing the repeated transmission of a signal of said second type over said trunk, and means associated with the signal receiving means at said other end of the trunk responsive to two signals of said second type in succession but non-responsive to two signals of said second type if a signal of said first type is interposed between the two signals of said second type.

6. In a telephone system, a trunk, means at one end of said trunk for transmitting over the trunk signals of a first type and signals of a second type, each signal of said first type consisting of an impulse of current of a first frequency characteristic within the voice frequency band followed by an impulse of current of a second frequency characteristic within the voice frequency band, each signal of said second type consisting of an impulse of current of said second characteristic followed by an impulse of current of said first characteristic, signal receiving means at the other end of said trunk for operatively responding to said signals, means at said other end of the trunk for transmitting over said trunk signals of a third type and signals of a fourth type, each signal of said third type consisting of an impulse of current of a third frequency characteristic within the voice frequency band followed by an impulse of current of a fourth frequency characteristic within the voice frequency band, each signal of said fourth type consisting of an impulse of current of said fourth characteristic followed by an impulse of current of said third characteristic, means at said one end of the trunk for causing the repeated transmission of a signal of said second type over said trunk, and means associated with the signal receiving means at said other end of the trunk responsive to two signals of said second type in succession, but non-responsive to two signals of said second type if a signal of said first type is interposed between the two signals of said second type, for causing the repeated transmission of a signal of said fourth type over said trunk.

7. In a telephone system, lines, a trunk included in a talking connection between a calling and a called line, means at one end of said trunk for transmitting over said trunk signals each of which consists of an impulse of current of a first one of four signaling frequencies within the voice frequency band followed by an impulse of current of a second one of said frequencies and for transmitting over said trunk signals, including disconnect signals, each of which consists of an impulse of current of said second frequency followed by an impulse of current of said first frequency, means at the other end of said trunk for receiving and operatively responding to said signals, means at said other end of the trunk for transmitting over said trunk signals each of which consists of an impulse of current of a third one of said frequencies followed by an impulse of current of the fourth one of said frequencies and for transmitting over said trunk signals, including disconnect acknowledgment signals, each of which consists of an impulse of current of said fourth frequency followed by an impulse of current of said third frequency, means rendered effective by the disconnection of said calling line from said trunk for causing the signal transmitting means at said one end of the trunk to transmit a disconnect signal over the trunk and to repeat the signal at predetermined intervals until a disconnect acknowledgment signal is received over the trunk from said other end of the trunk, and means at said other end of the trunk rendered effective in response to two successive disconnect signals for causing the signal transmitting means at said other end of the trunk to transmit a disconnect acknowledgment signal over the trunk and to repeat the signal at predetermined intervals as long as the disconnect signal is being received at said other end of the trunk.

8. In a telephone system, lines, a trunk included in a talking connection between a calling and a called line, means at one end of said trunk for transmitting over said trunk signals each of which consists of an impulse of current of a first one of four signaling frequencies within the voice frequency band followed by an impulse of current of a second one of said frequencies and for transmitting over said trunk signals, including disconnect signals, each of which consists of an impulse of current of said second frequency followed by an impulse of current of said first frequency, means at the other end of said trunk for receiving and operatively responding to said signals, means at said other end of the trunk for transmitting over said trunk signals each of

which consists of an impulse of current of a third one of said frequencies followed by an impulse of current of the fourth one of said frequencies and for transmitting over said trunk signals, including disconnect acknowledgment signals, each of which consists of an impulse of current of said fourth frequency followed by an impulse of current of said third frequency, means for holding the connection between said trunk and said called line, means rendered effective by the disconnection of said calling line from said trunk for causing the signal transmitting means at said one end of the trunk to transmit a disconnect signal over the trunk and to repeat the signal at predetermined intervals until a disconnect acknowledgment signal is received over the trunk from said other end of the trunk, and means at said other end of the trunk rendered effective in response to two successive disconnect signals for causing the signal transmitting means at said other end of the trunk to transmit a disconnect acknowledgment signal over the trunk and to repeat the signal at predetermined intervals as long as the disconnect signal is being received at said other end of the trunk, said holding means rendered ineffective a predetermined interval of time after receipt of the last disconnect signal thereby to cause the release of the connection between said trunk and said called line.

9. In a telephone system, lines, a trunk included in a talking connection between a calling and a called line, a selector comprising talking conductors in the connection between said trunk and said called line, means for holding the connection between said trunk and called line, means at the calling end of said trunk for transmitting over said trunk signals each of which consists of an impulse of current of a first one of four signaling frequencies within the voice frequency band followed by an impulse of current of a second one of said frequencies and for transmitting over said trunk signals, including disconnect signals, each of which consists of an impulse of current of said second frequency followed by an impulse of current of said first frequency, means at the other end of said trunk for receiving and operatively responding to said signals, means at said other end of the trunk for transmitting over said trunk signals each of which consists of an impulse of current of a third one of said frequencies followed by an impulse of current of the fourth one of said frequencies and for transmitting over said trunk signals, including disconnect acknowledgment signals, each of which consists of an impulse of current of said fourth frequency followed by an impulse of current of said third frequency, means rendered effective by the disconnection of said calling line from said trunk for causing the signal transmitting means at the calling end of the trunk to transmit a disconnect signal over the trunk and to repeat the signal at predetermined intervals until a disconnect acknowledgment signal is received over the trunk from said other end of the trunk, and means at said other end of the trunk rendered effective in response to two successive disconnect signals for causing the signal transmitting means at said other end of the trunk to transmit a disconnect acknowledgment signal over the trunk and to repeat the signal at predetermined intervals as long as the disconnect signal is being received at said other end of the trunk, said holding means rendered ineffective a predetermined interval of time after receipt of the last disconnect signal thereby to cause the return of said selector to normal.

NEAL D. NEWBY.