Jan. 9, 1945. S. I. CORY 2,366,835

PULSE REPEATING SYSTEM

Filed July 10, 1943

FIG. 1

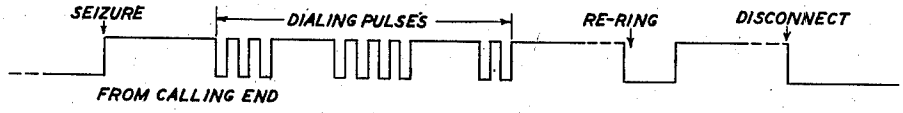


FIG. 2

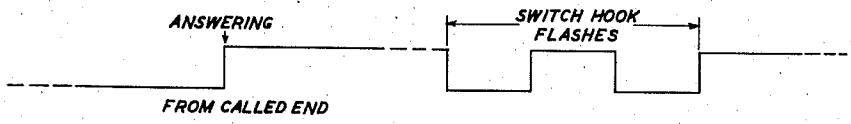


FIG. 3

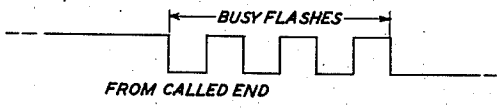
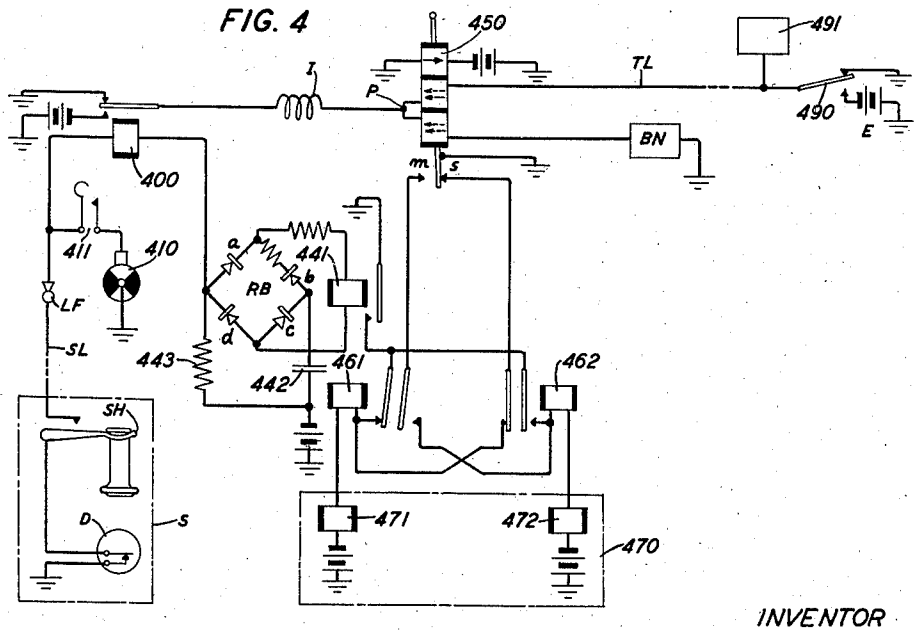


FIG. 4



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PULSE REPEATING SYSTEM

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4 Claims. (Cl. 179—84)

The invention relates to pulse repeating systems and more particularly to systems of this type operating on a duplex basis.

It is an object of the invention to provide a pulse repeating system with a simplified duplex balance and capable of efficient operation under conditions of line variations and interference.

It is a more specific object of the invention to provide a system of this type which with standardized equipment is adapted for repeating selecting and supervising pulses for telephone switching systems over lines of greatly differing characteristics and lengths.

The selective and supervisory operations of automatic telephone switching systems are frequently performed over extensive line circuits, such as toll lines, the lengths of which differ greatly and which are subject to well-known disturbances and interferences. The selecting pulses, usually termed the dial pulses, are usually transmitted from one telephone exchange to another over half-duplex pulse repeating circuits, which hitherto have been carefully balanced to operate satisfactorily under the changing operating conditions in the line circuit. The reason for duplexing the pulse circuit is mainly to be found in the fact that the traffic requirements include the transmission in both directions over the line circuit of supervisory signals or pulses. The operations are complicated by the requirements that, in the series of operations involved in the setting up of a connection, the line circuit is placed under two different conditions, which may be termed the idle and the busy conditions.

The pulse repeating system is adapted to receive dialing pulses from a calling station, which may be a remote telephone subscriber's station or a local operator's dialing circuit, and to repeat the pulses over an outgoing line circuit to a distant telephone exchange, equipped for automatic switching in response to the dial pulses for the selection of another exchange or another subscriber's station.

The repeating circuit includes a pole changing relay for applying two different transmitting potentials to the line circuit corresponding to the two conditions of the pulses, namely, marking and spacing or current and no current. The pulses from the pole changing relay are impressed upon a duplex circuit including the line circuit in one branch and the balancing circuit in the other branch.

A polar receiving relay is included in the duplex circuit for reception of signals incoming over the line circuit, this relay being unaffected by outgoing signals when the impedance balance is perfect. For this purpose the polar relay may be connected in any well-known manner, as by having its operating windings directly included in the two balanced circuits or connected in a bridge between the balanced circuits, in accordance with well-known practice in telegraph repeating systems. The system is also equipped for the transmission of busy signals comprising a series of pulses of a predetermined frequency, usually about 80 cycles per minute, which are impressed upon the duplex circuit by operation of the pole changer.

As is well-known it has hitherto been necessary to establish a fair balance between the line circuit and the balancing network in duplex systems of either type referred to above, in order to prevent the receiving relay from responding to the outgoing pulses. When signals are impressed on an unbalanced system unbalance currents arise which may operate the receiving relay. Thus in the differential duplex circuit the currents in the two operating windings will be unequal or unbalanced and the stronger current may operate the relay. In the bridge duplex circuit the potentials applied to the relay winding are unequal and an equalizer or unbalance current will flow through the windings and may operate the relay.

In accordance with a feature of the invention, the balancing network is simplified and is standadized to supply a fair balance for a large variety of line circuits so that it may be manufactured at comparatively low cost. In accordance with the invention the system is furthermore arranged so that it will be unecessary to adjust the balancing network to compensate for sporadic variations in the line circuits during ordinary operating conditions, including temperature and leakage changes. This simplification of the balancing network is further effective in reducing the large amount of designing work involved in the provision of a large variety of differently dimensioned balancing networks for the corresponding varieties of line circuits to satisfy the present day severe demands for accuracy.

For the purposes just outlined the invention provides an arrangement for preventing false operations, which would be due to improper responses by the receiving relay during the transmission of outgoing pulses resulting from unbalanced conditions. By this provision a given design of balancing network may be based on certain average or predominant line conditions among the large variety of conditions met with

in the plant. Such a network may thus provide an accurate balance for a large number of lines with average characteristics it would however be less accurate in the balancing of line circuits having more diverging characteristics, without, however, establishing a circuit condition which would result in false operations due to unbalance conditions caused by line variations or interference.

When the pulse repeating system is idle, the pole changing or sending relay will apply an idle condition to the toll line, which may be assumed to be a spacing or no current condition, the other end of the line circuit being assumed to apply a similar condition to the line. In response to the seizure of the repeater station by a calling station or an operator, the pole changer applies a busy or marking condition to the toll line. After the transmission of dialing pulses, the distant station also applies a marking or answering condition to the line circuit which consequently will operate the polar receiving relay at the repeating station.

After this condition has been reached, further pulses may be transmitted in either direction over the line circuit. For example, a rering pulse may be transmitted by the sending station in the form of a pulse which will cause the distant exchange to rering the called line; busy flashes may be transmitted back to the calling line; and switchhook flashes may be transmitted in either direction.

The polar receiving relay at the repeater station will respond to incoming pulses from the line circuit and will respond to the answering condition imposed upon the line circuit from the distant end by operating to marking position. Thus, the receiving relay is arranged to control circuit equipment which, in well-known manner, may be arranged to respond in proper sequence to the traffic signals, such as "answering" and "busy," from the called line. It may furthermore be arranged to function in response to dial pulses from the distant station, when the call is in the opposite direction, for control of the selecting operation of telephone switches at the exchange with which the repeater is immediately associated.

It will, therefore, be seen that in a sense the repeater operates under full-duplex conditions, inasmuch as it will operate with either of two polarities applied to either or both ends of the line circuit. However, though the repeater is required to operate in both directions, it will operate only in one direction at a time, so that for any particular line condition the repeater will be operating on a half-duplex basis.

This particular condition permits of the introduction of a feature of the invention which basically resides in rendering the receiving relay ineffective during the transmission of outgoing signals and restoring the receiving relay circuit to effectiveness upon termination of the retransmission of outgoing signals.

In accordance with a more specific feature of the invention, the control circuit from the contacts of the receiving relay is rendered immune to operations by the receiving relay during transmission of outgoing pulses and for this purpose by-pass circuits are provided for the receiving relay contacts for temporarily completing the control circuit irrespectively of fortuitous operations by the receiving relay during transmission of outgoing pulses.

In accordance with another specific feature of the invention the by-pass is applied across the marking contacts or the spacing contacts of the relay in accordance with the position of the receiving relay at any time, as determined by the line potential applied at the distant end.

The invention will now be described more in detail as to its organization and operation and as applied to a specific embodiment. In the description reference will be made to the attached drawing, in which:

Figs. 1, 2 and 3 are diagrammatic representations of different typical pulses that may be transmitted in either direction over the line circuit; and

Fig. 4 is a circuit diagram of a repeater circuit representing a specific application of the invention and including the features of the invention.

Referring to the drawing, it will be assumed that a subscriber's station is connected to a telephone exchange and desires to make a call to a distant subscriber's station at another telephone exchange. The two exchanges are connected together over toll lines.

In accordance with the established traffic conditions in the telephone plant, the subscriber first removes his receiver from the hook, thereby establishing a calling condition. Thereafter the subscriber operates his calling dial which transmits the usual groups of dialing pulses. The distant exchange then applies an answering condition to the line circuit and rings the called subscriber, who answers by lifting his receiver off the hook, thereby establishing a busy condition. If the called subscriber should be busy, a continuous series of busy pulses will be transmitted back to the calling station at the rate of 80 pulses per minute. Other busy conditions, as for local trunks or distant trunks, are indicated by similar pulses of different frequencies. Upon the distant subscriber disconnecting prematurely, a rering pulse may be transmitted from the calling end of the line circuit. Subscriber's switchhook flashes may be transmitted at any time in either direction.

The diagram in Fig. 1 shows the signaling current in the line circuit at the time of a call. Thus, when the line circuit is seized, the line current increases from a no current or spacing condition to a steady marking current condition. Thereafter the marking current is interrupted by the dialing pulses, whereupon the line current remains steady. In the case of a subsequent rering the line current is momentarily interrupted.

Fig. 2 refers to the conditions at the called end of the toll line, which normally is applying a spacing condition to the line circuit. Upon answering, the called exchange transmits a steady line current which may subsequently be interrupted by switchhook flashes.

Fig. 3 shows conditions at the called exchange when a busy condition exists, in which case the steady marking condition is interrupted by spacing conditions.

Referring now particularly to Fig. 4, the circuit is that of a repeater station R connected over a toll line circuit TL to a distant exchange station, represented at E. The repeater station may be assumed to be located at an exchange to which a plurality of subscribers are connected, one of which is shown at S.

The subscriber station S may be a convention station with a switchhook SH and dial D. The station is connected over a subscriber's line SL to the repeater station. However, for the purposes of the invention the line circuit SL may

be connected to a toll operator's circuit instead of to a subscriber's station, in which case the switchhook may be replaced by a key and the dial by an operator's pulse sending device.

The repeater station R comprises the pole changer or sending relay **400** connected in the line circuit SL to receive pulses and having contacts for alternately applying ground and battery to the line circuit TL in sending the pulses outgoing from the exchange. A source of busy signal **410** may be connected through busy key **411** or any other automatic means for applying the busy signal to the circuit SL for operation of relay **400**. The pulse circuit SL through relay **400** extends over resistance **443** to negative battery, the other end of this circuit being connected to ground at the dial D.

The polar receiving relay **450** has a biasing winding normally holding the relay in its spacing position and two operating windings cooperating to operate the relay to marking. The contacts of relay **400** are connected through an inductance I, through the operating winding of relay **450** to the toll line TL and through the lower operating winding to the balancing network BN. Thus, the operation of relay **400** in sending outgoing pulses will not ordinarily affect the relay **450**, since proportionate currents pass through the two windings in opposing relation in accordance with the balance between the line circuit TL and the network BN.

The distant exchange E may include a suitable responsive switch control circuit **491**. The station E may also include a repeater circuit similar to the circuit R with a receiving relay similar to relay **450** and with transmitting contacts **490** similar to those of relay **400**.

When the circuit is in the condition shown in the drawing, ground is applied to both ends of the line TL and to the balancing network BN so that no current will be flowing. When relay **400** operates, battery is connected to the bridge point P and current flows through one winding over the line circuit to ground at E and through the other winding through the balancing network to ground. The windings being opposed under this condition, relay **450** would not respond provided the balance is good. With relay **400** applying ground to the duplex circuit and contacts **490** at the distant end of the line operated to apply battery, the incoming line current will pass through the upper operating winding to ground at relay **400** and in a direction to overcome the biasing winding and operate relay **450** to marking. If now relay **400** be operated to also apply battery to the duplex circuit, practically no current will flow in the line and through the upper operating winding; the battery at relay **400** will, however, send current through the lower operating winding on relay **450** in a direction to keep relay **450** operated to marking. Thus in receiving incoming, marking, and spacing pulses, the two operating windings of relay **450** will be in cooperative relation to operate the relay to marking or spacing respectively.

Although the receiving relay **450** is shown in the drawing and is described herein as being connected in a differential duplex circuit, it should be understood that in accordance with the invention, this relay may be connected in a duplex bridge circuit with similar advantages.

A full-wave rectifier bridge RB, relay **441** and condenser **442** are connected across the resistance **443** to receive potential drops from the resistance for charging and discharging the condenser **442** as the pulse current rises and declines, respectively, through the resistance **443**; the charging and discharging currents momentarily operate relay **441**. The contacts of relay **441** are included in a control circuit from the contacts of the receiving relay **450**, through a pair of relays **461** and **462** for control of a circuit equipment **470** which is part of the exchange equipment and serves to selectively control switches for setting up a connection in response to pulses incoming from a distant exchange to the repeater R. The equipment **470** will have certain portions, represented by relay **471**, responsive to relay **450** in spacing position and other portions, represented by relay **472**, responsive to relay **450** in marking position. Relay **461** will be operated together with relay **471** over a break contact on relay **462** and the spacing contact of relay **450**; relay **462** will be operated in series with relay **472** over a break contact of relay **461** and the marking contact of relay **450**.

The operation of the circuit will now be described. It will be assumed that the circuit is in rest condition, as shown in the drawing.

When the subscriber removes the receiver from the hook SH, ground is extended over the subscriber's line SL, through the winding of relay **400** and resistance **443**. Relay **400** applies battery to the duplex circuit and over the line to the distant exchange E for operation of the switch control circuit **491**.

The rise of current through resistance **443** causes a charging current to flow from the upper positive side of the resistance through branch *a* of the rectifier bridge RB, relay **441**, branch *c* of the bridge, through condenser **442**, to the lower negative side of resistance **443**. The charging impulse operates relay **441** which connects ground to a locking circuit for relay **461** over a make contact of the relay and through relay **471** to battery, so that relays **461** and **471** will remain operated independently of any "kick-off" by relay **450** due to unbalance currents between the line circuit TL and the balancing network BN during the outgoing space-to-mark transition. It will be noted that the operated relay **461** at its break contact keeps open the operating circuit from the marking contact of relay **450** through the relays **462** and **472**, thereby preventing false operation of these relays in case of "kick-off." After the transition has passed into the line circuit and relay **441** has released, the equipment **470** will again be under control of relay **450**.

The subscriber now operates the dial, the contacts of which produce spacing pulses, as shown in Fig. 1, by short interruptions of the ground connection to the line SL. In response to the first interruption by the dial relay **400** releases. The decaying current through resistance **443** now causes the condenser **442** to discharge over a circuit from the upper positive side of the condenser, through the branch *b* of the rectifier bridge RB, through relay **441**, branch *d* and resistance **443** back to the negative side of condenser **442**. This discharging impulse again operates relay **441** for bridging the spacing contacts of relay **450** by applying ground to the holding circuit for relays **461** and **471**. These relays thus will remain operated independently of any "kick-off" of relay **450** during the mark-to-space transition in the line circuit. The circuit from the spacing contact of relay **450** also remains open at the break contact of relay **461**, thereby preventing operation of relays **462** and **472**. After

the transition has passed into the line circuit and relay 441 has released the circuit 470 will again be under control of relay 450.

At the end of the first dial pulse relay 400 operates to again apply battery to the duplex circuit and relay 441 operates to lock relays 461 and 471, as described above. During each pulse series relay 400 will repeat each marking and spacing transition and relay 441 performs its locking operation during each transition. During an interval between pulse series relay 400 remains attracted.

After the dialing has been completed steady battery will be applied to the duplex circuit by dialing relay 400 in marking position.

When the answering condition is established at the distant end of the line TL, as by the contacts 490 operating to battery, relay 450 will operate to marking, thereby applying ground to the equipment 470 and particularly to relay 472 for the proper reception of the answering signal. Relay 450 also opens the control circuit for relays 461 and 471, thereby releasing relay 461 which in turn completes the control circuit from the marking contact of relay 450 through relays 462 and 472. Relay 462, on operating, opens the control circuit from the spacing contact of relay 450 to relays 461 and 471 and at its make contact it prepares the locking circuit from relay 441 through relays 462 and 472.

The desired connection may now be assumed to have been established and the called subscriber will be rung from the ringing equipment at the exchange E. When the called subscriber answers, the conversation may be carried on over a talking circuit, not shown in the drawing, but which would be closely associated with the toll line TL, as by being included in the same cable quad or by some composite arrangement.

It will now be assumed that some special circumstance arises, as for example, that the distant subscriber hangs up prematurely, necessitating the sending of further pulses from the calling end, for example, a rering pulse, as indicated in Fig. 1. Relay 400 would momentarily interrupt the battery connection to the toll line and relay 441 will be operated once for each transition. Under this condition relay 441 closes the locking circuit for relays 462 and 472 by bridging the marking contacts of relay 450. The control circuit from the spacing contact of relay 450 remains open at the contact of relay 462. Thus, relays 471 and 472 are protected against fortuitous operation of relay 450 during each transition, also when relay 450 is in marking position.

In the case of a busy condition existing at the distant end after all dial pulses were transmitted, a series of pulses, shown in Fig. 3, would be transmitted by the contacts 490 over the line TL, through the windings of relay 450 and network BN to ground, causing the relay to operate in unison with the busy pulses and applying corresponding busy pulses to the circuit 470 for suitable response. The effect of this upon the switch control circuit will depend upon the operating characteristics of relays 461 and 462.

Thus, if these two relays are made slow to release to such an extent that they will remain operated during each busy pulse, the functions would be as follows: With relay 450 in marking position and relay 462 operated, the interruptions at the marking contact of relay 450 will cause relay 472 to oscillate for the proper busy control, whereas relay 462 will remain operated. Thus, relays 461 and 471 will remain unaffected by the busy impulses. However, if relays 461 and 462 should be fast enough to follow the operations of relay 450 during a busy signal, the functions would be as follows: Again assuming that relay 450 is in marking position when the busy signals arrive, relays 462 and 472 will be in operated condition. On the first opening of the marking contact of relay 450 relays 462 and 472 release. Relay 462 closes the control circuit for relays 461 and 471 which will operate over the spacing contact of relay 450. When relay 450 again goes to marking, relays 461 and 471 release and in the marking position of relay 450 relays 462 and 472 operate. Thus, under this condition relays 471 and 472 will be operated for the proper busy control in response to the space-to-mark and mark-to-space transitions, respectively, of the incoming busy signals.

In the case of a call incoming to repeater station R, relay 450 will be operated to marking in response to the application of battery at the distant exchange E to the line. Subsequent interruptions, as by dial pulses, would cause relay 450 to oscillate and apply corresponding pulses to the circuit 470 for selective operation of switches. The control of the circuit 470 will again depend upon the operating characteristics of relays 461 and 462, as described above in the case of busy signals. However, these relays may be made slow enough to hold over the comparatively short dial pulses and yet be fast enough to respond to each transition of the slower busy pulses. In response to this selective operation a switch may ultimately connect the subscriber's station S to the repeater station R. This switch is diagrammatically represented by contacts LF; contacts LF may also represent a line finder switch for connecting the subscriber's station to the repeater in response to a call by the subscriber. With the subscriber connected in this manner, switchhook flashes may be transmitted back to station E in the manner already described.

In case the subscriber S is busy, the connection at switch LF will remain open and the circuit 470 may be arranged to automatically operate the key 411 for application of busy signal from interrupter 410. This will cause relays 400 and 441 to operate in unison with the busy pulses and establish locking circuits for relays 461, 471 and 462, 472, as already described.

On observing the busy signal and distant calling station at E will hang up and thus will send a disconnect signal by applying steady ground over contacts 490, through the windings of relay 450, thereby operating the relay back to spacing. The circuit 470 responding to this operation may be arranged to automatically disconnect the interrupter 410 by means of contacts 411, whereupon the whole system will be restored to idle condition.

The inductance I is inserted between the contacts of relay 400 and the apex P for the purpose of shaping the outgoing pulses in any desired manner.

From the description presented above, it will be understood that the purpose of relays 441, 461 and 462 is attained during transmission of outgoing pulses. Thus, in accordance with the invention and as already explained above, the balancing network is of simple construction and is designed so that networks of this kind may be used universally with toll lines of different lengths and different characteristics. It is, of course,

within the scope of the invention that a few standardized types of network may be provided, each type to be used with lines having characteristics within comparatively narrow limits and the different types of networks supplementing one another to satisfy the requirements of all types of lines. Thus, any one network may be connected to a particular line circuit and establish only an approximate balance; and the unbalance may be so pronounced that the receiving relay ordinarily would "kick-off" during transmission of outgoing pulses.

It is furthermore well known that long line circuits, as used in toll service, are subject to sporadic variations in their characteristics which are beyond control. Where a very close balance is necessary it has been the practice to continuously observe the line conditions and correspondingly vary the balance by the network.

In the protecting equipment shown in the drawing the contacts of the receiving relay are disabled during the sending of pulses, thereby permitting the relay **450** to "kick-off" without disturbing effect upon the equipment **470**. Thus, appreciable leeway is afforded in the balancing of this circuit, thereby permitting the use of universal networks for approximate balancing over wide ranges and also in special cases obviating the need of continual readjustment of the network.

By switching the protecting circuit in accordance with the position of the receiving relay it is insured that fortuitous operations by this relay from either of its positions will have no disturbing effect.

It should be understood that the invention may readily be adapted for application to a telegraph repeating system with similar advantages, where sending takes place against two different signaling conditions imposed by the remote station.

What is claimed is:

1. A two-way signaling system comprising an approximately balanced line circuit normally maintained alternately in marking and spacing steady state conditions, receiving relay means having contacts for control of a receiving circuit in response to incoming marking and spacing signal pulses superimposed on said steady state conditions, auxiliary circuit means connected to be responsive to outgoing marking and spacing signal pulses to prevent said control by said contacts in response to unbalance currents due to said outgoing pulses, and switching relay means connected to be responsive to incoming line currents for the conditioning of said auxiliary circuit means for the proper prevention of said control under both of said steady state conditions, said auxiliary circuit means comprising locking circuit means connected to said contacts for locking said receiving circuit in marking or spacing condition in accordance with said conditioning.

2. A two-way signaling system comprising an approxmately balanced line circuit normally maintained alternately in marking and spacing steady state conditions, receiving relay means having contacts for control of a receiving circuit in response to incoming marking and spacing signal pulses superimposed on said steady state conditions, auxiliary circuit means connected to be responsive to outgoing marking and spacing signal pulses to prevent said control by said contacts in response to unbalance currents due to said outgoing pulses, and switching relay means connected to be responsive to incoming line currents for the conditioning of said auxiliary circuit means for the proper prevention of said control under both of said steady state conditions, said auxiliary circuit means comprising locking circuit means including a multiple path for each of said contacts for locking said receiving circuit in marking or spacing condition irrespectively of false operation of said receiving relay means, and said switching relay means having contacts for completing one or the other of said multiple paths in accordance with said steady state conditions.

3. A two-way signaling system comprising an approximately balanced line circuit normally maintained alternately in marking and spacing steady state conditions from the remote end, receiving relay means at the other end of said line circuit having contacts for control of a receiving circuit in response to incoming marking and spacing signal pulses superimposed on said steady state conditions, auxiliary circuit means connected to be responsive to outgoing marking and spacing signal pulses to prevent said control by said relay means contacts in response to unbalance currents due to said outgoing pulses, and switching means connected to be responsive to said steady state conditions for the conditioning of said auxiliary circuit means for the proper prevention of said control under both of said steady state conditions, said auxiliary circuit means comprising locking circuit means connected to said contacts for locking said receiving circuit in marking or spacing condition in accordance with said alternate steady state conditions, said switching means comprising relay means for conditioning said locking circuit means in accordance with said steady state conditions, and said auxiliary circuit means further comprising pulse relay means connected to be responsive to outgoing signal transitions for producing a locking pulse through said locking circuit means during a false operation of said receiving relay means.

4. A two-way signaling system comprising an approximately balanced line circuit normally maintained alternately in marking and spacing steady state conditions from the remote end, receiving relay means having contacts for control of a receiving circuit in response to incoming marking and spacing signal pulses superimposed on said steady state conditions, auxiliary circuit means connected to be responsive to outgoing marking and spacing signal pulses to prevent said control by said contacts in response to unbalance currents due to said outgoing pulses, and switching relay means connected to be responsive to said steady state conditions for conditioning said auxiliary circuit means for the proper prevention of said control under both of said steady state conditions, said auxiliary circuit means comprising locking circuit means connected to said contacts for locking said receiving circuit in marking or spacing condition in accordance with said alternate steady state conditions and pulse relay means connected to be responsive to outgoing signal transitions for producing locking pulses through said locking circuit means during false operations of said receiving relay means, and said switching relay means comprising a marking relay and a spacing relay connected to said locking circuit means one at a time to be locked by said locking pulses in the marking or spacing conditions, respectively, for locking said receiving circuit.

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