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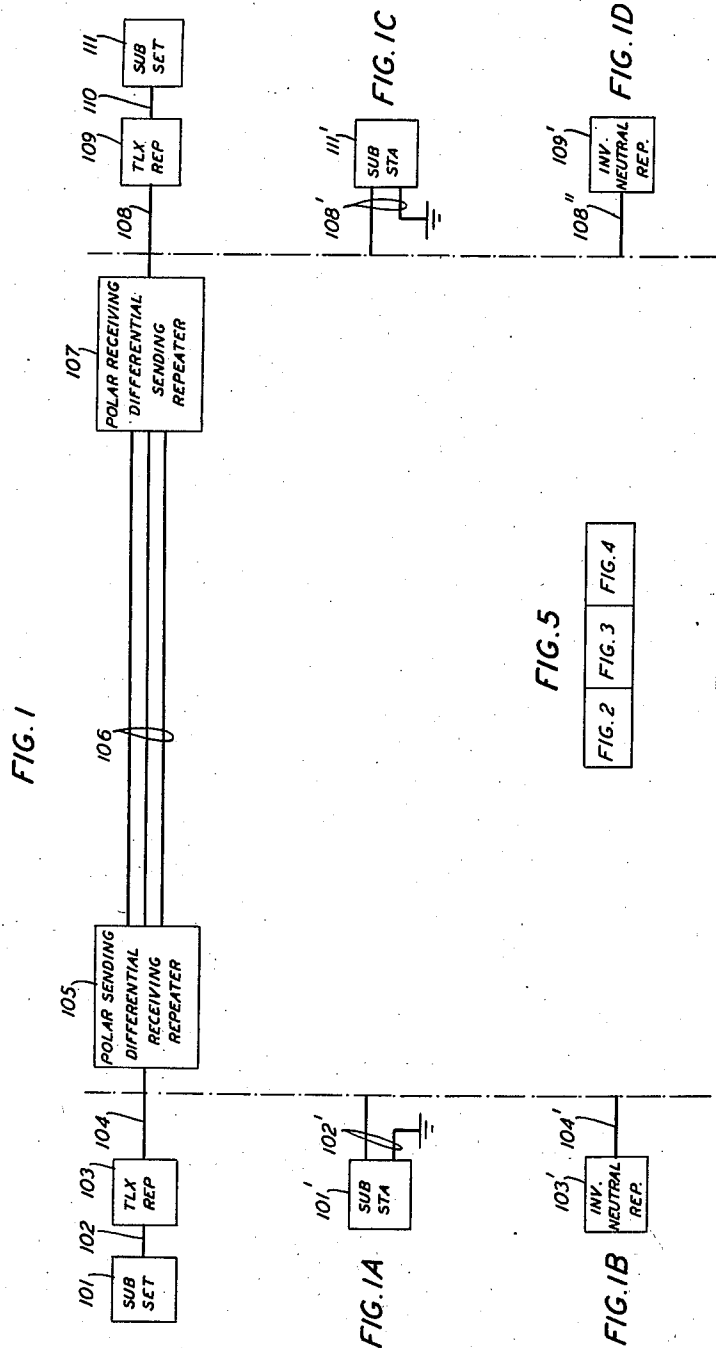
C. A. DAHLBOM ET AL

2,310,279

TELEGRAPH SYSTEM

Filed June 6, 1941

6 Sheets-Sheet 1



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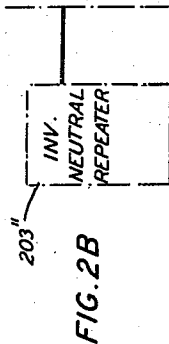
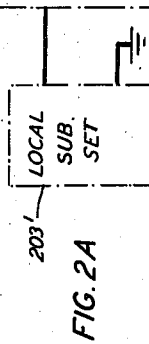
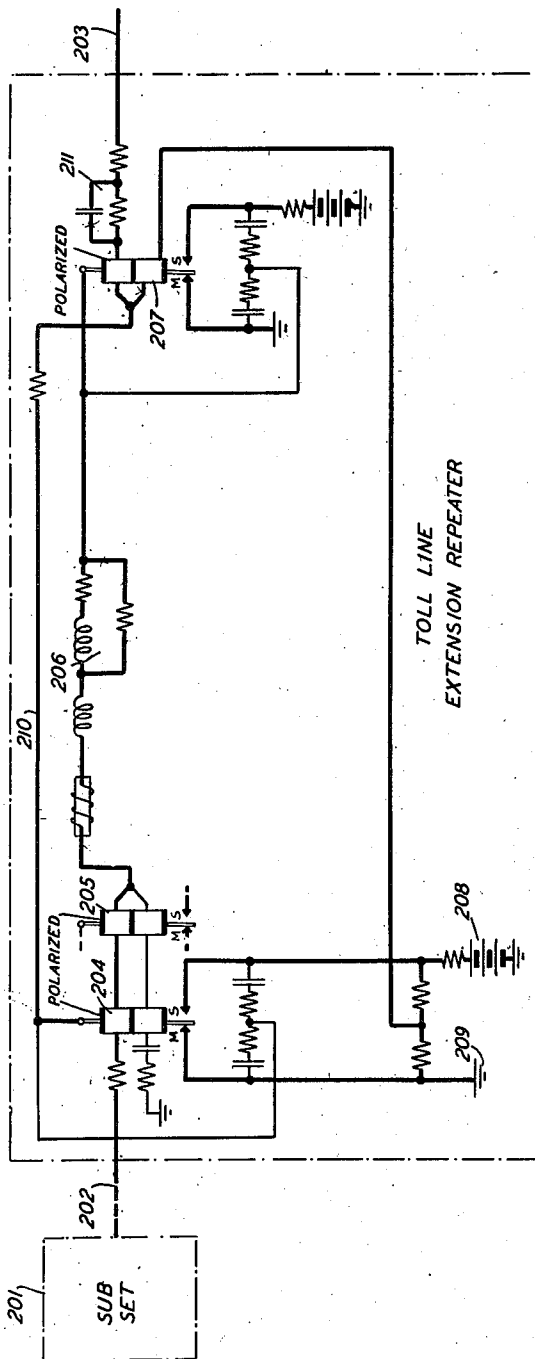
2,310,279

TELEGRAPH SYSTEM

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FIG. 2



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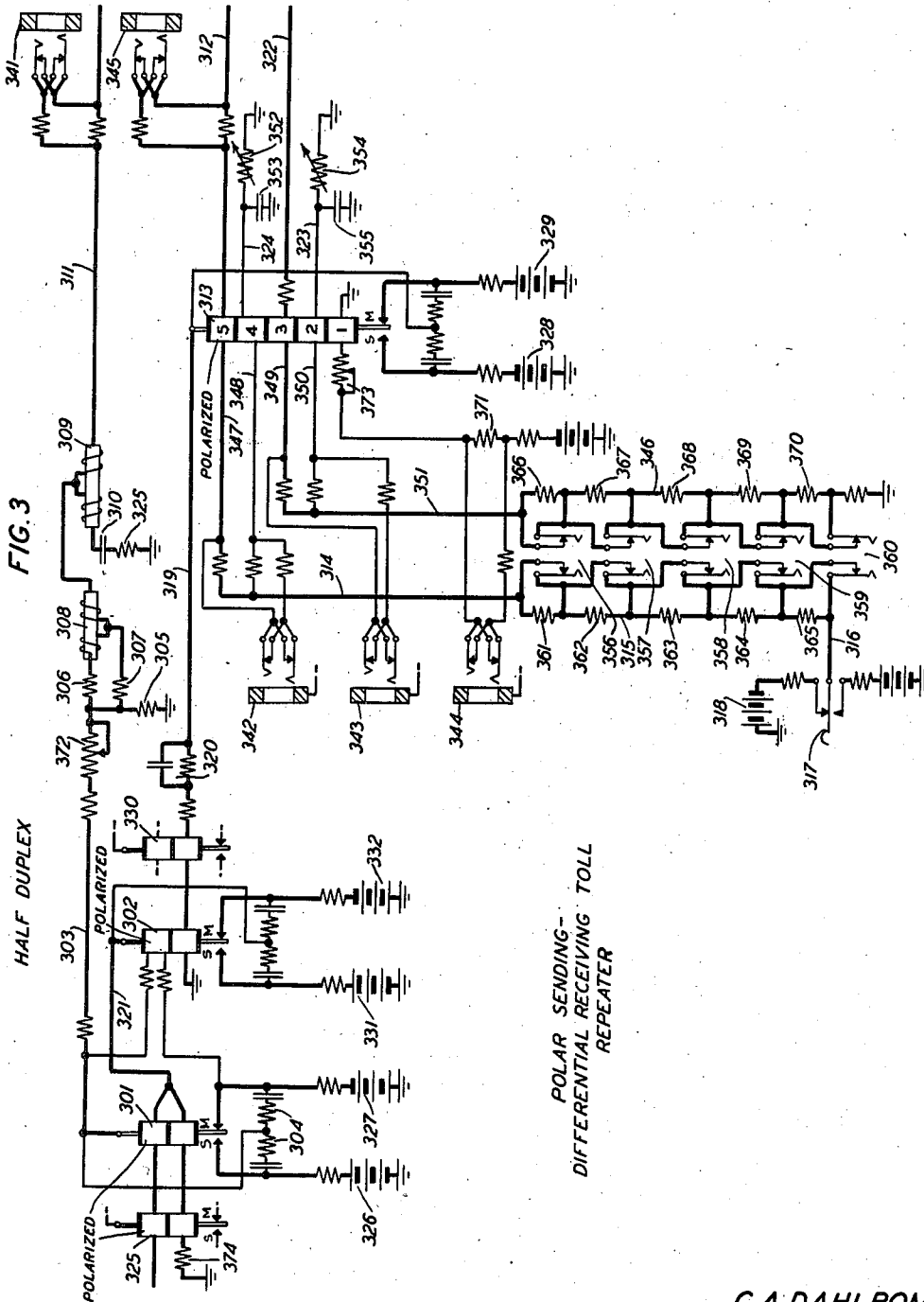
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TELEGRAPH SYSTEM

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6 Sheets-Sheet 3



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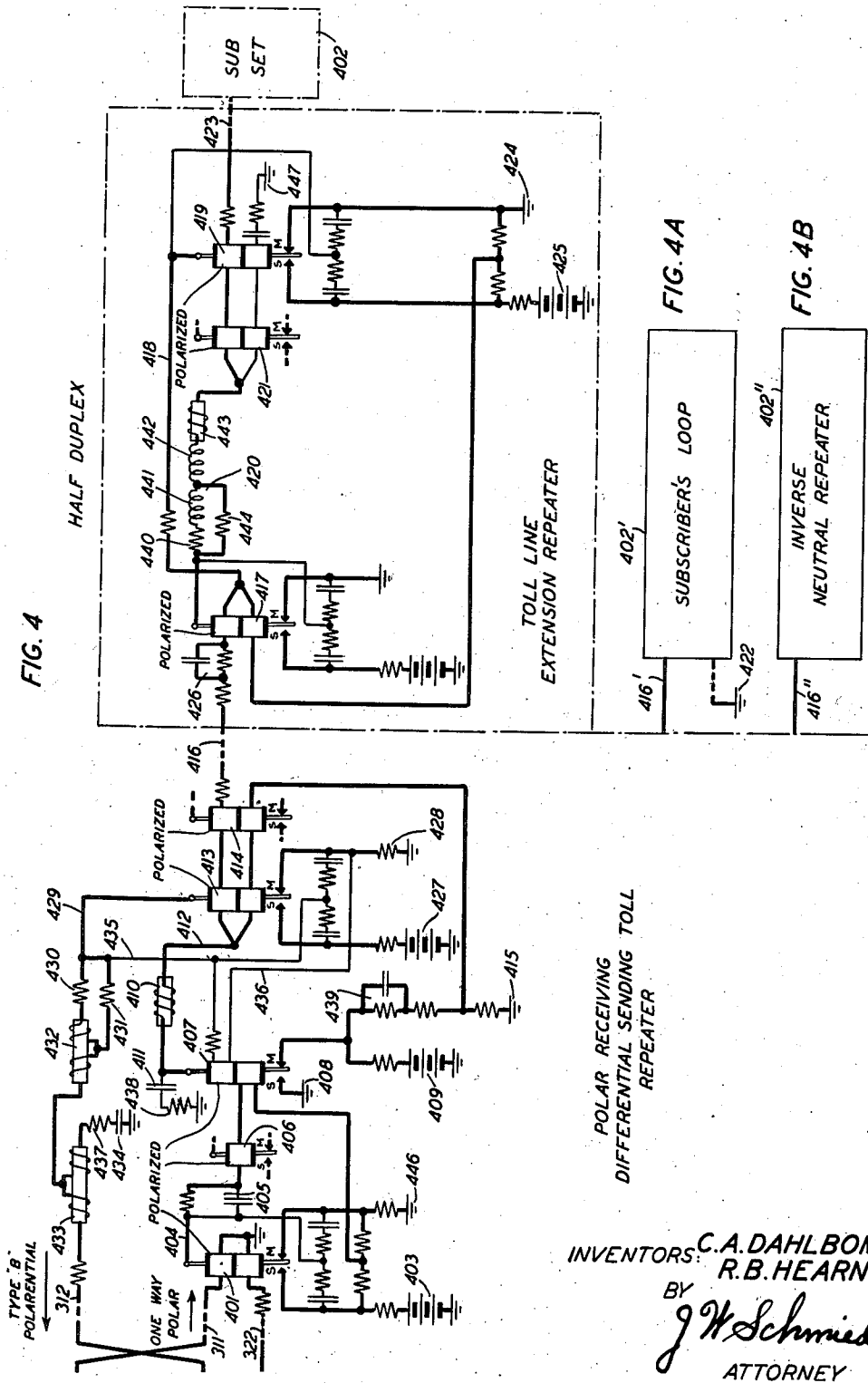
C. A. DAHLBOM ET AL

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TELEGRAPH SYSTEM

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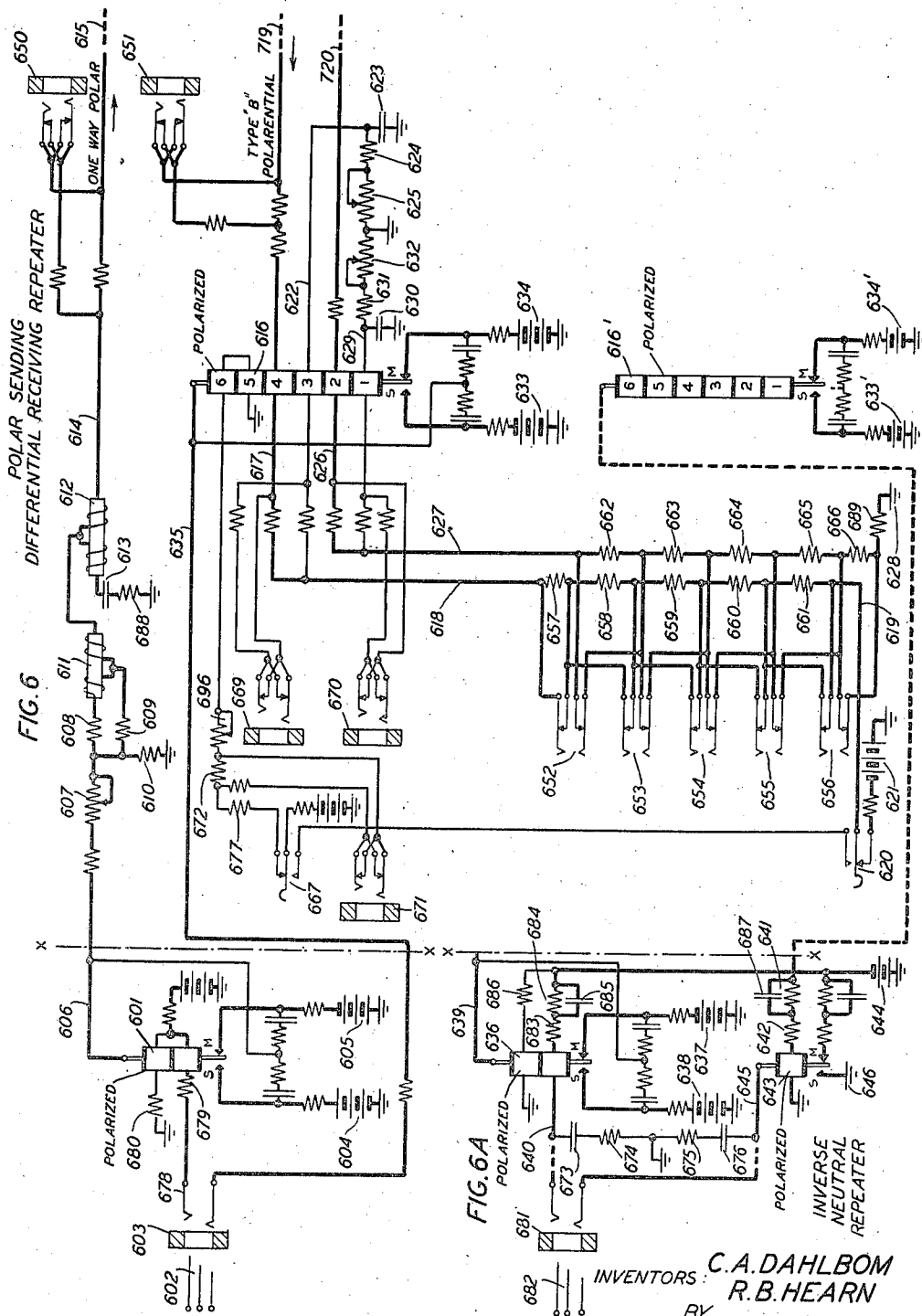
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TELEGRAPH SYSTEM

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6 Sheets-Sheet 5



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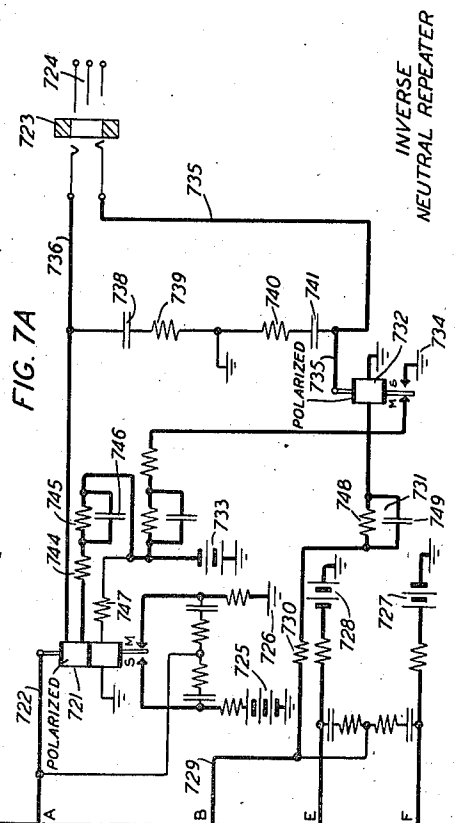
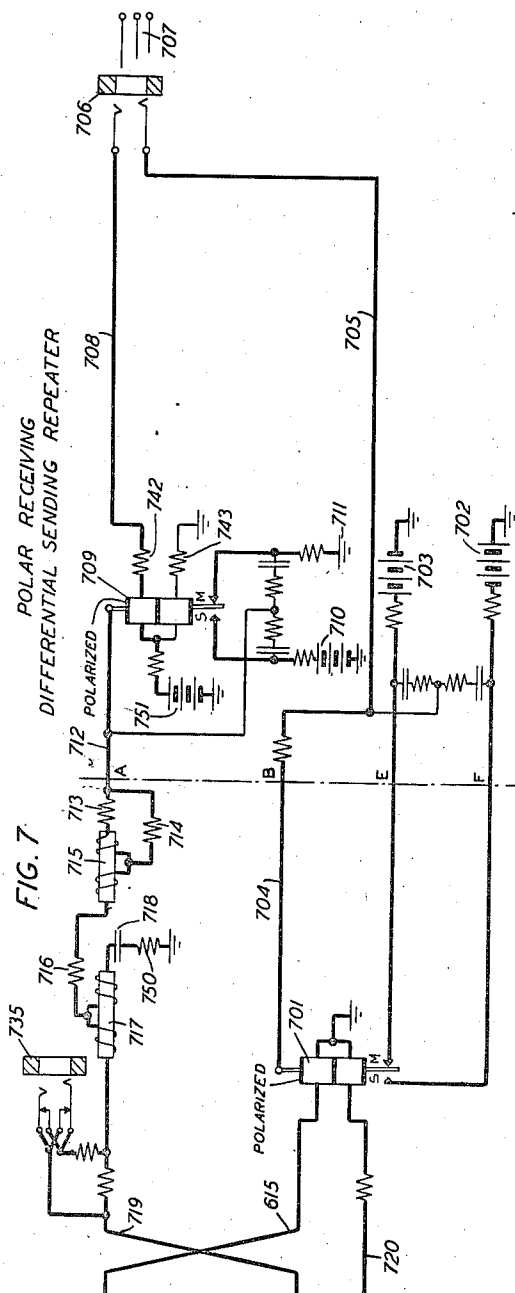
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2,310,279

TELEGRAPH SYSTEM

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6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

2,310,279

TELEGRAPH SYSTEM

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Application June 6, 1941, Serial No. 396,818

13 Claims. (Cl. 178-2)

This invention relates to telegraph transmission systems.

An object of the invention is to provide improved transmission in two-way telegraph systems, and in particular to provide transmission means and circuits which are less susceptible to distortion or needless adjustment or both on account of battery variations or variations in the characteristics of the line circuit, whether the variations be caused by capacity, inductance, leakage, or difference in ground potential at the terminals of the system.

Heretofore, in telegraph systems various types of circuits for transmitting messages were employed. Among these types are the neutral system, the one-way polar system, the two-path polar system, duplex systems and polarential systems. A brief description of the one-way polar and polarential systems will aid an understanding of the present invention.

One type of one-way polar system which permits transmission of messages in one way only, employs at the sending end of the line two batteries, one of each polarity, and at the receiving end of the line there is no battery, that is, the line is connected to a ground connection. When signals are being transmitted for the marking condition, one polarity of battery is connected to the line and for the spacing condition the other polarity of battery of the same magnitude is connected to the line. As a result, the currents for the marking and spacing conditions are of equal magnitude but opposite in direction, thereby producing a symmetrical wave as regards "marks" and "spaces." At the receiving end of the line a polar relay without an external bias is employed and the operation of this relay is governed by the polarity of current which is transmitted from the sending station. This principle of operation is called polar, and it has the advantage over the open-and-closed principle in that it is practically unaffected by battery variations or variations in the characteristics of the line.

Grounded telegraph circuits are sensitive to changes in the weather, since those changes bring about variations in line leakage and line resistance. Where telegraph relays are located at subscribers' premises or unattended remotely situated stations, frequent readjustment is impractical; to avoid it, the "polarential" method was developed. The "polarential" method operates in one direction on differences in current and in the other direction on reversals of cur-

rent. It includes two types of circuits; one type—A which is shown in Fig. 1 of U. S. Patent 2,131,870 granted to W. W. Cramer on October 4, 1938, and minimizes the effect of variations in line resistance; the other, type—B, which is shown in Fig. 2 of the Cramer patent, supra, and in Figs. 1 and 2 of U. S. Patent 2,136,984 granted to C. W. Smith on November 15, 1938, and also in U. S. Patents 2,133,380 and 2,140,673, respectively, granted to R. W. Deardorff on October 18, 1938, and M. L. Greene et. al. on December 20, 1938, greatly minimizes the effect of variation in line leakage. In the type—A system the battery voltages at each end of the line are chosen so that the current in the line, although in opposite directions for marking and spacing conditions in either direction of transmission, has the same magnitude for both, and a given change in line resistance will, therefore, affect both marking and spacing currents equally and cause no bias at the receiving relays. In the type—B system the voltage to ground at the middle point of the line reverses but has the same magnitude for marking and spacing, and a given leakage at the middle point of the line will, therefore, cause current to ground which is the same for marking and spacing and hence the change in the receiving relay current will be the same for these two conditions. The polarential systems are used only on circuits that require transmission of signals in one direction at a time.

Others may have defined specific examples of such systems in other terms or may have included specific characteristics of specific examples of such systems in definitions of such specific examples.

According to the present invention a polar sending-differential receiving telegraph repeater circuit is connected to a polar receiving-differential sending telegraph repeater by a three-wire trunk circuit, one wire is employed in a one-way polar system for transmitting message signals in one direction, the second wire is used in a type—B polarential system for transmitting message signals in the opposite direction, and the third wire is employed for neutralizing voltages induced in either of the systems, from ground potentials or other extraneous sources. The trunk circuit may be arranged for half duplex or full duplex operation as desired.

A feature of the present invention is a duplex system in which transmission in either direction

is independent of the leakage resistance of either line to ground.

Another feature is that only a single source of potential is required at one termination of the circuit.

Other objects and features will be noted in the following detailed description taken in conjunction with the accompanying drawings, of which:

Fig. 1 shows Figs. 2, 3 and 4 in diagrammatic form;

Figs. 1A and 1C show a modification of Fig. 1 wherein a local subscriber's loop is connected in place of a toll line extension circuit at each end of the system;

Figs. 1B and 1D show a modification of Fig. 1 wherein a hub circuit arranged for inverse neutral operation is connected in place of a toll line extension circuit at each end of the system;

Fig. 2 shows in block form a toll line subscriber station and in schematic form a toll line extension repeater interconnecting the toll line subscriber station and the repeater of Fig. 3;

Fig. 2A shows in block form the local subscriber station of Fig. 1A connected in place of the toll line extension repeater, to the repeater of Fig. 3;

Fig. 2B shows in block form a hub circuit arranged for inverse neutral operation, connected in place of the toll line extension repeater, to the repeater of Fig. 3;

Fig. 3 shows in schematic form a polar sending-differential-receiving repeater circuit designed for half duplex operation and arranged to be connected at one end to either a toll line station through the toll line extension repeater (Fig. 2), a local subscriber's set (Fig. 2A), or an inverse neutral repeater circuit (Fig. 2B), and at the other end to the three-wire trunk circuit;

Fig. 4 shows in schematic form a polar receiving-differential-sending repeater circuit designed for half duplex operation and connected at one end to the three-wire trunk circuit and at the other end to another toll line subscriber station through a toll line extension repeater it being also shown for connection at the other end to either of the modifications (Figs. 4A and 4B) of the termination of Fig. 4;

Fig. 4A shows a modification of Fig. 4 wherein the toll line extension circuit is replaced with a local subscriber's loop which is connected directly to the polar receiving-differential-sending repeater;

Fig. 4B shows a modification of Fig. 4 wherein the toll line extension circuit of Fig. 4 is replaced with the hub circuit arranged for inverse neutral operation;

Fig. 5 is a relative arrangement of Figs. 2, 3 and 4;

Fig. 6 shows in schematic form a polar sending-differential-receiving repeater circuit arranged for full duplex balanced loop operation;

Fig. 6A is a modification of Fig. 6 whereof its jack terminating end is arranged for inverse neutral repeater operation required for connection to a hub circuit;

Fig. 7 shows in schematic form the polar receiving-differential-sending repeater circuit arranged for full duplex balanced loop for double polarity operation;

Fig. 7A is a modification of Fig. 7 arranged for full duplex balanced loops for inverse neutral repeater operation required for connection to a hub circuit; and

Fig. 8 is the relative arrangement of Figs. 6 and 7.

A polar sending-differential receiving repeater may be defined as one which receives in one direction differential signals, that is by using differences in current flowing in one direction and sends in the other direction, polar signals, that is, by using reversals in current, such types of repeaters being shown in Figs. 3 and 6. A polar receiving-differential sending repeater is one which receives in one direction polar signals, or reversals in current, and sends in the other direction differential signals, that is, the differences in current flowing in one direction, such types of repeater being shown in the left-hand portion of Fig. 4 and in Figs. 7 and 7A. The differences in current flowing in one direction means currents having different amplitudes of effective values but of the same polarity.

Referring to Fig. 1, block 101 represents an outlying subscriber station circuit connected by line 102 to a toll line extension repeater circuit 103 which in turn is connected by line 104 to the toll line repeater 105 also identified herein as a polar sending-differential-receiving repeater. The toll line repeater 105 is connected over a toll line 106 to another toll line repeater 107 also identified herein as a polar receiving-differential-sending repeater, at a distant point. The toll line repeater 107 may be connected by line 108, 108' or 108'' to a toll line extension repeater 109, an outlying subscriber station 111' or an inverse neutral repeater 109' as indicated. The repeater 109 is connected in the line circuit 110 of an outlying subscriber's station 111.

Outlying subscriber stations such as those designated 101 and 111 are located at a considerable distance from the toll line repeater offices. Subscribers' loop circuits 101' and 111' are provided for those stations which are located at comparatively short distances from the toll line repeater offices. Inverse neutral repeaters 103' and 109' may be connected to a subscriber loop or to another toll line. A description of the inverse neutral repeater circuits may be had by reference to United States Patents 2,056,277 and 2,069,251 respectively granted to F. S. Kinhead on October 6, 1936, and February 2, 1937. Each of the above-mentioned arrangements will be referred to hereinafter as the subscriber circuit.

Figs. 2, 3 and 4 represent a system arranged for half duplex operation and Figs. 6 and 7 represent the system arranged for full duplex operation.

The following description is divided into two parts, one for describing the half duplex operation and the other, the full duplex operation. Each part is subdivided into a general and a detailed description, the detailed description of each part including the method of operation. Also, provision is made herein for the use of a third wire in the two-path trunk circuits respectively arranged for full duplex and half duplex operation, the third wire or conductor serving to neutralize in the other two wires ground potentials and voltage interference induced from extraneous sources. In both the full duplex and half duplex systems the transmission from one toll line repeater to another is on a one-way polar basis, and transmission in the opposite direction is on a differential basis, that is, with differential signals. In both systems supervision is on a full duplex basis over a pair of telegraph lines but it has not been herein described because it forms no part of the present invention.

HALF DUPLEX OPERATION

GENERAL DESCRIPTION

Polar sending-differential-receiving repeater
Fig. 3

The polar sending repeater, as shown in Fig. 3, is designed to operate between a toll line extension repeater TLX, shown in Fig. 2, and a toll line repeater circuit extending to a distant polar receiving repeater office shown in Fig. 4. The polar sending repeater comprises polarized send relay 301 and polarized receive relay 302.

Send relay 301 repeats the signals received from the toll line extension repeater TLX to send conductor 303 on a polar basis, that is, by current reversals, through the noise suppressor comprising resistances 306 and 307 and retardation coil 308, and the line equalizing, or shaping, network comprising retardation coil 309, condenser 310 and resistance 325. The send conductor divides at a mid-tap connection on the two windings of retardation coil 309, one path extending through the left-hand winding to condenser 310, resistance 325 to ground, and the other extending through the right-hand winding to trunk conductor 311. A potentiometer comprising rheostat 372 and resistance 305 is provided to reduce the voltage applied to the line.

Differential signals incoming from the differential sending repeater at the distant end of the line are received in a circuit traceable over line conductor 312, through winding No. 5 of polarized receive relay 313, conductors 347 and 314, keys 356 to 359 in their normal positions 315 and conductor 316, key 317 to grounded negative 130-volt battery 318. Relay 313, upon responding to the incoming signals, repeats them as polar signals in a circuit traceable over receive conductor 319, through wave shaper 320, through the lower windings, in series, of polarized supervisory relay 330 and polarized auxiliary receive relay 302 to ground. Auxiliary receive relay 302 repeats the signals as polar signals over conductors 321 and 203 to the toll line extension repeater TLX wherein the signals are repeated to subscriber line 201 as "current" and "no current" impulses. The output of relay 302 is traceable from grounded positive or grounded negative 130-volt battery 331 or 332, depending on whether the signal impulse is of a spacing or a marking type, spacing or marking contact and armature of relay 302, conductor 321, then through the upper and lower windings, in parallel, of polarized relays 301 and 325, in series, one path extending over conductor 203, and the other over an artificial line 374 to ground. The windings of each of relays 301 and 325 are differentially arranged with respect to each other and therefore relays 301 and 325 do not respond to signals received from the armature of relay 302. Relay 325 is for supervisory purposes. The receive line circuit comprising conductor 312 is arranged to provide good transmission with large variable amounts of line leakage present. Transmission over line conductor 311 to the distant repeater office is on a one-way polar basis and is therefore not affected in this direction by line leakage.

Partial neutralization of ground potential, cross-fire and other induced voltage interferences is accomplished by the use of a third conductor 322 extending between the toll line repeater shown in Fig. 3 and the toll line repeater shown in Fig. 4 at the distant office. The third conduc-

tor 322 is connected through winding No. 3 of receive relay 313 to ground, and at the distant office through the lower winding of receive relay 401 to ground so that it is subjected to the same induced voltages as both conductors 311 and 312, which are respectively connected to windings on relays 313 and 401, said two windings on each of the relays being arranged in differential relation. Consequently, the third conductor sufficiently neutralizes the effect of induced voltage interferences in either of the receive relays 313 and 401 to permit satisfactory transmission in either direction. Conductor 323 serves as an artificial line for conductor 322.

An adjustable resistance 352 is provided for balancing the telegraph trunk conductor 312 connected to the repeater. When a balance is obtained between trunk conductor 312 and artificial line 324, the differential effect of the current in windings Nos. 4 and 5 of relay 313, respectively connected in the circuit of trunk conductor 312 and the circuit of artificial line 324, is zero, particularly when the distant end of trunk conductor 312 is in a marking condition. The balancing network consists of resistance 352 and condenser 353. A duplicate set of balancing equipment is provided for use when a three-conductor trunk is used as shown in the drawings. The balancing network for three-conductor operation consists of resistance 354 and condenser 355. In other words, the balancing network connected to artificial line 324 is used for balancing trunk conductor 312 for two-conductor operation, while the balancing network connected to artificial line 323 is used for the neutralizing, or third, conductor. A biasing winding No. 1 is also provided on relay 313 to compensate for the direct-current flowing in winding No. 4 to insure proper operation of receive relay 313.

Apex keys

Five apex keys are provided to control the resistance in the circuits of trunk conductor 312 and third conductor 322. Each of these keys is arranged to affect the resistance of each of the apex circuits alike. The apex keys are of the locking type, preferably arranged to be operated with a turn-button top. Key 356 controls resistance 361 in the circuit of trunk conductor 312 and resistance 366 in the circuit of third conductor 322. In like manner, keys 357, 358, 359 and 360, respectively, control the four remaining pairs of resistances, as shown, resistances 362, 363, 364 and 365 being respectively paired with resistances 367, 368, 369 and 370.

Balance keys

Balance key 317 is non-locking and is of the push-button type. It is provided to reverse the apex voltage when the repeater is being lined up on the trunk conductor to which the repeater is connected.

Monitoring

Provision is made for common monitoring with an indicating milliammeter arranged to be patched to any one of five jacks connected in the repeater circuit. The indicating milliammeter serves for observation of signals and line balance under different conditions. This meter is of the single-coil type, has a double indicating scale with a zero mid-point and is adapted to operate in opposite directions in accordance with the direction of the operating current. This de-

vice is known; see United States Patent 1,809,026 granted to G. C. Cummings on June 6, 1931.

For the purpose of "lining up" of the repeater it will be assumed that connections have been made to a subscriber station circuit at one end and to a three-conductor trunk circuit extending to the trunk repeater at the distant office.

Jack 341 is provided in series with said trunk conductor 311 for checking the line current and to permit observation of signals transmitted over the line. The reading indicated on the milliammeter patched to the send trunk conductor 311 is the actual line current.

Jack 345 is provided in series with the receive trunk conductor 312 for checking the line current and to permit observation of signals received over the line. The reading on the milliammeter patched to receive trunk conductor 312 is likewise the actual line current.

Balance jack 342 is provided for connecting the milliammeter to indicate the differential current between receive trunk conductor 312 and its associated artificial line 324. The reading on the milliammeter is the actual differential current. After necessary adjustments of resistances, a normal balance may be obtained.

Balance jack 343 is provided for connecting the milliammeter to indicate the interference on the neutralizing, or third, conductor 322 for comparison with the interference on the receive trunk conductor 312. After the necessary adjustments of resistances, a similar normal balance may be obtained.

Bias jack 344 is provided for connecting the milliammeter to the biasing circuit so that the biasing current in winding No. 1 of receive relay 313 may be adjusted to the proper value. The shunting resistance 371 across bias jack 344 is so proportioned that the value of current indicated on the milliammeter when the biasing current is properly set will be equal to the current obtained with the milliammeter patched to balance jack 342 when a spacing signal is transmitted from the repeater at the distant office.

These tests with the milliammeter must be made in conjunction with the attendant at the distant office, who sends steady marking and steady spacing signals, the steady signals being produced by locking in the letter "R" signal in the teletypewriter at the distant end of the trunk and adjusting the biasing current and winding No. 1 of receive relay 313 to obtain a maximum margin range on a monitoring teletypewriter in good adjustment, connected to a loop circuit at the operator's switchboard.

Noise suppressor

A noise suppressor consisting of retardation coil 308 and resistance elements 306 and 307 is provided in series with send conductor 303.

Contact protection

Contact protection is provided across the contacts of relays 301, 302 and 313. The condensers and resistance elements connected across the contacts of each of these relays prevent the occurrence of sparks at the gaps.

Send line potentiometer

Send line potentiometer consisting of rheostat 372 connected to the apex of the send line of the repeater and resistance 305 connected to ground are provided so that the current in send trunk conductor 311 may be adjusted to say

± 35 milliammeters when the repeater voltages are 130 volts.

Bias potentiometer

Bias potentiometer 373 is provided in the biasing circuit of receive relay 313 so that the current in this circuit may be adjusted to the proper value.

Receive relay

Receive relay 313 is provided for receiving signals from the distant end and retransmitting them to the subscriber's circuit. The relay is equipped with five windings which are arranged for connection in five circuits. One winding, No. 5, is connected to receive trunk conductor 312; another, No. 4, is connected in the artificial line 324; still another, No. 3, is connected in third conductor 322; still another, No. 2, is connected in the artificial line 323 for third conductor 322; and still another, No. 1, is connected in the biasing circuit which is required for type "B" polarential operation.

Auxiliary receive relay

Auxiliary receive relay 302, responds to the signals retransmitted by relay 313 and repeats them over a circuit extending through the windings of relays 301 and 325 and over two parallel paths, one along conductor 203 to the subscriber's line and other to ground through artificial line 374.

Send relay

Send relay 301 is provided for receiving signals from the subscriber's line and to retransmit them to send trunk conductor 311. This relay is equipped with two windings differentially arranged with respect to each other, one winding being connected in series with conductor 203 of the loop circuit and the other in series with artificial line 374. Relays 301 and 325 do not respond to the signals repeated by auxiliary receive relay 302, because of their differential windings.

Equalizing networks

An equalizing network is provided for the send conductor 311 as hereinbefore mentioned, it being adjusted for optimum transmission to the repeater at the distant office. An equalizing network is provided for receive conductor 312 comprising condenser 353 which is adjusted for optimum transmission. Condenser 355 is a duplicate of condenser 353 and is provided for the neutralizing, or third, conductor 322 in order to maintain a duplicate balance for receive conductor 312 and neutralizing conductor 322.

Polar receiving—differential sending repeater Fig. 4

This circuit is designed to provide a half duplex terminal repeater operating over two conductor lines with provisions for partial neutralization of line interference by use of a third line conductor. Transmission from the polar sending repeater at a distant office is on a one-way polar basis and the repeater is designed, therefore, to receive polar signals from the trunk circuit and to repeat the signals to a subscriber's loop or to a toll line extension repeater, for transmission to a subscriber's set. The repeater is designed to receive signals from a subscriber's loop or from a toll line extension repeater and to repeat the signals to the trunk circuit as the differential sending end of the system. The repeater will operate without

transmission losses due to line leakage, since inward transmission is polar and readjustment may take care of the other deviation. In order to compensate for ground potentials and induced voltage interferences provision is likewise made at this repeater for using the third conductor to serve as a neutralizing circuit.

Signals transmitted from subscriber's station 402 or 402' are received over conductor 416 by polarized send relay 413 which operates and thereby repeats the signals over conductor 429, noise suppressor and wave shaper, trunk conductor 312 to the trunk repeater at the distant office. The signals thus transmitted to the distant office are ground and positive 130-volt battery for the polarential sending end of the type "B" polarential system.

The polar signals received from the distant office are repeated by the polarized receive relay 401 to a polarized auxiliary receive relay 407 which, in turn, repeats the signals over conductor 416 to either of the subscriber's stations 402 or 402'.

Subscriber's station 402 is located at a considerable distance from the office and therefore requires a toll line extension repeater interconnecting conductors 416 and 423. Subscriber's station 402' is located at a comparatively short distance from the office and is therefore connected directly to the repeater at the office. Subscriber's station 402' is of the ordinary subscriber's loop type whereas subscriber's station 402 is of the type disclosed in Fig. 1 of U. S. Patent 2,143,000 granted to W. W. Cramer et al. on January 10, 1939.

Partial neutralization of ground potential, cross-fire and other induced voltage interferences is accomplished by use of the third conductor 322 between the distant office and this office, which is subjected to the same exposures as the operating path of conductors 311 and 312. Winding No. 3 on receiving relay 313 at the distant office and the lower winding of relay 401 at this office are connected together by this third conductor 322.

Transmission to the repeater at the distant office has been improved by the use of a line wave shaper comprising retardation coil 433 and condenser 434 which are adjusted for optimum transmission over the particular trunk circuit used. This wave shaper serves as an equalizing network for the telegraph line circuit and, in addition, helps to decrease telegraph thump to a satisfactory level.

Send relay

Send relay 413 is provided for receiving signals over conductor 416 and retransmitting them over send trunk conductor 312 to the distant office. Relay 413 is equipped with two windings, one of which is connected in series with conductor 416 which may extend either through the toll line extension circuit to subscriber's station 402 or directly to subscriber's station 402'. The other winding of relay 413 is connected in series with the artificial line terminating at ground connection 415.

Receive relay

Polarized receive relay 401 is provided for receiving signals from the distant office and retransmitting them over a circuit extending from ground 446 or battery 403 depending upon which of its two contacts the armature of relay 401 is in engagement with at the time the circuit is closed over conductor 404 through the winding

of polarized relay 406, the lower winding of polarized auxiliary receive relay 407 to a potentiometer connected between positive 130-volt battery 403 and ground 446. Relay 401 is equipped with two windings, one of which is connected to receive trunk conductor 311 and receives signals incoming from the distant office, and the other, is connected to third conductor 322 and is provided for neutralizing induced voltage interferences.

Auxiliary receive relay

Polarized receive relay 407 is provided for receiving signals repeated by receive relay 401 and retransmitting them to conductor 416. Relay 407 is equipped with two windings, one of which, as hereinbefore stated, receives the signals repeated by relay 401 and the other is a biasing winding for holding relay 407 in its right hand, or marking, position when transmission is toward the distant office.

Supervisory relay

Polarized relay 414, both windings of which are respectively connected in series with those of send relay 413, and polarized relay 406, the winding of which is connected in series with the lower, or signal, winding of auxiliary receive relay 407, are for supervisory purposes but inasmuch as supervision forms no part of the present invention no further description is deemed necessary.

Noise suppressor

A noise suppressor consisting of retardation coil 432 and resistances 430 and 431 is provided in series with send trunk conductor 312.

Equalizing network

An equalizing network is provided for send trunk conductor 312 and comprises retardation coil 433, resistance 437 and condenser 434. The resistance and the condenser are adjusted for optimum transmission toward the repeater at the distant office.

Contact protection

Contact protection is provided across the contacts of send relay 413 and receive relay 401.

Anti-kickoff network

A network 439 is provided to prevent kickoff when relay 407 transmits signals to the subscriber loop.

Toll line extension repeater circuit

The toll line extension circuit is provided to repeat signals transmitted from subscriber's station 402, to the trunk repeater for retransmission to the distant office, and to retransmit signals received from the distant office and repeated to subscriber's station 402. Signals received from subscriber's station 402 over conductor 423 are repeated by polarized relay 419 to conductor 416 and signals received from conductor 416 are repeated by polarized relay 417 to conductor 423.

Shaping networks

Several wave shapers are provided for improving the signals incoming over conductor 416. Satisfactory wave shapers are shunted condenser 426 and network 420. Network 420 comprises resistance 440, inductances 441 and 442 and resistance 444, the latter resistance shunting resistance 440 and inductance 441.

Contact protection

Contact protection is provided across the contacts of relays 417 and 419.

Supervisory relay

Polarized relay 421 is provided for furnishing supervision over signals received from the subscriber station 402 but, as hereinafter stated, a description of the supervisory features is not deemed necessary.

DETAILED DESCRIPTION

METHOD OF OPERATION

Transmission from the toll subscriber station at polar sending end to toll subscriber station at polar receiving end

When a connection is established for transmission from toll subscriber station 201 to toll subscriber station 402, signals are received in a circuit extending over conductor 202, through the upper winding, in series, of polarized relays 204 and 205, shaping network 206, armature and marking, or left-hand, contact of polarized relay 207 to ground. Relays 204 and 205 respond to these signals. Relay 205 is for a supervisory relay and may be used to control signal circuits, lamps or other devices not shown. Relay 204, upon responding to the signals, repeats them by means of its spacing and its marking contacts which are, respectively, connected to grounded positive 130-volt battery 208 and ground connection 209, and its operating armature in a circuit extending over conductor 210, through the upper and the lower windings, in parallel, of relay 207, the path of the lower winding extending to a fixed potentiometer connected between grounded positive 130-volt battery 208 and ground connection 209, and the path of the upper winding extending over wave shaper 211, conductor 203, through the upper windings, in series, of polarized relays 325 and 301, conductor 321, armature and marking, or right-hand, contact of auxiliary relay 302 to grounded negative 130-volt battery 332. Signal current impulses incoming over lead 203 from the toll line extension repeater shown in Fig. 2 overcome the biasing current in the lower winding of relay 301 so that the relay becomes responsive to the incoming signals. Connected in series with relay 301 is polarized relay 325 which is used for supervisory purposes not described herein.

The incoming polar signals are repeated by means of the spacing and marking contacts respectively connected to grounded positive 130-volt battery 326 and grounded negative 130-volt battery 327 and the operating armature of relay 301 in a circuit extending over conductor 303, potentiometer rheostat 372, through the noise-killer, and the equalizing network trunk conductor 311, through the upper winding of polarized receive relay 401 to ground. Any voltage from an extraneous source induced in trunk conductor 311 is likewise induced in third conductor 322. Conductor 311 extends through the upper winding of receive relay 401 and third conductor 322 extends through the lower winding of relay 401 and therefore the effect of the induced voltage in conductor 311 is neutralized by the induced voltage of equal magnitude in conductor 322, since both windings are differentially wound with respect to each other. The transmitted polar signals are, during transmission, unaffected by battery variations or variations in the characteristics of the trunk conductors 303 and 311.

Receive relay 401 responds to the message signals incoming over trunk conductor 311 and repeats them by means of the spacing and marking contacts respectively connected to grounded positive 130-volt battery 403 and ground 446, depending upon the contact engaged at the time by the armature of relay 401, and the operating armature of the relay, in a circuit extending over conductor 404, through the shaping network 405, through the winding of polarized supervisory relay 406, through the lower winding of polarized auxiliary receive relay 407 to a potentiometer between grounded positive 130-volt battery 403 or ground 446. Auxiliary receive relay 407 is held in the position shown, namely, marking, when transmission is toward the polar sending repeater office as hereinbefore stated.

Auxiliary receive relay 407 responds to the signals repeated by receive relay 401 and repeats the signals by means of the spacing and the marking contacts respectively connected to ground 408 and grounded positive 130-volt battery 409 and the operating armature of relay 407, in a circuit extending over retardation coil 410, conductor 412, through the upper and the lower windings, in parallel, of polarized relays 413 and 414, connected in series, over two paths, one extending through the artificial line to ground 415 and the other over toll conductor 416 to the repeater in the toll line extension circuit. The windings of relays 413 and 414 are differentially wound with respect to each other and are normally held in their marking, or right-hand, positions as shown and do not respond to signals repeated as "current" and "no current" impulses by relay 407. The signals repeated by relay 407 over trunk conductor 416, through the upper winding of polarized send relay 417, conductor 418, armature and marking, or right-hand, contact of polarized relay 419 to ground connection 424 to cause relay 417 to operate. Relay 417, upon responding to the incoming signals, repeats them, without change, except that due to attenuation in a circuit extending over operating armature of relay 417, shaping network 420, through the upper and lower windings, in parallel, of polarized relays 421 and 419 connected in series, the path through the upper winding extending over conductor 423 to the outlying subscriber station 402 whereat the signals are recorded, and the path through the lower winding extending through the artificial line to ground 447. Relays 421 and 419 do not operate at this time. Subscriber station 402 may be so equipped as to furnish both attended and unattended service as disclosed in Fig. 1 of United States Patent 2,143,000, supra.

In the event that conductor 416 is connected through a local subscriber loop to subscriber station 402', the toll line extension repeater circuit is omitted and conductor 416 is connected directly to the subscriber station as is disclosed at the right side of Fig. 5 of the United States Patent 2,143,000 supra, wherein conductors R and T, respectively, correspond to conductors 416 and the dash line shown connected to ground at connection 422.

Likewise, if conductor 416 is connected to an inverse neutral repeater 402'' the toll line extension repeater circuit is omitted and the conductor 416 may be connected directly to any of the inverse neutral repeater arrangements disclosed in United States Patents 2,056,277 and 2,069,251, respectively granted to F. S. Kinkead et al. on October 6, 1936, and F. S. Kinkead on February 2, 1937.

Transmission from a toll subscriber station at polar receiving end to toll subscriber station at polar sending end

When a connection is established for transmission from the outlying, or toll, subscriber station 402, to toll subscriber station 201, signals are received in a circuit extending over conductor 423, through the upper windings, in series, of relays 419 and 421, shaping network 420, armature and marking, or right-hand, contact of relay 417 to ground. Relays 419 and 421 respond to these signals. Relay 421 is for supervisory purposes and its operation and effect is not described herein. Relay 419, upon responding to the signals, repeats them by means of its spacing and its marking contacts which are respectively connected to grounded positive 130-volt battery 425 and ground connection 424, and its operating armature in a circuit extending over conductor 418, through the upper and the lower windings, in parallel, of relay 417, the path of the lower winding extending to a fixed potentiometer connected between grounded positive 130-volt battery 425 and ground connection 424, and the path of the upper winding extending over wave shaper 426, conductor 416, through the upper windings, in series, of relays 414 and 413, conductor 412, retardation coil 410, armature and marking, or right-hand, contact of relay 407 to a fixed potentiometer connected between grounded positive 130-volt battery 409 and ground connection 415, or to ground connection 408, depending upon the nature of the received signal. Send relay 413 operates in response to the signals. Supervisory relay 414 likewise responds but the effects of its operation are not described herein.

Send relay 413, upon responding to the signals received from conductor 416, repeats the signals by means of its spacing and its marking contacts which are respectively connected to grounded positive 130-volt battery 427 and ground connection 428, and its operating armature, in a circuit traceable over conductor 429, the noise suppressor and the wave shaper, trunk conductor 312, through winding No. 5 of receive relay 313, conductors 347 and 314, through the normally closed keys 356 to 359, in series, conductor 316, key 317 to grounded negative 130-volt battery 318. One or more resistances 361 to 365 may be added as desired by operating their respectively associated keys 356 to 360, whereby corresponding resistances 366 to 370 are included in the circuit of third conductor 322.

Relay 313 responds to the differential signals incoming over trunk conductor 312, and thereby repeats them as polar signals by means of its spacing and its marking contacts which are respectively connected to grounded negative 130-volt battery 328 and grounded positive 130-volt battery 329, and its armature, in a circuit traceable over conductor 319, wave shaper 320, through the lower windings, in series, of relays 330 and 302 to ground. Relay 330 is for supervisory purposes, and its operation and effect are not described herein inasmuch as, as hereinbefore stated, the supervisory features are no part of the present invention. Relay 302 responds to the signals received over conductor 319 and thereby repeats the polar signals by means of its spacing and its marking contacts which are respectively connected to grounded positive 130-volt battery 331 and grounded negative 130-volt battery 332, and the relay armature, in a circuit traceable over conductor 321, through the upper and the

lower windings, in parallel, of relays 301 and 325 in series, the path of the lower windings extending to ground through an artificial line 374 and the path of the upper windings extending over conductor 203, shaping network 211, through the upper winding of relay 207, conductor 210, armature and marking, or left-hand, contact of relay 204 to ground connection 209. Relay 207 responds to the signals incoming over conductor 203 and repeats them, as signals of "current" and "no current," in a circuit traceable over shaping network 206, through the upper and the lower windings, in parallel, of relays 205 and 204, in series, the path through the upper windings extending to the toll subscriber set 201 and the path through the lower windings extending to ground over an artificial line. Relay 205 is for supervisory purposes and relay 204 is the send relay, but neither operate in response to incoming signals because of the differential arrangement of their respective windings.

It will be noted that transmission from send relay 301, over conductor 311, to receive relay 401 is of the one-way polar signal type which, as hereinbefore stated, requires no compensation for line leakage. The transmission in the opposite direction, that is, from send relay 413, over conductor 312, to receive relay 313 is of the differential type. The latter type uses as signals currents of markedly different amplitudes but of the same polarity and the above-mentioned circuit comprising conductor 312 requires adjustments principally by means of keys 356 to 359 and the aid of the attendant at the concentrating unit office, but once the circuit is adjusted for the line leakage practically no further adjustments are necessary regardless of whether the weather is wet or dry.

FULL DUPLEX OPERATION

General Description

Polar sending-differential receiving repeater Fig. 6

This circuit is designed to provide a full duplex telegraph repeater system comprising two conductor lines with provision for partial neutralization of line voltage interferences by use of a third conductor line. The local side of the repeater provides full duplex legs for balanced loop operation or for 48-volt inverse neutral operation. Losses from cross-fire, voltage interference and earth potential are partially eliminated by the use of the third conductor so long as the three conductors of the trunk remain balanced.

Transmission from the repeater shown in Fig. 6 to the repeater shown in Fig. 7 is on a one-way polar signal basis. Transmission in the opposite direction is on a differential basis. The repeater shown in Fig. 6 operates on a full duplex basis.

Five jacks are provided for patching an indicating milliammeter to measure the signal current in the trunk conductors and the biasing circuit for receiving relay 616 and to indicate the differential current in the receive relay 616. The indicating milliammeter is for observing signals and line balance under different conditions. This meter is of the same type as hereinbefore described, which is a single coil type and a scale with a zero mid-point and is adapted to operate in opposite directions in accordance with the direction of the operating current.

Apex keys

Five apex keys are provided to control the resistance in the circuits of trunk conductor 719 and third conductor 720. Each of these keys is arranged to affect the resistance of each of the apex circuits alike. The apex keys are of the locking type, preferably arranged to be operated with a turn-button top. Key 652 controls resistance 662 of third conductor 720. In like manner keys 653, 654, 655 and 656, respectively, control the four remaining pairs of resistances as shown, resistances 658, 659, 660 and 661 being, respectively, paired with resistances 663, 664, 665 and 666.

Balance keys

Balance key 620 is non-locking and is of the push-button type. It is provided to reverse the apex voltage when the repeater is being lined up on the trunk conductor to which the repeater is connected. Balance key 667 is of the same type as key 620 and is provided to normally remove the battery from key 620 and thus be held operated when key 620 is used when balancing the repeater.

Monitoring

Provision is made for common monitoring with an indicating milliammeter arranged to be patched to any one of five jacks connected in the repeater circuit. The indicating milliammeter serves for observation of signals and line balance under different conditions. This meter is of the single coil type, has a scale with a zero midpoint and is adapted to operate in opposite directions in accordance with the direction of the operating current. This type is well known in the art as hereinbefore stated. It is used to facilitate adjustment and balance. The five jacks are as follows:

Jack 650 is provided in series with send trunk conductor 615 for checking the line current and to permit observation of the signals transmitted over the line. The reading indicated on the milliammeter is the actual line current.

Jack 651 is provided in series with receive trunk conductor 719 for checking the line current and to permit observation of signals received over the line. This reading likewise is the actual line current.

Balance jack 669 is provided for connecting the milliammeter to indicate the differential current between received trunk conductor 719 and its associated artificial line 622. The reading on the milliammeter is the actual differential current.

Balance jack 670 is provided for connecting the milliammeter to indicate the interference on the neutralizing, or third, conductor 720 for comparison with the interference on the received trunk conductor 719.

Bias jack 671 is provided for connecting the milliammeter in the biasing circuit so that the bias current may be adjusted to the proper value. The shunting resistance 672 across bias jack 671 is so proportioned that the value of current indicated on the milliammeter when the biasing current is properly set will be equal to the current obtained with the meter patched to balance jack 669 when a spacing signal is transmitted from the repeater at the distance office.

Noise suppressor

A noise suppressor consisting of retardation coil 611 and resistance elements 608 and 609 is provided in series with send conductor 614.

Contact protection

Contact protection is provided across the contacts of send relays 601 and 636 and across the contacts of receive relay 616. The condensers and resistance elements connected across the contacts of each of these relays prevent the occurrence of sparking.

Leg circuit wave shapers

Wave shapers to ground are connected across conductors 640 and 645 to compensate for the armature travel time of relay 643 transmitting to the leg circuit. The wave shaper connected to conductor 640 consists of condensers 673 and resistance 674. The wave shaper connected to conductor 645 consists of condenser 676 and resistance 675. Resistances 674 and 675 have equal value.

Potentiometers—Send line potentiometer

Send line potentiometer comprising rheostat 607 connected in the apex of the send line of the repeater and resistance 610 connected from the apex to ground is provided so that the current in send trunk conductor 615 may be adjusted to ± 35 milliamperes.

Balancing resistance potentiometers

The balancing resistance potentiometers consist of two units, namely, 625 and 632 shown mounted on opposite sides of a ground connection. The potentiometers are used to obtain direct current balances in the artificial line circuit of the received trunk conductor 719, and the neutralizing, or third, conductor 720. For two-wire operation, that is where the third conductor is omitted, potentiometer 632 may also be omitted.

Bias potentiometer

Bias potentiometer 696 is provided in the biasing circuit of receive relay 616 so that the current in this circuit may be adjusted to the proper value. Resistance 677 may be strapped in or out of the circuit to extend the current range beyond the value obtained with the potentiometer.

Receive relay

Receive relay 616 is provided for receiving signals from the distant end of the line and retransmitting them to the local loop or leg multiple circuit at the operator's switchboard. This relay is equipped with six windings which are arranged for connection in five circuits. One winding, that is, No. 4, is connected to the receive trunk conductor 719 as shown, and the second winding, No. 3, is connected to the artificial line 622 which is used for balancing the received trunk conductor. The third and the fourth windings, Nos. 2 and 1, are respectively connected to the third conductor 720, and artificial line 629, for effecting the desired neutralization of induced voltage interferences on the trunk conductors 719 and 615. The remaining two windings, Nos. 6 and 5, are connected in series and are used for biasing the relay as required for type B polar operation.

Send relay

Send relay 601 is provided for receiving signals from the local loop and to transmit them as polar signals to send trunk conductor 615. This relay is equipped with two windings; one winding is connected in series with conductor 678 of the loop and resistance 679 and the other

is connected in series with an artificial line comprising resistance element 680.

Send relay 636 is provided for receiving signals from conductor 640 to which is patched by means of jack 681 plug 682 of the operator's cord circuit which is connected to a hub circuit at its other end. Relay 636 repeats the received signals, as polar signals to send conductor 659 which is an alternative conductor for conductor 606. Send relay 636 is equipped with two windings. One winding is connected over conductor 640 to the hub circuit on one side and on the other side in series with resistances 683 and 684 to grounded 48-volt battery. Resistance 684 is shunted by condenser 685. The other winding of send relay 636 is connected in series with a biasing circuit comprising resistance 686 between ground and grounded 48-volt battery.

Receive relay (inverse neutral operation)

Receive relay 643 is provided for receiving signals from receive relay 616 which is shown in Fig. 6 as relay 616', and to retransmit the signals to conductor 645 to a hub circuit connected to the opposite end of the cord circuit, plug 682 of which is patched to jack 681. This assures uniform travel time from the contacts of the relay repeating signals over conductor 645. Relay 643 is equipped with one winding which is connected in series with resistances 642 and 641 to the armature of receive relay 616. Resistance 641 is shunted by condenser 687 for wave shaping purposes.

Networks

An equalizing network is provided for the send conductor 614 comprising retardation coil 612, condenser 613, and resistance 688, the condenser and resistance being adjusted for optimum transmission to the repeater at the distant office. A line balancing network is provided for receive conductor 719, comprising condenser 623 and resistances 624 and 625 which are adjusted for optimum transmission. Condenser 630 and resistances 631 and 632 are a duplicate of condenser 623 and resistances 624 and 625 and is provided for the neutralizing, or third, conductor 720 in order to maintain a duplicate balance for receive conductor 719 and neutralizing conductor 720.

Polar receiving-differential-sending repeater *Fig. 7*

The circuit shown in Fig. 7 is designed to provide a full duplex telegraph repeater system operating over two conductor lines with provision for partial neutralization of line interferences by use of a third line conductor. Transmission from the repeater shown in Fig. 6, as hereinbefore stated, is on a one-way polar basis.

Monitoring

Jack 735 is provided for patching a milliammeter to receive trunk conductor 719 for measuring the line current. The reading indicated on the meter is the actual line current.

Noise suppressor

A noise suppressor consisting of retardation coil 715 and resistances 713 and 714 is provided in series with the send conductor 719.

Contact protection

Contact protection is provided across the contacts of send relay 709 and send relay 721 and across the contact of receive relay 701.

Leg circuit wave shapers

Wave shapers to ground are connected across conductors 736 and 735 to compensate for the armature travel time of relay 732 transmitting to the leg or hub circuit. The wave shaper connected to conductor 736 comprises condenser 738 and resistance 739. The wave shaper connected to conductor 735 comprises condenser 741 and resistance 740. Resistances 739 and 740 are of equal value.

Receive relay

Receive relay 701 is provided for receiving signals from the distant office and retransmitting them to the local loop or leg multiple, or hub, circuit. Relay 701 is equipped with two windings, one of which is connected to the receive conductor 615 and receives the signals incoming from the distant office, and the other is connected to third conductor 720 and is provided for neutralizing voltage interference.

Send relay

Send relay 709 is provided for receiving signals over send conductor 708 and retransmitting them over the send trunk conductor 719 to the distant office. Relay 709 is equipped with two windings, one of which is connected in series with resistance 742, send conductor 708 and the send conductor of the operated cord circuit to which plug 707 is attached, and the other winding of which is connected in series with resistance 743 of the artificial line.

Send relay 721 is provided for receiving signals from a hub circuit connected to send conductor 736 over a cord associated with plug 724 and retransmitting them over send conductor 722 and send trunk conductor 719 to the distant office. Relay 721 is equipped with two windings one of which is connected to send conductor 736 and in series with resistances 744 and 745 to grounded negative 48-volt battery 733. Resistance 745 is shunted by condenser 746. The other winding of relay 721 is connected in series with a biasing circuit comprising resistance 747 and grounded negative 48-volt battery 733.

Equalizing network

An equalizing network is provided for send trunk conductor 719 and comprises retardation coil 717, condenser 718, and resistance 750. The condenser and the resistance are adjusted for optimum transmission toward the repeater at the distant office.

DETAILED DESCRIPTION

METHOD OF OPERATION

Transmission from the polar sending repeater shown in Fig. 6 to the polar receiving repeater shown in Fig. 7

When a connection is established for transmission from the local side of the polar sending repeater shown in Fig. 6 to a subscriber's loop that may be connected at the repeater shown in Fig. 7, polarized send relay 601 receives the signals in a circuit traceable over plug 602 patched to jack 603, through the lower winding of relay 601 to grounded positive 130-volt battery. Relay 601 which is normally in the position shown, due to a biasing current flowing in a circuit traceable through the upper winding of the relay and through the artificial line to ground, responds to the signals incoming from the operator's teletypewriter or a subscriber's loop circuit

either of which may be connected to the switchboard cord circuit of plug 602. Relay 601, upon responding to the incoming signals, repeats them as polar signals in a circuit traceable from grounded positive 130-volt battery 604 or grounded negative 130-volt battery 605, their respective spacing and marking contacts and the relay armature, conductor 606, potentiometer rheostat 607, noise suppressor, equalizing network, trunk conductor 615, through the upper winding of polarized receive relay 701 to ground. Receive relay 701 responds to the signals repeated by send relay 601 and, upon responding, repeats the polar signals in a circuit traceable from grounded negative 130-volt battery 702 and grounded positive 130-volt battery 703, their respective spacing and marking contacts in engagement with the associated armature of the relay, conductor 704, conductor 705, to the lower spring member of jack 706 at an attendant's switchboard where the signals repeated by receive relay 701 are received at an attendant's teletypewriter or transmitted to a substation as desired.

The transmission just described is on a one-way polar basis and is practically unaffected by battery variations and variation in the characteristics of conductors 614 and 615.

Transmission from the differential sending repeater shown in Fig. 7 to the differential receiving repeater shown in Fig. 6

When signals are received from a local or a toll subscriber station they are impressed on a circuit traceable over plug 707 patched to jack 706, conductor 708, through the upper winding of polarized send relay 709 to grounded 130-volt battery 751. Normally when jack 706 is engaged, relay 709 is in the position shown due to the current flowing through its upper winding and conductor 708. Relay 709 responds to the signals received over conductor 708 and, upon responding, repeats the signals as "current" and "no current" impulses in a circuit traceable from grounded positive 130-volt battery 710 and ground connection 711, their respectively associated spacing and marking contacts and the relay armature, conductor 712, noise suppressor, equalizing network, trunk conductor 719, through winding No. 4 of receive relay 616, conductors 617 and 618, through the upper normally closed contacts of keys 652 to 656 or through one or more of resistances 657 to 661, depending upon which of control keys 652 to 656 are operated to opened positions at their upper contacts, conductor 619, non-locking push-button key 620 to grounded negative 130-volt battery 621. Resistances 662 to 666 which respectively correspond to resistances 657 to 661 in value, are included in the circuit of third conductor 720 in accordance with the operation of one or more of keys 652 to 656 to opened positions at their lower contacts. Differentially arranged with trunk conductor 719 which is connected to winding No. 4 of relay 616 is artificial line 622 connected to winding No. 3 of relay 616 to ground over two paths, one path including condenser 623 and the other path including resistance 624 and potentiometer rheostat 625.

Transmission over trunk conductor 719 towards the repeater shown in Fig. 6 is on a differential basis.

Partial neutralization of ground potentials, cross-fire and other induced voltage interferences is accomplished by the use of third conductor 720 extending between the trunk repeater at

this office (Fig. 7) and a trunk repeater at the distant office (Fig. 6). The third conductor 720 is connected at the distant office to a circuit extending through winding No. 2 of relay 516, conductors 526 and 627, through the normally closed lower contacts of keys 652 to 656 or one or more resistances 662 to 666 depending upon whether one or more of control keys 652 to 656 are operated, resistance 689 to ground connection 628. At this office, third conductor 720 is connected to the lower winding of receive relay 701 to ground so that it is subjected to the same induced voltages as trunk conductors 615 and 719 and consequently sufficiently neutralizes the effect of induced voltage interferences in either of receive relays 701 and 616 to permit satisfactory transmission. Conductor 629 serves as an artificial line for the third conductor 626 and comprises in one path to ground condenser 630 and in the other path to ground resistance 631 and potentiometer 632. A biasing circuit extends through the two windings Nos. 5 and 6 in series of relay 616 and is provided for biasing this relay.

Receive relay 616 responds to the signals received over trunk conductor 719 and, upon responding, repeats the signals on a polar basis in a circuit traceable from grounded negative 130-volt battery 633 or grounded positive 130-volt battery 634, their respectively associated spacing and marking contacts and armature of the relay, conductor 635 to the lower spring of jack 603 to which plug 602 is patched for connecting a local subscriber station.

Figure 6A

In Fig. 6A the terminating equipment for the repeater at the polar sending repeater office is shown for connection to multiple jacks at the switchboard whereby is furnished inverse neutral, or hub, circuit operations as disclosed in United States Patents 2,056,277 and 2,069,251, supra. Send relay 636 is normally held in the position shown by the biasing current in its upper winding. A line current will normally flow from grounded negative 130-volt battery 637, marking, or right-hand, contact and armature of relay 636, conductor 639, potentiometer 607, noise suppressor and equalizing network, over trunk conductor 615 as hereinbefore described. When a spacing impulse of the signal is received from the hub circuit by the application of ground at the local switchboard, and over conductor 640, relay 636 operates to its spacing, or left-hand, contact due to current flowing in the lower winding of the relay. Relay 636 in its spacing position, transmits current from grounded positive 130-volt battery 638, spacing, or left-hand, contact and armature of relay 636, conductor 639, potentiometer 607, noise suppressor and equalizing network, trunk conductor 614 as hereinbefore described. The signals repeated by send relay 636 are on a polar basis.

Signals transmitted from the repeater at the polar receiving repeater office and received by receive relay 616 are repeated on a polar basis as hereinbefore described but are transmitted through wave shaper 641, resistance 642, winding of receive relay 643 to ground. Relay 643 responds to the polar signals as "current" and "no current" impulses of 130 volts and thereby repeats the signals from grounded negative 48-volt battery 644 and ground connection 646. The signals are repeated to a hub circuit over conductor 645.

Figure 7A

In Fig. 7A is shown a modification of the trunk termination at the polar receiving repeater office whereby the trunk circuit is connected to multiple jacks for inverse neutral, or hub, circuit operation at 48 volts. Polarized send relay 721 is normally held in its marking position as shown by biasing current flowing through its lower winding and relay 721 normally transmits over conductor 722, through the noise suppressor and equalizing network to trunk conductor 719 a marking signal. When a spacing signal is received from the hub circuit over the upper spring member of jack 723 by the application of ground in the cord circuit of plug 724, relay 721 operates to its alternate, or spacing, position due to line current flowing in its upper winding. Relay 721, upon responding to signals received from the hub circuit, repeats the signals on a differential basis, in a circuit traceable from grounded positive 130-volt battery 725 or grounded connection 726 and their respectively associated spacing and marking contacts and armature of the relay, conductor 722, noise suppressor and equalizing network to trunk conductor 719.

Signals received from the polar sending repeater office over trunk conductor 615 are on a one-way polar basis and are repeated by receive relay 701 on a polar basis in a circuit extending from grounded positive 48-volt battery 727 and grounded negative 48-volt battery 728, their respectively associated spacing and marking contacts and armature of relay 701, over conductors 724 and 729, resistance 730, wave shaper 731, through the winding of polarized receive relay 732 to ground. Relay 732 operates and repeats the signals as "current" and "no current" impulses, in the circuit extending from grounded negative 48-volt battery 733 and ground connection 734, their respectively associated marking and spacing contacts and armature of relay 732, conductor 735 to a hub circuit associated with the opposite end of the cord circuit associated with plug 724.

What is claimed is:

1. In a telegraph transmission system, the combination of a polar sending-differential-receiving repeater circuit, a polar receiving-differential-sending repeater circuit, circuits interconnecting said repeater circuits, sending means at each of said repeater circuits for transmitting signal impulses to the other of said repeater circuits over separate circuits of said interconnecting circuits, and receiving means at each of said other repeater circuits for receiving said signal impulses.

2. In a telegraph transmission system, the combination of a polar sending-differential-receiving repeater circuit, a polar receiving-differential-sending repeater circuit, circuits interconnecting said repeater circuits, sending means at each of said repeater circuits for transmitting signal pulses to the other of said repeater circuits over separate circuits of said interconnecting circuits, receiving means at each of said other repeater circuits for receiving said signal impulses and a ground potential balancing conductor common to the relays of said repeater circuits.

3. In a telegraph transmission system, the combination of a polar sending-differential-receiving repeater circuit, a polar receiving-differential-sending repeater circuit, circuits interconnecting said repeater circuits, sending means at

each of said repeater circuits for transmitting signal impulses to the other of said repeater circuits over a separate one of said interconnecting circuits, receiving means at each of said other repeater circuits for receiving said signal impulses, and means common to said interconnecting circuits for neutralizing the effect of voltage interference induced in either of said interconnecting circuits during transmission of signal impulses in either direction.

4. In a telegraph transmission system, the combination of a polar sending-differential-receiving repeater circuit, a polar receiving-differential-sending repeater circuit, circuits interconnecting said repeater circuits, sending means in each of said repeater circuits for transmitting signal impulses to the other of said repeater circuits over a separate one of said interconnecting circuits, receiving means in each of said other repeater circuits for receiving said signal impulses, and other means at the sending end of each of said interconnecting circuits for shaping signal impulses outgoing over said interconnecting circuit, said means comprising a differentially wound retardation coil, one of said windings on said coil including the interconnecting circuit and the other including an artificial line to ground.

5. In a telegraph transmission system, the combination of a polar sending-differential-receiving circuit, a polar receiving-differential-sending repeater circuit, circuits interconnecting said repeater circuits, sending means in each of said repeater circuits for transmitting signal impulses to the other of said repeater circuits over a separate one of said intercommunicating circuits, receiving means in each of said other repeater circuits for receiving said signal impulses, another circuit interconnecting the receiving means of said repeater circuit and a plurality of adjustable impedances connected to one of the first-mentioned interconnecting circuits and said other interconnecting circuits for effecting a balance of impedance in said system.

6. In a telegraph transmission system, the combination of a polar sending-differential-receiving repeater circuit, a polar receiving-differential-sending repeater circuit, circuits interconnecting said repeater circuits, terminating circuits respectively adapted at one end for connecting to each of said repeater circuits and respectively arranged at the other end for connection to a toll line subscriber's circuit, a local subscriber's station loop, and an inverse neutral circuit.

7. In a telegraph transmission system, the combination of a polar sending-differential-receiving repeater circuit, a polar receiving-differential-sending repeater circuit, circuits interconnecting said repeater circuits, each of said repeater circuits comprising a sending device, a main receiving device, and an auxiliary receiving device, subscribers' stations connected to each of said repeater circuits, each of said subscribers' stations connected to each of said repeater circuits having means for effecting in conjunction with its associated sending and associated auxiliary receiving device half duplex operation between any one of said stations connected to one repeater circuit and any one of said stations connected to the other repeater station.

8. In a telegraph transmission system, the combination of a polar sending-differential-receiving repeater circuit, a polar receiving-differential-sending repeater circuit, circuits intercon-

necting said repeater circuits, a sending and a receiving device in each of said repeater circuits, terminating circuits respectively connected to the sending and the receiving devices of each of said repeater circuits and cooperating therewith for effecting full duplex operation between said repeater circuits.

9. In a telegraph transmission system, comprising a first repeater circuit, a second repeater circuit, a first telegraph line for transmitting signal impulses from said first repeater circuit to said second repeater circuit, a second telegraph line for transmitting signal impulses from said second repeater circuit to said first repeater circuit, two substantially equal sources of voltage of opposite polarities in said first repeater circuit, transmitting apparatus in said first repeater circuit connected to said first telegraph line for alternately connecting said sources of opposite polarities thereto in accordance with the impulses to be transmitted from said first repeater circuit to said second repeater circuit, receiving apparatus in said second repeater circuit connected between said first telegraph line and ground, a single source of voltage in said second repeater circuit, transmitting apparatus in said second repeater circuit connected to said second transmission line for alternately connecting ground at said single source of voltage and said ground to said second line in accordance with the signal impulses to be transmitted from said second repeater circuit to said first repeater circuit, receiving apparatus in said first repeater circuit connected between said second line and a source of voltage thereat which is of opposite polarity to that of said single source of voltage in said second repeater circuit, and means for controlling the magnitudes of the current transmitted over said second line so that the transmission thereover is substantially independent of the leakage resistance of said line.

10. In a half duplex operated telegraph transmission system comprising a first repeater circuit, a second repeater circuit, a first telegraph line for transmitting impulses from said first repeater circuit to said second repeater circuit, a second telegraph line for transmitting impulses from said second repeater circuit to said first repeater circuit to substantially equal sources of voltage of opposite polarities in said first repeater circuit, transmitting apparatus in said first repeater circuit connected to said first telegraph line for alternately connecting said sources of opposite polarities thereto in accordance with the impulses to be transmitted from said first repeater circuit to said second repeater circuit, receiving apparatus in said second repeater circuit connected between said first telegraph line and ground, a single source of voltage in said second repeater circuit, transmitting apparatus in said second repeater circuit connected to said second telegraph line for alternately connecting ground and said single source of voltage to said second line in accordance with the impulses transmitted from said second repeater circuit to said first repeater circuit, receiving apparatus in said first repeater circuit connected between said second line and the source of voltage thereat which is of opposite polarity to the voltage of

said single source at said second repeater circuit, a second receiving apparatus in said first repeater circuit for reversing the polarities of signals repeated by the first-mentioned receiving apparatus in said first repeater circuit for further transmission, and means for controlling the magnitude of the current transmitted over the second line so that the transmission thereover is substantially independent of the leakage resistance of said line.

11. In a full duplex operated telegraph transmission system comprising a first repeater circuit, a second repeater circuit, a first telegraph line for transmitting impulses from said first repeater circuit to said second repeater circuit, a second telegraph line for transmitting impulses from said second repeater circuit to said first repeater circuit, two substantially equal sources of voltage of opposite polarities in said first repeater circuit, transmitting apparatus in said first repeater circuit connected to said first telegraph line for alternately connecting said sources of opposite polarities thereto in accordance with the impulses to be transmitted from said first repeater circuit to said second repeater circuit, receiving apparatus in said second repeater circuit connected between said first telegraph line and ground, a single source of voltage and a ground connection in said second repeater circuit, transmitting apparatus in said second repeater circuit connected to said second telegraph line for alternately connecting ground connection and said single source of voltage to said second line in accordance with the impulses to be transmitted from said second repeater circuit to said first repeater circuit, receiving apparatus in said first repeater circuit connected between said second line and the source of voltage thereat which is of opposite polarity to that of said single source in said second repeater circuit, and means for controlling the magnitudes of the current transmitter over said second line so that the transmission thereover is substantially independent of the leakage resistance of said line.

12. In a full duplex operated telegraph transmission system, in accordance with claim 10, wherein said means is a third line connecting said first repeater and said second repeater circuit and connected at each end to a winding which is arranged in differential relation to a winding connected to one of said telegraph lines, said third line thereby serving to neutralize the effect in said receiving apparatus in each of said repeater circuits of any voltages induced in said first and said second telegraph lines.

13. In a differential receiving telegraph system for receiving from a distant sending station over a conductor, a main receiving conductor, a receiving relay having a winding in series with said conductor, a ground potential balancing conductor also extending from said distant station, a winding of said relay in series with said balancing conductor, operable means for changing the resistance of said one of said conductors, and means operable coincidentally therewith for changing the resistance of the other conductor by a corresponding amount.

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