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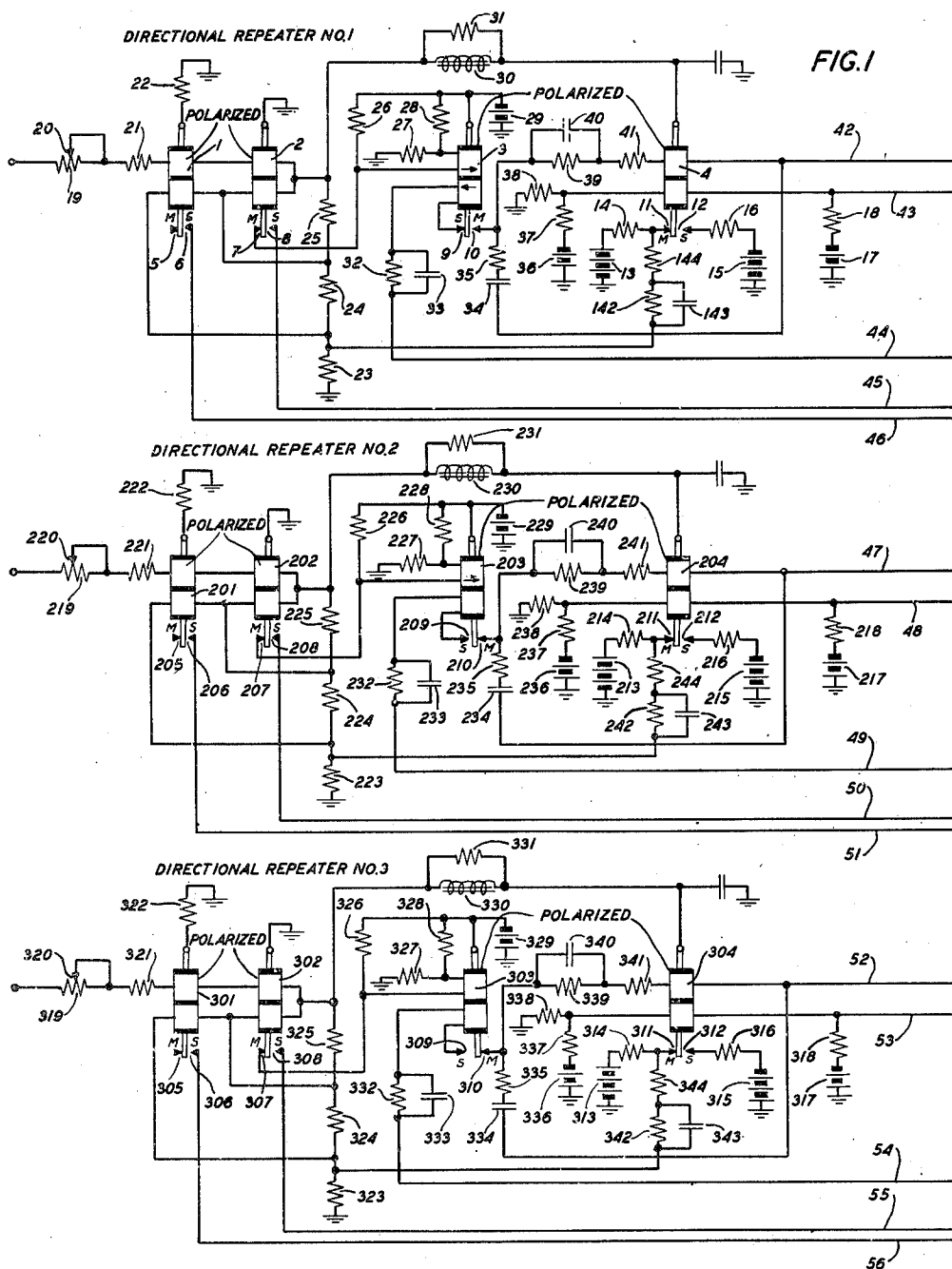
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2,481,919

MULTIWAY REGENERATIVE REPEATER SYSTEM

Filed Aug. 25, 1945

3 Sheets-Sheet 1



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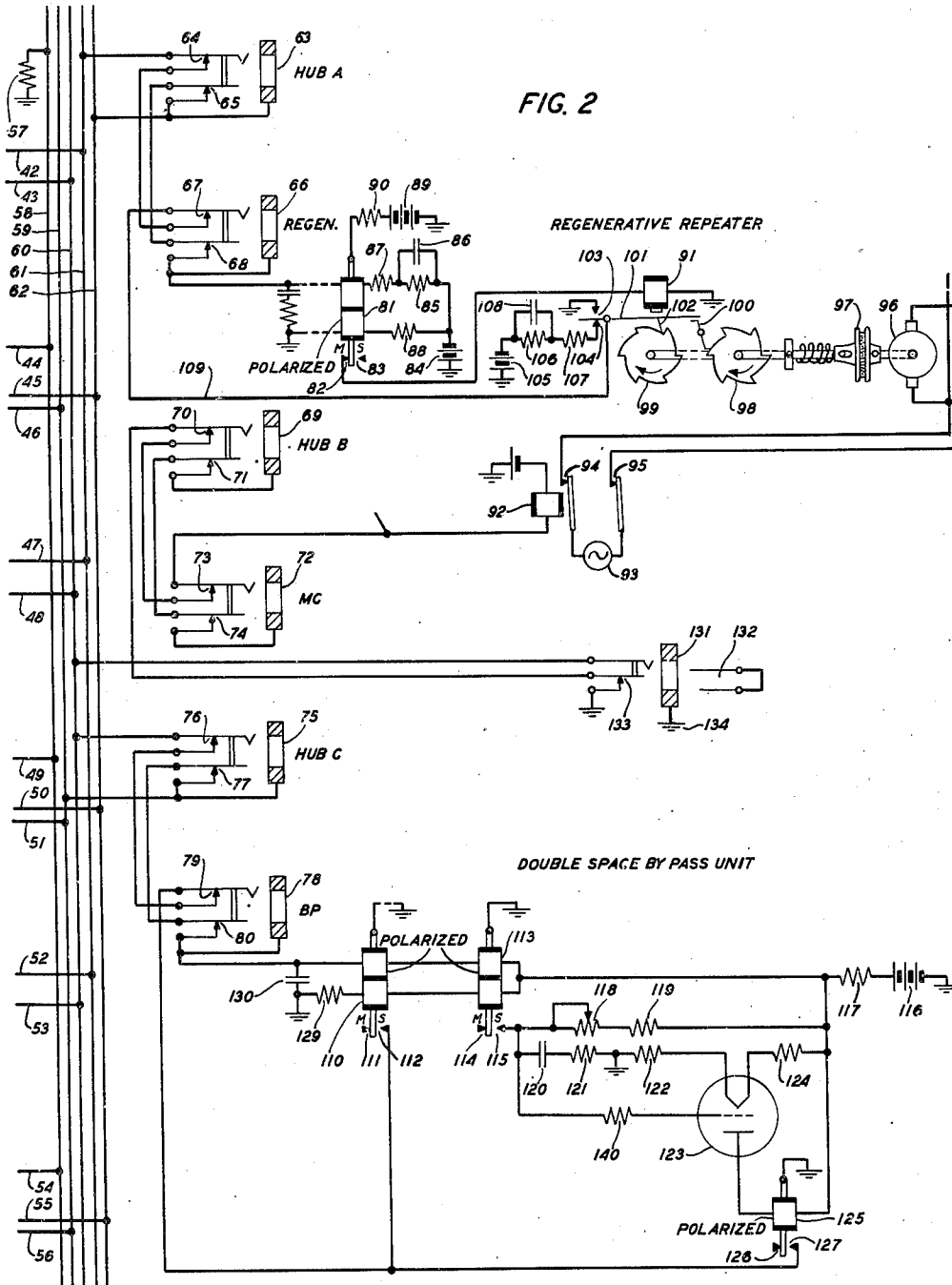
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

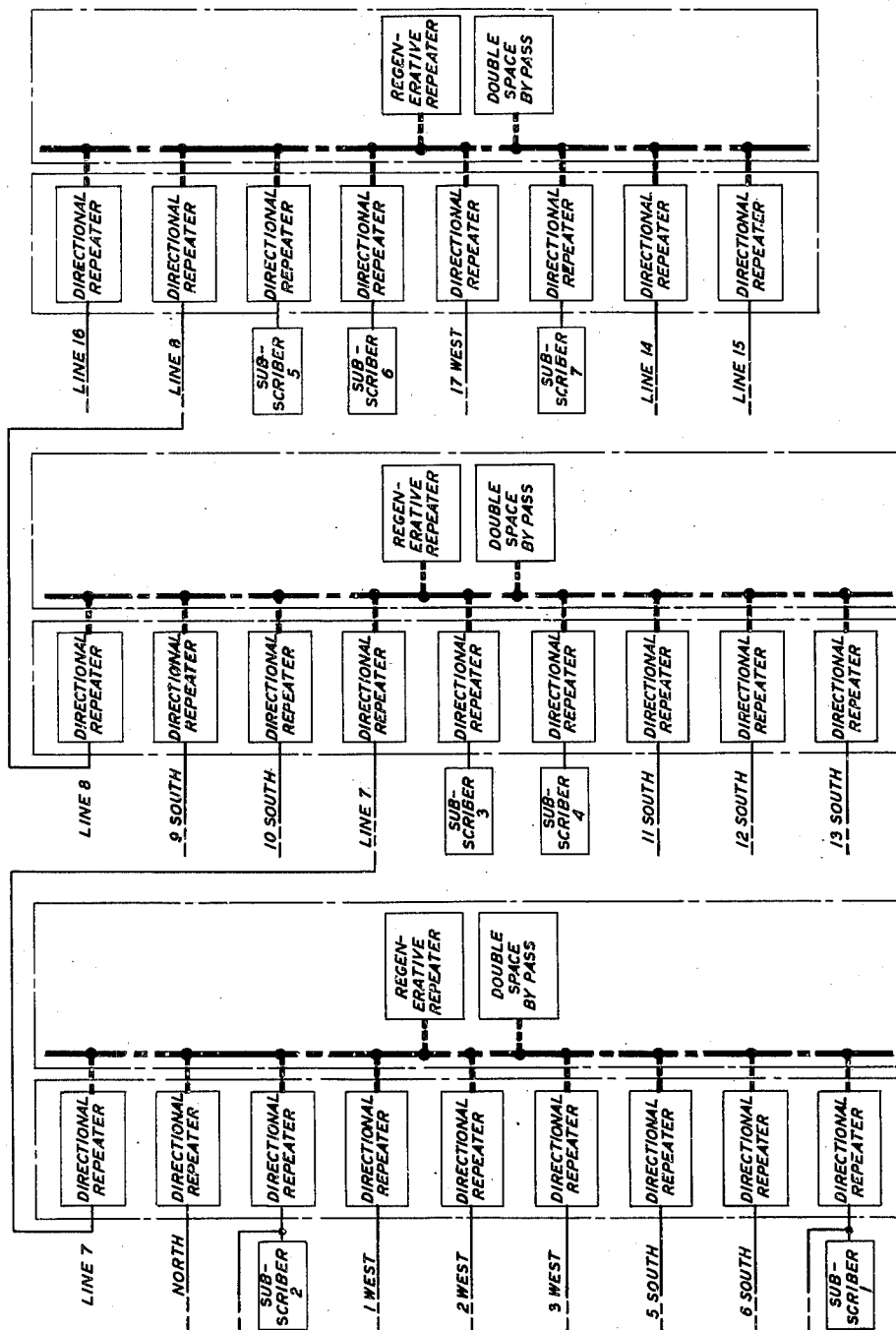


FIG. 3

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UNITED STATES PATENT OFFICE

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MULTIWAY REGENERATIVE REPEATER
SYSTEMKarl E. Fitch, Summit, N. J., assignor to Bell
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Application August 25, 1945, Serial No. 612,679

12 Claims. (Cl. 173-73)

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This invention relates to telegraph repeaters and more particularly to an improved multiway regenerative telegraph repeater.

An object of the invention is the improvement of telegraph repeaters.

A more particular object of the invention is the improvement of multiway regenerative repeaters.

By a multiway regenerative telegraph repeater is meant an arrangement wherein more than two telegraph lines or loops, each equipped with an individual telegraph repeater, are interconnected through a hub into a half-duplex concentration group served by a single regenerative repeater unit in such a manner that any one of the individual telegraph lines or loops can transmit through the single regenerative unit to all of the other interconnected lines or loops simultaneously. As is well known in the art when telegraph signals are transmitted over long lines, which may include telegraph repeaters of the nonregenerative type, they tend to become distorted. It is therefore necessary at times, before further transmission is feasible, to transmit the signals through a regenerative repeater which is designed to receive the distorted signal elements and in response thereto regenerate and retransmit signal elements which correspond exactly with the original signal element in shape and duration. The regenerative repeater identifies the nature of each signal element, generally by sensing the middle portion of the signal element, and then transmits a signal element of corresponding nature and of standard length by means of a mechanically or electrically controlled timing device which restores each signal element to its standard duration. It is particularly pointed out that only a single regenerative repeater unit is required to serve any concentration group of interconnected lines or loops in a multiway regenerative repeater at a particular city. Numbers of such groups located in different cities remote from each other are ordinarily interconnected together through an individual regenerative repeater for each group. Although presently known multiway regenerative repeaters operate generally satisfactorily, it has been found that they are subject to a difficulty which results in the occasional loss of a short message when two or more parties at remote points seize the line approximately simultaneously. The reason for this is that spacing signals cannot pass each other over the system.

It is a more specific object of this invention

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to prevent the loss of short messages on multi-group networks interconnected through multiway repeaters.

The loss of short messages on multigroup networks is prevented through the modification of the presently known multiway repeater circuits to provide what will be termed hereinafter a double-space by-pass feature. The double-space by-pass feature permits space signals in effect to pass each other at regenerative points and minimizes simultaneous sending by assuring rapid and positive mutilation of local copy which serves as an indication of the attempted simultaneous transmission.

A feature of the invention is a double-space by-pass arrangement incorporated into a multiway regenerative repeater.

A further feature of the invention is an arrangement whereby the multiway regenerative repeater and the double-space by-pass circuit may be readily interconnected or disconnected as required by the repeater attendant depending on the needs of particular networks as they are established or modified thus effecting a saving in the number of double-space by-pass units required.

A further feature of the invention is the modification of the directional repeater so that it can respond to a spacing or break signal received from a connected line repeater during the interval while a spacing signal is being transmitted from the directional repeater toward the line repeater.

A further feature of the invention is the provision of an arrangement in the directional repeater so that it can discriminate between a spacing or break signal received from a line repeater and a spacing or break signal received from a subscriber loop during the interval while the directional repeater is transmitting a spacing signal toward the line repeater or the subscriber loop and which enables the directional repeater to respond to the spacing or break signal received from the line repeater and remain unresponsive to the spacing or break signal received from the subscriber loop under such conditions.

These and other features of the invention may be understood from reference to the associated drawing, disclosing a preferred embodiment of the invention, in which:

Fig. 1 shows three directional repeaters connected individually to three telegraph channels;

Fig. 2 shows a regenerative repeater, a double-space by-pass unit and a hub through which the

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directional repeaters of Fig. 1 are interconnected to Fig. 2; and

Fig. 3 shows a typical half-duplex multiway regenerative repeater network formed by interconnecting subscriber loops and telegraph lines through three Figs. 1 and 2 in three different cities.

GENERAL DESCRIPTION OF THE SYSTEM

Refer to Figs. 1 and 2. Before proceeding with a detailed description, a general description of the operation of the system will be given. Figs. 1 and 2 when interconnected with Fig. 1 at the left of Fig. 2 exemplify the circuits constituting a particular concentration group together with its regenerative repeater and its double-space by-pass unit in a telegraph test board at a particular city. Other corresponding circuits such as Fig. 1 and Fig. 2 will be located at distant cities and interconnected into a network by a single telegraph channel interconnecting the groups as indicated in Fig. 3. Extending from the left-hand margin of Fig. 1 are three conductors. Each of these three conductors may connect externally to a telegraph line repeater, not shown, and through the repeater to a telegraph channel extending to a distant city or the conductor may connect to a local subscriber telegraph loop or a particular conductor may connect to both a line repeater and a loop. Each telegraph channel is interconnected through an individual directional repeater marked directional repeater No. 1, 2 and 3, in Fig. 1 to a hub circuit shown at the left of Fig. 2. The three directional repeaters are served by a single regenerative repeater unit shown at the top of Fig. 2 and by a double-space by-pass unit shown at the bottom of Fig. 2. Although there are but three directional repeaters shown in Fig. 1, it is understood that any number of repeaters up to ten may be interconnected in a particular concentration group. If more than ten are to be interconnected, two hub groups are interconnected. Signals may be received from the facility connected to directional repeater No. 1 over its corresponding telegraph channel and impressed on the regenerative repeater. The regenerative repeater will reshape and retune the signal and transmit the signal simultaneously to directional repeater No. 2 and directional repeater No. 3 and through them over the telegraph channels individual to each to remote cities where the channels are extended through individual directional repeaters to the hubs of other concentration groups or to the connected subscriber loop. Thus, any one of the telegraph facilities connected to directional repeater 1, 2 or 3, or others if there are more in the group, may transmit through the single one-way regenerative repeater unit to all of the other channels interconnected to a particular group at a particular city, as well as to all of the other groups at the remote cities and through the regenerative repeaters at the remote cities to each of the facilities connected into the various groups at the remote cities.

Signals incoming to a particular directional repeater connected to a particular channel of a group at a particular city are impressed on the incoming circuit of the single regenerative repeater unit associated with the group and, after regeneration, are impressed simultaneously by the outgoing circuit of the single regenerative repeater unit on all of the other directional repeaters connected into the group except the directional repeater from which the signal was received.

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There has heretofore been a difficulty encountered in the operation of multiway regenerative repeater networks in that it was impossible for a spacing signal generated in one concentration group at a particular city to pass another spacing signal generated in a concentration group at another city. Under such circumstances short messages were frequently lost. The double-space by-pass unit shown at the lower part of Fig. 2 now prevents this from happening. By means of the double-space by-pass unit, if for instance directional repeater No. 1 is transmitting a spacing signal and simultaneously a spacing signal is received from directional repeater No. 2, the double-space by-pass unit will identify the condition. The double-space by-pass unit will prolong the spacing interval for a measured period whenever two spacing signals are received simultaneously or in such a time relation that their intervals overlap. When such a condition occurs the double-space by-pass unit will impress a prolonged spacing signal on the entire system. The spacing interval will be prolonged sufficiently so that it has time to reach the most remote facility connected into the system. As long as simultaneous transmission continues, long spacing signals will be generated and impressed on the system by the double-space by-pass unit. The effect of this is to mutilate the signals which are transmitted and to insure that they are received by every facility connected into the system. The message which is received at each station will definitely be mutilated and will continue to be mutilated as long as simultaneous transmission continues. This serves as an indication that more than one transmitter is being operated simultaneously on the system. On observing the condition, the parties who are transmitting simultaneously will stop and transmitting may be resumed by one party.

On its regenerative side each directional repeater is wired to five individual hub circuits shown at the left of Fig. 2. The regenerator and double-space by-pass unit are connected to certain of these hubs through a special jack circuit shown also at the left of Fig. 2. The jack circuit provides for substitutions of regenerators and double-space by-pass units by patching.

DETAILED DESCRIPTION OF OPERATION OF SYSTEM

Repeater and network when idle

Each of the relays shown in Figs. 1 and 2 except power supply relay 92 in Fig. 2 is a high speed polar relay. The circuit per Figs. 1 and 2 is shown for the idle condition which is the same as for the marking condition. The various relays in Fig. 1 and Fig. 2 will be in the condition shown for reasons which will become apparent hereinafter. When the network is idle receiving break relay 4 and receiving relay 2 associated with directional repeater No. 1 are in the marking condition as shown. The corresponding relays in directional repeater No. 2, relays 201 and 202, and the corresponding relays in directional repeater No. 3, relays 301 and 302, are also in the marking condition. The directional repeaters transmit polar signals toward the distant end from batteries which may, for instance, be ± 130 volts. The directional repeaters transmit neutral signals through a hub circuit toward the regenerative repeater. The signals may, for instance, be negative 48 volts for marking and ground for spacing. The regenerative repeater terminates on its incoming side in negative 48-volt battery 75 and on its sending side connects negative 48

Volts to the sending hub for marking and ground for spacing.

It will be assumed that the incoming signals were last received by directional repeater No. 1 from the incoming channel. Under this circumstance holding relay 3 will be in the spacing condition. Holding relays 203 and 303 in directional repeaters Nos. 2 and 3 will be in the marking condition. The sending relays Nos. 4, 204 and 304 in directional repeaters Nos. 1, 2 and 3 will be in the marking condition. The reasons for this will be made apparent below. The detailed operation of the regenerative repeater in the upper portion of Fig. 2 is described in detail in Patent 2,105,173, Walter J. Zenner et al., January 11, 1938, and Patent 2,337,496, W. T. Rea, December 21, 1943. The descriptions of these patents are incorporated herein by reference as though fully set forth herein. Receiving relay 81 in the regenerative repeater will be in the marking condition. The transmitting element 101 of the regenerator unit will be in such position that contact 104 is closed.

Plug 132 will be withdrawn as indicated from jack 131. Under this condition a circuit may be traced from battery through the winding of relay 92, contact 73, contact 70 and contact 133 to ground energizing relay 92. The armatures of relay 92 will be actuated to close contacts 94 and 95. With contacts 94 and 95 closed, power is supplied from power source 93 to motor 96 so that the driving shaft associated with the regenerative repeater mechanism is turning continuously. A stop arm, not shown, engages a shoulder on cam 99 and prevents the driven shaft of the regenerator from rotating through friction clutch 97. The filament of vacuum tube 123 is heated over a circuit which may be traced from ground through battery 116, resistance 117, resistance 124, filament of tube 123 and resistance 122 to ground. Condenser 120 is charged to the potential of battery 116 over a circuit from ground through positive battery 116, resistance 117, resistance 119 and variable resistance 118 to the left-hand terminal of condenser 120, the right-hand terminal of which is connected through resistance 121 to ground. The grid of tube 123 is connected through resistance 140 to the junction between the left-hand terminal of condenser 120, left-hand terminal of variable resistance 118 and spacing contact 115 of relay 113 which at this time is open. Current normally flows through vacuum tube 123 over a circuit which may be traced from ground through resistance 122, filament of tube 123, plate of tube 123, winding of relay 125 and resistance 117 to grounded positive battery. For this condition the armature of relay 125 is actuated to the left to engage its contact 126.

With the various relays in the assumed condition, a circuit may be traced from positive battery 13, through resistance 14, marking contact 11 of transmitting relay 4, through inductance coil 30 and resistance 31 in parallel to the apex of relay 2 where parallel branches are formed. One branch extends through the top winding of relay 2, top winding of relay 1, resistance 21 and variable resistance 19, which connects either to a line repeater and through the line repeater to a multiway regenerative repeater concentration group, such as that per Figs. 1 and 2 at a distant city as indicated in Fig. 3, or the variable resistance 19 may be connected to a subscriber loop circuit. In either case the connecting circuit is terminated in negative and positive battery of

the same magnitude as batteries 13 and 15. Negative battery will be connected at the distant end for marking and positive battery at the distant end for the transmission of a spacing signal from the distant end.

From the apex of relay 2, the lower branch of the circuit extends through the bottom winding of relay 2, bottom winding of relay 1 and resistance 23 to ground. The bottom winding of relay 2 is shunted by resistance 25. The bottom winding of relay 1 is shunted by resistance 24. From the right-hand terminal of resistance 14 a branch extends through resistance 144, and resistance 142 which is shunted by condenser 143 to the top terminal of resistance 23. These resistances and their connected battery constitute a potentiometer network which controls the magnitude of the currents flowing in the bottom winding of relays 1 and 2 which varies one from the other for different conditions to be explained hereinafter. The effect of the current flowing in the top winding of relays 1 and 2 for this condition tends to operate the armatures of relays 1 and 2 toward the left to engage with their respective marking contacts 5 and 7, while the effect of the current flowing in the bottom windings of relays 1 and 2 tends to actuate the armatures of these relays toward their respective right-hand contacts 6 and 8. For the marking condition the effect of the current flowing through the upper windings of relays 1 and 2 is dominant over the effect of the current flowing in the bottom windings of relays 1 and 2 and the armatures of relays 1 and 2 are maintained in engagement with their respective marking contacts 5 and 7.

Since contact 8 is open and ground from the armature of relay 26 is therefore not connected to contact 8 and since the same condition prevails at contacts 208 and 308 there is no ground connected through conductors 45, 50 or 55 to receiving hub 62. From hub 62 a circuit may be traced through contact 65, contact 68, top winding of relay 81, resistance 87, resistance 85, which is shunted by condenser 86, and negative battery 84 to ground. For this condition therefore the top winding of relay 81 is not energized. A circuit may be traced from grounded negative battery 84, through resistance 88 and the bottom winding of relay 81 to ground. The effect of current flowing in its bottom winding maintains the armature of relay 81 in engagement with its marking contact 82. For this condition a circuit may be traced from grounded battery 89, through resistance 90, armature and contact 82 of relay 81 and the winding of the regenerative receiving magnet 91 to ground, energizing magnet 91. When the magnet 91 is energized while awaiting the reception of a train of signal elements, the driven shaft of the regenerative repeater mechanism is prevented from rotating in the manner explained in the foregoing. Sending contact 104 of the regenerative repeater is closed for this condition and a circuit may be traced from grounded negative battery 105, through resistance 106 which is shunted by condenser 108, resistance 107, contact 104, conductor 109, contact 67, contact 64 to sending hub 61, where parallel branches are formed. In the case of directional repeater No. 1, branch 42 extends through the top winding of relay 4, resistance 41 and resistance 39 shunted by condenser 40 to contact 10 of relay 3, which is open since as explained heretofore, the armature of relay 3 is in engagement with its spacing contact 9. In the case of directional repeater No. 2 the parallel

branch extends through conductor 47, top winding of relay 204, resistance 241, resistance 239, which is shunted by condenser 240, contact 210, which is closed, and the armature of relay 203 to negative battery 229. In the case of directional repeater No. 3 the parallel branch extends through conductor 52, top winding of relay 304, resistance 341, resistance 339, which is shunted by condenser 340, contact 310, which closed, and the armature of relay 303 to negative battery 329. No current therefore flows in the top windings of any of the sending relays in directional repeaters No. 1, 2 or 3. The armatures of each of these relays is maintained in engagement with its respective marking contact due to the effect of current flowing through its bottom winding in each instance. In the case of relay 4 the circuit may be traced from ground through resistance 38 to parallel branches. One branch extends through resistance 37 and negative battery 36 to ground. The other branch extends through the bottom winding of relay 4, resistance 18 and negative battery 17 to ground. The corresponding circuit for relay 204 may be traced from ground through resistance 238 to parallel branches. One branch extends through resistance 237 to negative battery 236. The other branch extends through the bottom winding of relay 204 and resistance 218 to negative battery 217. In the case of relay 304 the circuit extends from ground through resistance 338 to parallel branches. One branch extends through resistance 337 to negative battery 336. The other extends through the bottom winding of relay 304, resistance 318 and negative battery 317 to ground.

A circuit may be traced from negative battery 29 through the armature spacing contact 9 and bottom winding of relay 3, resistance 32, which is shunted by condenser 33, and conductor 44 to holding hub 58 which extends through the holding hub resistance 57 to ground. The current flowing through the bottom winding of relay 3 may, for instance, be .025 ampere for this condition and its effect is tending to actuate the armature of relay 3 towards its spacing contact 9. With the armature of relay 2 in engagement with contact 7 this effect is opposed by the effect of current in the upper winding of relay 3 which is tending to actuate the armature of relay 3 towards its marking contact 10. The magnitude of the current in the upper winding may, for instance, be .020 ampere and the armature of relay 3 will be maintained, as has been mentioned, in engagement with its spacing contact No. 9. The circuit which controls the flow of current through the upper winding of relay 3 is in the form of a double potentiometer. The circuit may be traced from negative battery 29 to the junction between resistances 26 and 28. From this junction one branch of the circuit extends through resistance 28 to the junction of second parallel branches. One second branch extends through resistance 27 to ground. The other second branch extends through the top winding of relay 3 to the lower terminal of resistance 26, from which point the circuit extends to marking contact 7 of receiving relay 2. When the armature of receiving relay 2 is in engagement with its marking contact 7 the circuit is extended through the armature of relay 2 to ground. The magnitudes of the resistances and of the battery forming the potentiometer have been so chosen that the direction of the flow of current through the top winding of relay 3 is reversed as the armature of relay 2 engages with and disengages from contact 7. This re-

versal is almost instantaneous because it is effected simply by the engagement and separation of the armature of relay 2 with and from contact 7. In the case of relays 203 and 303, since their respective armatures are not in engagement with their respective spacing contacts 209 and 309, no current is flowing through the bottom windings of these relays. The potentiometer circuit connected to the top windings of relays 203 and 303 is identical in its arrangement with that connected to the top winding of relay 3. The effect of the current flowing through the top windings of relays 203 and 303 is in each instance in a direction to maintain the armatures of these relays in engagement with their respective marking contacts 210 and 310.

Transmission toward the regenerator

It will now be assumed that the line associated with directional repeater No. 2 starts to send toward the regenerator. It will be assumed that the signals which are received are the well-known trains of start-stop permutation code signals comprising a start element which is always a spacing signal element, five permutation code character forming elements which may be marking or spacing signal elements in any combination depending upon the particular character and a stop element which is always a marking signal element.

The first signal element which is received is a spacing signal element and will interrupt the flow of current in the upper windings of relays 201 and 202 and thereby cause these relays to operate to their respective spacing contacts 206 and 208 under the influence of current in their lower windings. Closure of contact 298 connects ground through conductor 50 to receiving hub 62 from which point the circuit has been traced through the top winding of relay 81. As a result of this, the armature of relay 81 will be actuated to engage its open spacing contact 83. This in turn will deenergize regenerator receive magnet 91 which will remove the stop arm (not shown) from engagement with a raised surface on the periphery of cam 99 and permit cams 98 and 99 to rotate through one complete revolution during which interval, in addition to the start pulse, the five character forming elements and the stop signal element of which each signal train is constituted will be received in sequence from directional repeater 2. The armatures of relays 201 and 202 operate in unison while relay 204 remains in the marking condition. The instant that the armature of relay 202 breaks from its marking contact 207 and before the armature of relay 202 has completed its travel to engage its spacing contact 208, the direction of the flow of current in the top winding of relay 203 will be reversed and the armature of relay 203 will be actuated to engage with its spacing contact 209. When the armature of relay 203 engages with its spacing 209 a circuit may be traced from negative battery 229, through the armature spacing contact 209 and bottom winding of relay 203, resistance 232 which is shunted by condenser 233, conductor 49, holding hub 58 and through hub resistance 57 to ground. Since the armature of relay 3 is still in engagement with its spacing contact 9, since it is assumed that the external channel connected to directional repeater 1 was the last to transmit toward the regenerator, there are two parallel branches, namely, the branches connected to conductors 44 and 49, connected to holding hub resistance 57. The magnitude of

the current flowing in the bottom winding of relay 3 and in the bottom winding of relay 203 may be, for instance, approximately .015 ampere for this condition. This current will be insufficient to maintain the armature of relay 3 in engagement with its spacing contact for this condition since, as explained in the foregoing, it is opposed by a current of approximately .020 ampere in the top winding of relay 3 which is tending to actuate the armature of relay 3 toward its marking contact 10. The armature of relay 3 will therefore be actuated to close its marking contact 10. In the case of relay 203 the effect of the current in both its top and bottom windings at this time is tending to maintain the armature of relay 203 in engagement with its spacing contact and the armature of relay 203 will remain in engagement with its spacing contact. The instant that the armature of relay 3 disengages from its spacing contact 9 one of the parallel branches connected to holding hub resistance 57, namely, the branch through conductor 44 in directional repeater No. 1, will be disconnected and the current through the bottom winding of relay 203 will rise to its full value of .025 ampere in a spacing direction and this will be sufficient to hold the armature of relay 203 in engagement with its spacing contact 299 after the current in its upper winding has been reversed to .020 ampere in a marking direction by reception of marking pulses from the line repeater associated with repeater No. 2 during communication and the consequent closing of contact 207.

From the foregoing it will be apparent that only one of the holding relays, 3, 203, or 303 in the various directional repeaters can be locked in the spacing condition by current flow through its bottom winding to the holding hub resistance 57 at any one time.

It is very important that a holding relay such as 3, 203 or 303, which has been previously locked to its spacing contact while it has been receiving communication from its external channel or during the waiting interval thereafter, be very quickly released, when a second channel starts to transmit and the corresponding holding relay in the second channel is operated to its spacing contact by current in its upper winding, in order to arrange the circuit of the holding relay which has been formerly locked to spacing so that the directional repeater with which it is associated is in a condition to transmit, before the first regenerated signal element from the newly transmitting channel is received from the regenerative repeater. Mention was made of the double potentiometer arrangement connected to the top winding of each of the holding relays 3, 203 and 303 and of the fact that current through the top winding of these relays was reversed instantly upon the engagement or disengagement of the corresponding receiving relay 2, 202, or 302 with or from its respective marking contact 7, 207 or 207. It is the function of the condenser such as 33, 233 or 333, shunting resistance 32, 232 or 332 to speed up the release of a relay which has been locked in the spacing condition. The effect of the connection of the condenser in each of these circuits is to produce an instantaneous surge of current in the marking direction of a magnitude sufficient to release the held relay, such as relay 3 in the directional repeater which last transmitted toward the regenerator.

It has been assumed that the directional repeater No. 1 was the last to receive from its ex-

ternal channel and that the armature of its relay 3 is in the spacing condition when a signal is first received by directional repeater 2. If the start pulse had been received from the circuit associated with directional repeater No. 3, relay 3 of directional repeater No. 1 would have been operated to marking when relay 303 of directional repeater 3 was operated toward spacing in the manner described for directional repeater No. 2. The start pulse in this case would have been transmitted over conductor 55 and into the regenerative repeater through hub 62. If the start pulse had been received from the line repeater associated with directional repeater No. 1 the holding relay 3 of directional repeater 1 would have remained in the spacing condition and receiving relay 2 would have transmitted the start pulse through hub 62 to the regenerative repeater. The holding relay such as 3, 203 or 303 in any directional repeater is therefore operated to spacing only when its directional repeater starts to send toward the regenerator and the holding relay remains locked in the spacing position as long as transmission continues to be received from the line associated with this particular regenerative repeater, and, after transmission in this particular direction ceases, the armature of the holding relay will remain in the spacing condition until it is released by the operation of a holding relay in another directional repeater which starts to send toward the regenerator.

The directional repeater which is sending toward the regenerator will continue to transmit through hub 62 on an inverse neutral basis connecting ground to the hub through its respective receiving relay for spacing and removing ground from the hub for the marking condition.

Reception from the regenerator

The initial start pulse transmitted toward the regenerator by the receiving relay 202 of directional repeater No. 2 as described in the foregoing will be regenerated and after a momentary delay will be repeated by the regenerator to sending hub 61. The regenerator grounds sending hub 61 in repeating the start pulses by positioning the right-hand end of transmitting lever 101 in its lower position in response to the deenergization of magnet 91, which closes contact 103 connecting ground through contacts 67 and 64 to hub 61. Current flows from ground on hub 61 through the top windings of all transmitting relays such as 4 and 304 to negative 48-volt battery such as 29 and 329 except through transmitting relay 204 associated with directional repeater No. 2 which is transmitting toward the regenerator. Current is prevented from flowing through the top winding of relay 204 because the associated holding relay 203 is in the spacing condition and there is no closed path therefore through the top winding of relay 204, contact 210 and the armature of holding relay 203 to negative 48-volt battery 229. Transmitting relay 204 of directional repeater No. 2 thus remains in the marking condition under the influence of current in its lower winding. The transmitting relays of all other directional repeaters are operated to the spacing condition by the effect of current in their upper windings because the path through the armature of each of the holding relays such as 3 and 303 is closed through to negative battery such as 29 and 329 in each instance. The start pulse will therefore be repeated to all line and loop facilities which are associated with directional repeaters other than directional repeater No. 2 which is sending

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toward the regenerator. This is known as the duplex feature. Marking and spacing signal elements will follow in accordance with the permutation code combination of the particular character which is being received from the channel connected to directional repeater 2, and the signal elements will be regenerated in the regenerator as cams 98 and 99 continue in their first rotation. Finally a stop pulse which is a marking pulse will stop the rotation of cams 98 and 99 by again interposing the stop arm in the path of a raised surface of cam 99. Then the cycle will be repeated for the next character.

When the direction of transmission changes the holding relay of directional repeater No. 2 which has been transmitting toward the regenerator is operated to the marking condition and the holding relay of the directional repeater which is beginning to transmit toward the regenerator is locked in the spacing condition before the start pulse is retransmitted by the regenerator.

Break feature

First the manner in which the multiway regenerative repeater functions for the transmission of a break signal when the double-space by-pass circuit is disconnected will be described. Let it be assumed that contacts 76 and 77 are opened disconnecting the double-space by-pass circuit.

While directional repeater No. 2 is transmitting toward the regenerator let it be assumed that the line associated with directional repeater No. 1 tries to break by sending a spacing pulse of several seconds duration by connecting positive battery to the channel incoming to directional repeater No. 1. If the spacing pulse is received when the transmitting relay 4 of directional repeater No. 1 is in the spacing condition receiving relay 2 of directional repeater 1 will remain in the marking condition because the magnitude of the holding current in the lower winding of relay 2 exceeds the magnitude of the spacing current in the upper winding of relay 2. It is important to observe that with this arrangement, that is with the double-space by-pass circuit disconnected, a break signal is not effective while a spacing signal is being transmitted against it.

As soon as the transmitting relay 4 operates to marking, however, in response to the next marking signal element from the regenerator, the current in the lower winding of relay 2 reverses to the spacing direction and since there is now no current in the upper winding of relay 2, relay 2 operates to the spacing condition followed by its associated holding relay 3. Operation of holding relay 3 to the spacing condition will serve to prevent reoperation of transmitting relay 4 to the spacing condition and thus insure passage of the break signal by removal of negative 48-volt battery from the operating circuit of relay 4 at open contact 10. This will also cause the holding relay 203 of directional repeater No. 2 to operate to its marking condition in the manner described in the foregoing. Operation of receiving relay 2 of directional repeater No. 1 to the spacing condition connects ground through conductor 45 to receiving hub 62 and transmits the break signal to the regenerator. After a momentary delay the break signal is repeated by the regenerator which connects ground to sending hub 61 and causes the transmitting relays 204 and 304 of directional repeaters Nos. 2 and 3, respectively, to operate to the spacing condition and repeat the break signal to their

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associated lines and loops. In case two directional repeaters receive steady spacing or breaking signals from their associated lines simultaneously the directional repeater which continues to receive a spacing signal after the other directional repeater has changed back to marking will gain control of the network, since its holding relay will be in the spacing condition.

DOUBLE-SPACE BY-PASS CIRCUIT

General

As mentioned above the double-space by-pass circuit is shown at the lower right of Fig. 2. It is connected to double-space receiving hub 59 and double-space sending hub 60 by way of hub jack 75 and by-pass jack 76 which permit substitution of one double-space by-pass circuit for another by patching. The by-pass circuit provides a form of break feature since its purpose is to notify all interconnected teletypewriter stations and particularly a sending teletypewriter station that more than one teletypewriter station on the same half-duplex network is sending simultaneously. The by-pass circuit need not always be provided and without it the multiway regenerative repeater network is capable of breaking in the normal manner described in the foregoing. The by-pass circuit is particularly useful when a number of multiway regenerative repeater arrangements are included in a large multistation teletypewriter half-duplex network. It includes a timing circuit which protracts the spacing signal for an extended interval when two are received substantially simultaneously to insure its propagation to the most remote station connected to the most remote group in the network. Further it makes it possible to receive a space through a directional repeater which at the instant is transmitting a space received from the regenerator. Thus no signals can be "lost." The effect of the operation of the double-space by-pass circuit is to continue to transmit long spacing signals while simultaneous transmission persists which mutilates the signals received by all stations interconnected through the network as an effective indication of the condition.

Operation

During normal transmission from a directional repeater to the regenerator the receiving break relay in the particular directional repeater which is transmitting toward the regenerator such as receiving break relay 4 in directional repeater No. 1 responds to the signals incoming from the line repeater or subscriber's loop. Each time the receiving break relay such as relay 4 operates to spacing it connects a high resistance ground such as grounded high resistance 22 through a conductor such as conductor 46 to the double-space by-pass receiving hub 59. From hub 59 the circuit extends through contact 77 of jack 75 and contact 80 of jack 76, top winding of relays 110 and 113 in series and resistance 117 to positive battery 116. This causes spacing current which may, for instance, be approximately .012 ampere to flow through the upper windings of relays 110 and 113 in the double-space by-pass circuit. This will not operate relays 110 and 113 to spacing, however, since the marking current in the lower windings of these relays may, for instance, be approximately .017 ampere in value. If spacing signals are received simultaneously from the lines or loops associated with two directional repeaters, such as directional repeaters 1 and 2, the receiving break relays, such as relays 4 and 204, of both di-

rectional repeaters will be operated to spacing and both relays will connect high resistances, such as 22 and 222, in parallel between ground and hub 59. This will cause a spacing current which may, for instance, be approximately .024 ampere to flow in the upper windings of relays 110 and 113 of the by-pass circuit and this will cause relays 110 and 113 to operate to spacing. The operation of relay 110 to its spacing contact 112 will establish a circuit from ground through contact 112, contact 79 and contact 76 to the double-space by-pass sending hub 60. From hub 60 circuits extend through the bottom windings of each of the transmitting relays, such as relays 4, 204 and 304, of the various directional repeaters. In response to this each of the transmitting relays, such as 4, 204 and 304, will be reversed to spacing which will transmit a space or break signal out to all interconnected lines and loops.

In order to insure that the break signal reaches all of the stations on the network it is desirable that this spacing or break signal be transmitted for an appreciable period and since relays 110 and 113 will remain in the spacing condition only momentarily during the interval while both incoming space signals persist simultaneously the protraction of the spacing signal must be accomplished by special means. This is accomplished in the following manner.

When relay 113 closes its spacing contact 115 ground is connected to the left-hand plate of condenser 120 in the by-pass circuit which causes condenser 120 to be discharged. This reduces the grid potential of tube 123 sufficiently to stop the flow of plate current in tube 123 which plate current normally flows through the winding of relay 125 to positive 130-volt battery 116. Relay 125 therefore operates under the influence of its mechanical bias spring so as to close contact 127. This establishes a circuit from ground through contact 127, contact 79 and contact 76 to hub 60, supplementing the ground that initially was connected to hub 60 through contact 112 of relay 110. When relays 110 and 113 return to the marking condition at the end of the "double-space" interval relay 110 removes ground from hub 60 and relay 113 removes ground from the left-hand plate of condenser 120 which begins to charge over a circuit which has heretofore been traced.

After a predetermined interval of delay, which can be adjusted between the limits of 50 and 500 milliseconds by means of variable resistance 118, the left-hand plate of condenser 120 and the grid of tube 123 reach a potential sufficiently high to cause the normal plate current to be reestablished in tube 123. At this moment relay 125 opens contact 127 and closes contact 126 removing ground from hub 60 and thereby restoring the current in the lower winding of the transmitting relays, such as 4, 204 and 304, of all directional repeaters to the marking direction. If all lines and loops are in the marking condition toward their respective directional repeaters the armatures of all transmitting relays such as relays 4, 204 and 304 will be operated to close their marking contacts. However, if one line or loop is still in the spacing condition all transmitting relays will remain in the spacing condition except that of the directional repeater which is transmitting a spacing signal toward the regenerator which transmitting relay will be in the marking condition. The length of time which the spacing or break pulse should be transmitted should be slightly longer than the

propagation time of a signal to the most remote station on the network.

Full-duplex loop feature

The directional repeater is so designed that when its transmitting relay such as relay 4 is in the spacing condition, reception of a spacing signal from a line repeater to which it is connected will cause its associated receiving break relay such as relay 1 to operate to the spacing condition. This enables the receiving break relay of the directional repeater to respond to spacing signals from the line repeater regardless of the position of the sending relay such as relay 4 of the directional repeater. This is achieved by means of the potentiometer circuit connected to the bottom windings of the receiving and receiving break relays in each directional repeater. Without this feature a spacing signal from a line repeater on reaching a directional repeater, the sending relay of which happened to be in the spacing condition, would fail to operate the receiving break relay to spacing. Thus, unless two spacing signals arrived almost simultaneously from the two lines involved, one would lock the other out. The double-space by-pass circuit would not respond in the manner desired without this feature which is called the full-duplex loop feature.

When a space signal from a line repeater is received by a directional repeater the sending relay of which is in the spacing condition, the receiving break relay operates to spacing due to a spacing current which may, for instance, be approximately .0585 ampere in its upper winding, which opposes a marking current which may, for instance, be approximately .0465 ampere in its lower winding. Under such condition the associated receiving relay remains on marking due to a marking current which may, for instance, be approximately .070 ampere in its lower winding which opposes a spacing current, which may, for instance, be approximately .0585 ampere in its upper winding. It should be noted, however, that the receiving break relay and the receiving relay in a directional repeater both remain in the marking condition when the associated transmitting relay is transmitting a spacing signal and a spacing signal is received from a subscriber loop instead of from a line repeater. The break signal received from a subscriber loop opens the path through the top winding of the receiving and receiving break relays, such as relays 1 and 2 so that, if it is received while transmitting relay 4 is on spacing, the armature of both relays 1 and 2 will be maintained on their respective marking contacts under the influence of the current in their bottom windings which will be in a marking direction for this condition.

"Goodnight" feature

When it is desirable to temporarily remove a multiway regenerative repeater arrangement from service either for the periodic "goodnight" or for more or less extended intervals it may be done by inserting plug 132, which has its tip conductor connected to its sleeve conductor, in jack 131, at the test board. This opens the path which was formerly traced through the winding of relay 92, opening contacts 94 and 95 and disconnecting the power source 93 from motor 96. The insertion of plug 132 in jack 131 establishes a circuit from ground 134 through the sleeve of jack 131, sleeve of plug 132, tip of plug 132, tip of jack 131 and hub 60 to the transmitting 75 branches which extend into each directional re-

peater such as branches 42, 47 and 52. This operates each of the transmitting relays, such as relays 4, 264 and 304, to the spacing condition. The transmitting relays are maintained in this condition as a "goodnight" signal which is transmitted to all of the interconnected lines and loops in the network.

Substitution of a regenerative repeater

A spare regenerative repeater may be substituted for the regularly assigned unit in the following manner.

One end of a two-conductor tip sleeve patching cord is connected to the regenerator jack 66 in Fig. 2 of an idle unit. This disconnects the regenerative repeater regularly assigned to the idle unit by opening contacts 67 and 68. The opposite end of the tip sleeve patching cord may be connected to jack 63 of the Fig. 2 in which the substitution is to be made. This disconnects the regularly assigned regenerative repeater by opening contacts 64 and 65 and connects the idle unit through the tip sleeve conductors of the jacks and the patching cord.

A similar patch is made from motor control jack 72 associated with the idle unit to hub B jack 69 of the assigned unit to provide "good-night" control.

Double-space by-pass circuit substitution

A double-space by-pass circuit may be substituted for the regularly assigned by-pass circuit in the following manner.

One end of a two-conductor tip sleeve patching cord is connected to a jack such as jack 78 of an idle double-space by-pass unit. This disconnects the idle double-space by-pass unit from the concentration group to which it is regularly assigned by opening the contacts corresponding to 79 and 80. The opposite end of the patching cord is connected to the double-space by-pass hub jack 75 in the concentration group in which the substitution is to be made. This disconnects the regularly assigned double-space by-pass circuit from its concentration group by opening contacts 76 and 77 and connects the idle double-space by-pass circuit through the tip sleeve patching cord and the tip and sleeve of jack 75 to the sending and receiving double-space by-pass hubs 59 and 60 respectively.

What is claimed is:

1. A half-duplex multiway regenerative telegraph repeater system comprising more than two individual telegraph repeaters interconnected through hubs to a single one-way regenerative repeater unit, said system including means whereby but one of said individual repeaters may effectively transmit through said regenerative repeater to all of the others of said individual repeaters simultaneously through said hubs at any one time, and means in said system for effectively indicating, at remote stations connected to said multiway repeaters, a condition whereunder more than one of said individual repeaters attempt to transmit at any one time to said other individual repeaters, said latter means comprising instrumentalities for transmitting signals of protracted duration, substantially longer than the duration of normal signals, so as to insure reception at said remote stations.

2. A half-duplex multiway regenerative telegraph repeater comprising more than two individual telegraph repeaters connected through a sending and receiving hub to a single one-way

regenerative telegraph repeater, means for transmitting telegraph signals, received from any telegraph channel connected to any one of said individual telegraph repeaters, through said receiving hub to said regenerative repeater at a first time, means responsive to the reception of said signals from said individual repeater by said regenerative repeater for transmitting regenerated telegraph signals from said regenerative repeater through said sending hub, through all of the others of said individual repeaters to telegraph channels connected to said other telegraph repeaters simultaneously and through said channels to remote stations, means connected to said individual repeaters for identifying a condition whereunder more than one of said individual repeaters attempt to transmit signals into said single regenerative repeater at said first time, and means for effectively indicating the attempted simultaneous transmission through said regenerative repeater to said remote stations, said latter means comprising instrumentalities for transmitting signals of protracted duration, substantially longer than the duration of normal signals, so as to insure reception at said remote stations.

3. A half-duplex multiway regenerative telegraph repeater comprising more than two individual telegraph repeaters connected through a single one-way regenerative repeater unit, means for transmitting telegraph signals from any one of said individual repeaters through said single regenerative repeater unit to all of the others of said individual repeaters simultaneously, means connected to said individual repeaters for identifying telegraph signals incoming from more than one of said individual repeaters simultaneously toward said regenerative repeater, and means connected to said individual repeaters responsive to the reception of said simultaneous signals by said individual repeaters for transmitting a characteristic protracted signal to effectively indicate the condition at remote stations connected to said multiway repeater, said protracted signal of substantially longer duration than a normal signal.

4. In a telegraph system, a half-duplex multiway regenerative repeater network comprising a plurality of half-duplex multiway regenerative repeater groups, each of said groups interconnected by a telegraph channel to another of said groups, at least three individual telegraph repeaters in each of said groups, each of said individual repeaters in a particular group interconnected together through an individual hub circuit for each of said groups to a single one-way regenerative repeater unit, means in said system responsive to the transmission of telegraph signals through any of said directional repeaters in a particular group into the corresponding regenerative repeater for transmitting regenerated telegraph signals through all other directional repeaters forming part of the same group simultaneously, means in said system for propagating said regenerated signals through said channels connected to said other directional repeaters to each other group forming part of said network, means including said regenerative repeaters in said other groups for again regenerating said signals as they are propagated through each of said other groups, a double-space by-pass circuit connected to a particular one of said groups, means connected to said by-pass circuit for simultaneously receiving two spacing signal elements generated in two groups of said network

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different from said particular one group and means connected to said by-pass circuit for imposing a protracted condition on said system in response to said simultaneous reception.

5. In a telegraph system, a first, second and third half-duplex multiway regenerative telegraph repeater group, each of said groups comprising at least three individual telegraph repeaters interconnected through an individual hub circuit to a single one-way regenerative telegraph repeater unit individual to each of said groups, a first telegraph channel interconnecting an individual repeater in said first group with a first individual repeater in said second group, a second telegraph channel interconnecting a second individual repeater in said second group with an individual repeater in said third group, means in said system responsive to a telegraph signal received by any of said individual repeaters in any of said groups for transmitting regenerated telegraph signals to all other individual repeaters in each of said groups, a double-space by-pass circuit connected to said second group, and means in said by-pass circuit for effectively passing through said second group a spacing signal generated in said third group while a spacing signal generated in said first group is passing through said second group.

6. In a telegraph system, a multiway regenerative repeater group, a double space by-pass circuit connected to said group, and means in said group responsive to the operation of said by-pass circuit for effectively transmitting a characteristic signal indicating the simultaneous reception of two spacing signals in said group.

7. A multiway direct current half-duplex regenerative repeater group comprising a first directional repeater, a second directional repeater, and a single one-way regenerative repeater unit interconnected through a hub circuit, means in said first directional repeater for receiving a spacing signal and impressing said spacing signal through said regenerative unit on said second directional repeater in a first direction, means in said second directional repeater for receiving a second spacing signal incoming to said second directional repeater from a second direction, while said first spacing signal persists, and means connected to said repeater group for propagating a characteristic signal indicating the simultaneous reception of a spacing signal by said first and said second repeaters.

8. A direct current half-duplex telegraph repeater, means in said repeater for transmitting a first spacing signal through said repeater in a first direction, a double-space by-pass circuit connected to said repeater, a transmitting device in said circuit, a time delay control connected

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to said device for controlling the transmitting of protracted signals from said device, means in said repeater for receiving a spacing signal incoming to said repeater from a second direction, while said first spacing signal persists, means interconnecting said repeater and said by-pass circuit for impressing said second spacing signal on said by-pass circuit, and means connected to said by-pass circuit for propagating a protracted signal from said transmitting device in response to said second spacing signal.

9. A direct current half-duplex telegraph repeater comprising a receiving relay, a receiving break relay and a sending relay, an armature, a marking contact and a spacing contact on said sending relay, a telegraph channel extending from said armature through a line winding on said receiving relay and a line winding on said receiving break relay in series, a biasing path extending from said armature through a biasing winding on said receiving relay and a biasing winding on said receiving break relay in series, a potentiometer connected to said biasing windings, means comprising said potentiometer for controlling said receiving relay and said receiving break relay so that said receiving break relay will respond to a spacing signal incoming to said repeater from said channel while said armature engages its spacing contact and while said receiving relay remains unresponsive to said signal.

10. A half-duplex repeater in accordance with claim 9 and a double-space by-pass circuit including a first and a second transmitting device and means connected to said devices for actuating said devices for intervals of substantially differing durations connected to said repeater for propagating said spacing signal incoming from said channel.

11. A half-duplex repeater in accordance with claim 9 and a double-space by-pass circuit comprising a timing device for protracting said spacing signal incoming from said channel.

12. A half-duplex multiway regenerative repeater, a double space by-pass circuit including signal element protracting means and means for flexibly interconnecting said repeater and said by-pass circuit.

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