Feb. 17, 1925. **1,526,550**

E. D. JOHNSON

TWO-WAY TRANSMISSION WITH REPEATERS

Filed Feb. 7, 1923 2 Sheets-Sheet 1

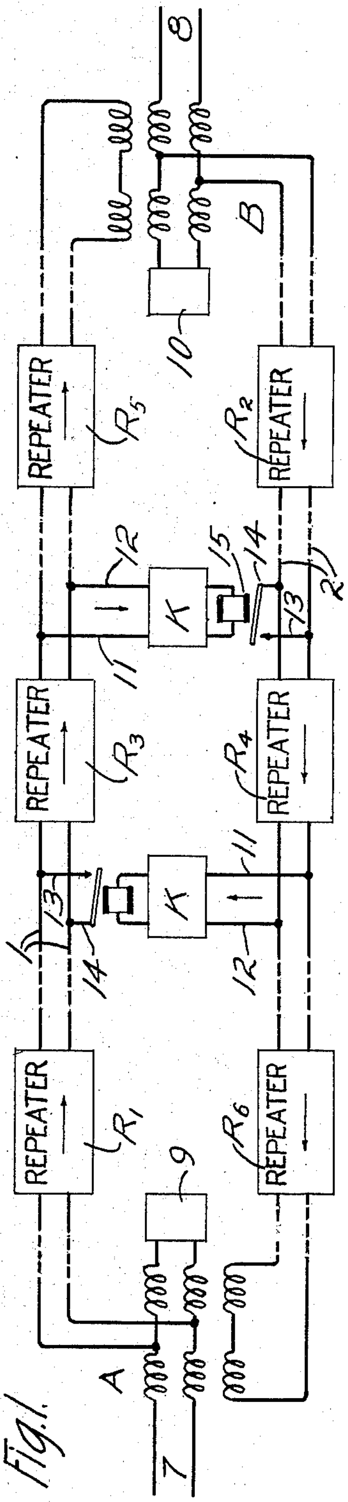

Fig. 1.

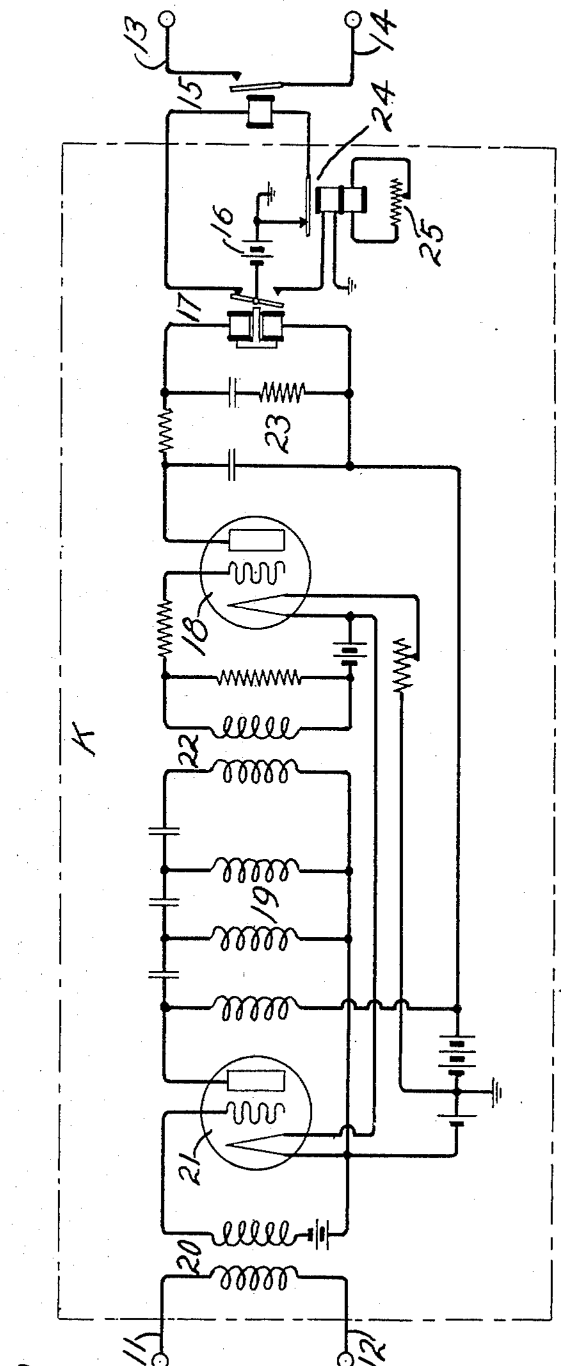

Fig. 2.

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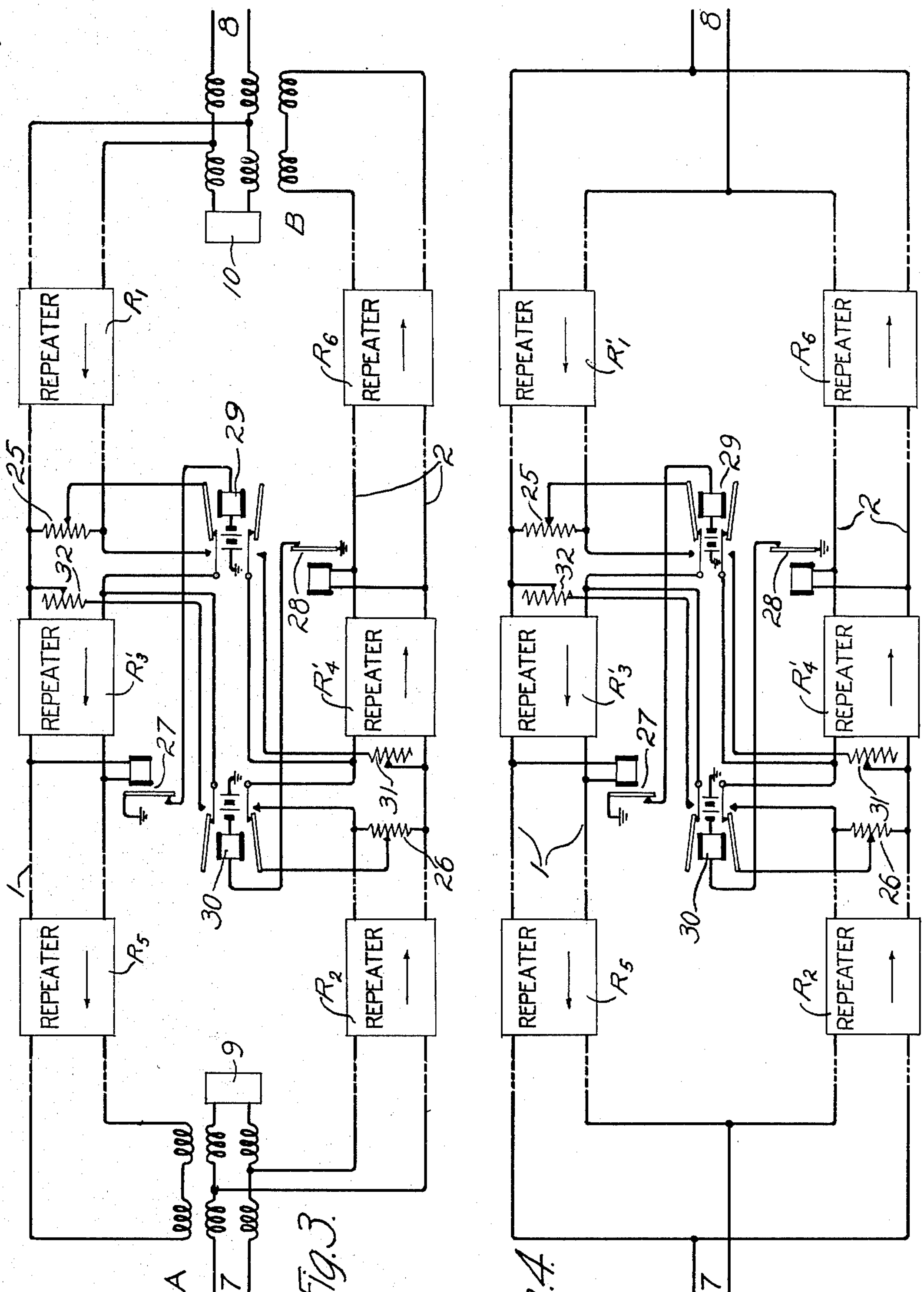

Fig. 3.

Fig. 4.

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Patented Feb. 17, 1925. **1,526,550**

UNITED STATES PATENT OFFICE.

EDGAR D. JOHNSON, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

TWO-WAY TRANSMISSION WITH REPEATERS.

Application filed February 7, 1923. Serial No. 617,512.

To all whom it may concern:

Be it known that I, EDGAR D. JOHNSON, a citizen of the United States, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Two-Way Transmissions with Repeaters, of which the following is a full, clear, concise, and exact description.

This invention relates to repeater circuits, and more particularly to telephone lines in which are employed one or more repeaters for carrying currents in one direction and one or more other repeaters for carrying currents in the opposite direction.

The object of the invention is to improve transmission in such circuits, and especially to reduce the transmission in a given direction of currents transmitted in the opposite direction, to thereby reduce "echo effects" in the system or prevent "singing" of the repeaters, or both, as explained hereinafter. The nature and effects of echo currents have been explained by A. B. Clark in his article on Telephone transmission over long cables, Journal of the American Institute of Electrical Engineers, Jan. 1923, page 1, and reference may be had to that article for a better understanding of the phenomena of echo effects.

In accordance with the invention two lines either with or without balancing networks are connected by a two-way repeater circuit having the amplification of the repeaters, when transmission is not taking place, adjusted to values too low to cause singing; and when normal transmission takes place through the repeating path in either direction a relay connected to that path and responsive to voice currents causes a decrease in the transmitting efficiency of the repeating path in the opposite direction (in the general fashion disclosed in Mills Patent No. 1,434,790, November 7, 1922, "two-way transmission with repeaters"), and may also cause an increase in the transmitting efficiency of the repeating path through which the desired transmission is to pass. Each voice relay is so connected to the repeating path with which it is associated, that when the transmitting efficiency of the path is decreased the relay is rendered ineffective to cause the transmitting efficiency of the other path to be decreased.

Fig. 1 of the drawing is a circuit diagram of a form of the invention as applied to a four-wire repeating system; Fig. 2 shows, somewhat in detail, voice relay operating circuits which in Fig. 1 are merely blocked in; and Figs. 3 and 4 show modifications of the circuit of Fig. 1, the circuit of Fig. 4 employing no networks for balancing the impedances of the lines between which the repeating paths are connected.

By a four-wire line or circuit is meant one in which the talking currents in one direction for the greater portion of the distance between two points geographically remote from each other are carried over a different pair of wires from the currents in the other direction, as distinguished from a two-wire circuit which is one in which the talking currents in both directions between two points are carried over the same pair of wires for the greater portion of the distance between those points.

The four-wire repeating system shown in Fig. 1 is of the general type disclosed in Campbell Patent No. 1,352,786, September 14, 1920, "four-wire transmission system," lines 1 and 2 being separate transmission lines forming a four-wire transmission circuit. Line 1 includes repeaters such as R_1, R_3, R_5, preferably of the electron discharge type, which amplify telephonic waves propagated from west to east, that is from left to right. Line 2 includes repeaters such as R_2, R_4, and R_6 for amplifying telephonic waves from right to left. Line 1 therefore transmits in one direction only, while line 2 transmits in the opposite direction only. At station A lines 1 and 2 are coupled to line 7, while at station B lines 1 and 2 are coupled to line 8. Lines 7 and 8 may terminate in central offices or in subscribers' stations. The arrangements whereby the four-wire system is coupled to the terminating lines 7 and 8 are three-winding transformers, well known to the art. A balancing network or artificial line designed to have an impedance approximating that of line 7 is indicated at 9, and a balancing network for line 8 is indicated at 10. The broken portions of lines 1 and 2 indicate portions of considerable length and may, of course, include repeaters.

Frequently, under conditions experienced in practice, a considerable degree of unbalance obtains between the lines 7 and 8 and their respective artificial lines, with the result that currents transmitted through the repeating path in one direction are transmitted back to the sending end through the oppositely directed repeating path, and then transmitted again through the first repeating path, etc., so that both at the sending end and at the receiving end there are heard sounds lagging slightly behind the original voice vibrations and resembling echoes. The greater the time lag of the primary echo, the more disturbing the echoes are likely to prove.

Further, whenever points of either normal or transient impedance unbalance or discontinuity occur in a circuit, electrical energy is reflected from these points, and where, in circuits of the type to which this invention relates, the time required for transmission is sufficiently great and the losses imposed upon the reflected transmission are sufficiently counteracted by the repeaters, the reflection currents may produce troublesome echo effects.

The permissible gain of the repeaters may be limited primarily by the disturbing effects of echo currents such as those referred to above, rather than by any singing of the repeaters. Therefore, even where balancing networks such as those indicated in Fig. 1 cause the transmission losses around the repeater paths to be greater than the gains of the repeaters it is desirable, particularly when the time required for propagation of energy over the line is considerable, to substantially prevent normal transmission passing through either repeater path from returning to the sending end through the oppositely directed repeater path. In Figs. 1 and 2, means are shown for accomplishing this desirable result in such manner as to insure that the permissible gain of the repeaters will be limited only by their tendency to sing.

These means comprise two circuits such as the one shown in detail in Fig. 2. Each of these two circuits terminates at one end in leads 11 and 12 and at the other end in leads 13 and 14, and for convenience will be called an echo suppressor. One of the echo suppressors, the right hand one in Fig. 1, has its leads 11 and 12 connected to line 1, preferably at the output side of repeater R_3, and the other echo suppressor, the left hand one in Fig. 1, has its leads 11 and 12 connected to line 2 preferably at the output side of repeater R_4, as indicated in Fig. 1. This left hand echo suppressor has its leads 13 and 14 connected to line 1, preferably substantially at or somewhat west of the juncture of line 1 with the leads 11 and 12 of the other echo suppressor, for example at the input side of repeater R_3 as shown, but by no means necessarily on the input side of the repeater. The right hand echo suppressor has its leads 13 and 14 connected to line 2, preferably substantially at, or somewhat east of the juncture of line 2 with the leads 11 and 12 of the left hand echo suppressor, for example at the input side of repeater R_4 as shown, but by no means necessarily on the input side of the repeater.

Each of the echo suppressors comprises a relay 15, which, when deenergized, closes its contact to connect leads 13 and 14 and thereby establish a short circuit across the line to which these leads are connected. The remaining parts of each echo suppressor are collectively designated K, as indicated by the block K in Fig. 2 and the two blocks K in Fig. 1. The block K includes a battery 16 which normally energizes relay 15, a voice relay 17 at the upper contact of which the circuit of relay 15 is normally closed, and a circuit for controlling relay 17 in response to voice currents impressed on leads 11 and 12 from line 1 or line 2.

Referring to this last mentioned circuit, leads 11 and 12 feed a three-electrode rectifier 18 through a high-pass filter 19 having a cut-off frequency of say 500 cycles per second, the filter being preferably connected to leads 11 and 12 by means of a transformer 20 and an amplifier 21 of one or more stages and to the electron tube rectifier by means of a transformer 22. The tube 18 in turn feeds the relay 17 through a low-pass filter 23 having approximately the same cut-off frequency as filter 19.

Were the relay 17 connected directly in the output circuit of the rectifier without filters 19 and 23, difficulty might be encountered owing to the fact that the currents of voice frequency would be amplified by the tube and the low frequency components particularly, or the components having frequencies in the neighborhood of the mechanical resonance frequency of the relay tongue, would tend to cause chattering of the relay during the periods when it should be held in the operating position by the rectified voice currents. It would be possible to exclude these amplified voice currents from the relay 17 by merely inserting between the output of tube 18 and the relay 17 a low-pass filter, for instance, of the general type shown in Fig. 7 of Campbell Patent No. 1,227,114, May 22, 1917, having a lower cut-off frequency than the filter 23. However, unless this cut-off point were made fairly low, the voice currents whose frequencies were below the cut-off might cause chattering. If the cut-off frequency were made low, the speed of operation of the relay would be reduced, since the time required for the propagation of the currents through a given number of filter sections varies inversely as the cut-off frequency. Increased speed of operation may be secured by using a low-pass filter with relatively high cut-off, say 400 or 500 cycles. In order to make it feasible to employ such a cut-off frequency in the low-pass filter without danger of chatter from the lower components of the voice currents, the high-pass filter 19 is used in the input circuit of the tube 18. When the high-pass filter is used, the only currents reaching the relay 17 are those resulting from the detection of the higher voice frequencies, and hence the relay will respond more exactly to the starting and stopping of the voice currents in leads 11 and 12. A still further advantage of this arrangement is that it prevents the relay from being operated by extraneous line currents of low frequency such as cross-ringing, Morse thump and power interference, which are likely to be greater in actual magnitude than the voice currents themselves.

The reason for employing the specific form of low-pass filter shown at 23 instead of the form shown in Fig. 7 of the Campbell Patent No. 1,227,114, referred to above, is that under severe conditions of variable voice volume, lack of damping in the low-pass filter may cause chattering of the relay due to free oscillation set up on sudden changes in amplitude. When a resistance-condenser filter such as that shown in Fig. 2 is employed, both satisfactory filtering and sufficient stability are attainable without necessitating the employing of inductance in the filter, and by the elimination of inductance the time required for the propagation of currents through the filter may be reduced.

Passing the voice energy through a high-pass filter before rectifying and through a low-pass filter of approximately the same cut-off after rectifying, is the invention of R. V. L. Hartley, and is claimed in his application Serial No. 602,273, filed November 20, 1922, entitled "Transmitting electrical energy," assigned to the assignee of this application.

For reasons made apparent hereinafter, it is desirable that the relay 15 be quick operating as regards closure, but in effect, slow operating as regards opening of its contact. To obtain the effect of the slow operation without sacrificing quickness of closure, the circuit of relay 15 is controlled by a slow-acting auxiliary relay 24, which in turn is controlled by the lower contact of relay 17. In addition to its operating winding, the relay 24 has a winding closed on itself through a resistance 25 which may be varied to adjust the time of release of the relay 24. When relay 17 opens its upper contact, relay 15 quickly places a short circuit across line 1 or line 2 through leads 13 and 14, and when relay 17 closes its lower contact relay 24 opens in the circuit of relay 15 a gap in series with the gap which the relay 17 has made at its upper contact. Thereafter, when relay 17 opens its lower contact and closes its upper contact, the circuit of relay 15 will not be completed until relay 24 releases. Preferably, the echo suppressors are located at a repeater station approximately midway between lines 7 and 8, and in that case the relays 24 in the two echo suppressors may be adjusted to have the same time lag.

In the operation of the system of Fig. 1, when currents, such for instance as voice currents, come from line 7 and line 1 into the repeater station comprising the echo suppressors and are amplified by repeater 3, the echo suppressor which has its leads 11 and 12 connected to the output of that repeater causes a short circuit through the armature of relay 15 to be established across line 2 at the input side of repeater 4. This substantially prevents any portion of the talking current from flowing back through repeaters R_2, R_4, R_6, etc., from east to west due for instance to unbalance at station B or to reflection from station B, or from any point east thereof; for the time required for operation of relay 15 is less than that required for propagation of currents from the output of repeater R_3 through station B to the input of repeater R_4. Thus, echo currents flowing from station B to line 2 are not only prevented from circulating in the system, but are also prevented from reaching the echo suppressor which has its leads 11 and 12 connected to the output side of repeater R_4. Therefore, the input of repeater R_3 can not be short circuited due to echo currents in line 2, even if the echo currents flowing in line 2 between station B and repeater R_4 are of the magnitude of the currents required in leads 11 and 12 to operate the echo suppressor. Any repeater connected in line 2 between station A and repeater R_4 will prevent transmission of current from station A to repeater R_4 due to its unidirectional current transmitting property. The operation of the system in transmitting energy from east to west will not be described since it will be evident from the operation of the system in transmitting from line 7 to line 8 as just described.

With the system of Fig. 1 it is clear that if the echo suppressors be made sufficiently effective in reducing the deleterious effects of echo-currents, the permissible gain of the repeaters will no longer be limited by considerations of the magnitude of the echo currents while the system is in use (that is, while one or the other of the echo suppressors is in operation), but will rather be limited primarily by the requirement that for a satisfactory system the total transmission gains around the repeating paths should not exceed the total transmission losses around the repeating paths. In other words, the limit of the permissible repeater gains will be the singing point, and will be the singing point when the system is not in use (that is, when neither echo suppressor is in operation) rather than when the system is in use. It follows that, notwithstanding high repeater gains, if the repeating paths are long or the transmission losses around the repeating paths are large aside from the losses introduced at the three-winding transformers, satisfactory operation may be attained in many cases even though the degree of unbalance between the lines 7 and 8 and their balancing networks is large, or indeed even though the balancing networks are omitted as in a well known four-wire repeating system disclosed in Van Kesteren Patent No. 1,189,411, July 4, 1916.

The relay 24 makes possible rapidity of action in the rendering of an echo path inoperative in spite of the necessity for relatively slow action in the subsequent restoration of the path to operativeness, and is to insure that when a party starts talking, over a portion of the circuit which transmits away from him, a portion of the circuit which transmits toward him is rendered inoperative soon enough to prevent him from hearing any considerable amount of talk which the other party may have started before hearing the first party but after the first party started to talk. Thus, there is prevented any confusion which might otherwise arise in case a party started to talk before hearing the distant party but after the distant party had started to talk. Moreover, confusion under such circumstances is avoided and yet, even after a cessation in normal transmission, circulation of echo currents due to that transmission is prevented.

If the repeater station at which the echo suppressors are located is not midway between the lines 7 and 8, the relays 24 in the two echo suppressors should be adjusted to different time lags since, in each echo suppressor, the time elapsing between the operation of relay 17 and the consequent opening of relay 15 should not be less than the time required for propagation of currents from the repeater station at which the echo suppressor is located to a terminating set of the four-wire circuit and back to the leads 13 and 14 of the echo suppressor. If the time elapsing is too great, the ability of the listener to break in on the talker may be unduly limited.

By connecting leads 11 and 12 of the echo suppressors to the outputs of the repeaters, the echo suppressors receive more voice current energy than they would receive were the leads 11 and 12 connected to the repeater inputs.

Although, as noted above, in the system shown in Figs. 1 and 2 the limit of the permissible gain of the repeaters is the singing point when the system is not in use, such a system can have its repeaters set for gains just within a working margin of the singing point when the system is not in use and can be arranged so that when normal transmission passes through one or the other of the repeater paths the gain of the repeating means in that path is increased by an amount not greater than the transmission loss which the operative echo suppressor introduces in the oppositely directed path. As indicating how such a system may conveniently be arranged to thus increase the transmitting efficiency of the repeating path through which the desired transmission is to pass, Fig. 3 shows a system which may be considered a modification of the system of Fig. 1 in that a different form of echo suppressor is employed, and moreover, in that the system of Fig. 3 embodies means for causing the desired increase in the transmitting efficiency of the operative repeating path. This feature is of special utility in cases where good balance between the lines 7 and 8 and their balancing networks can only be attained with unwarranted expense, due for instance to impedance irregularities in the lines, and is also especially useful in cases in which it is desirable to omit the balancing networks.

In Fig. 3, lines 1, 2, 7 and 8, the balancing networks 9 and 10 and the repeaters R_1, R_5, R_2, and R_6 correspond to the lines, networks and repeaters so designated in Fig. 1; and repeaters R'_3 and R'_4 correspond to the repeaters R_3 and R_4 in Fig. 1 except that the potentiometers for the repeaters R'_3 and R'_4, are shown separate from the repeaters and are designated 25 and 26 respectively. A relay 27 responsive to voice currents to, in effect, open its contact, is connected to the output of repeater R'_3. This voice relay may be, for instance, of the vibrating type disclosed in S. G. Brown Patent No. 1,185,472, May 30, 1916.

A similar relay 28 is connected across the output of repeater R'_4. The voice relay 27 controls a direct current relay 29 and the voice relay 28 controls a direct current relay 30. The relay 29 controls the potentiometer 25 and an echo reducing and gain reducing shunt circuit across the input of repeater R'_4, the shunt circuit containing a variable resistance 31. Similarly the relay 30 controls the potentiometer 25 and an echo reducing and gain adjusting shunt circuit, containing a variable resistance 32, across the input of repeater R'_3. When no transmission is taking place in the system, the shunts comprising resistance 31 and 32 are open circuited and the potentiometers 25 and 26 are set at some point sufficiently below the maximum gain setting to prevent singing of the repeaters due to noise currents on the line.

In the operation of the system, assuming transmission, such as voice currents for instance, to approach repeater R'_3 over lines 8 and 1 and be amplified by the repeater R'_3, the voice relay 27 deenergizes relay 29, which thereupon connects the input of repeater R'_3 to receive the full voltage across potentiometer 25 and closes the shunt comprising resistance 31 across the input of repeater R'_4. The increase in the gain of repeater R'_3 due to the change of its potentiometer connection is made such as to not exceed the gain reduction imposed upon repeater R'_4 by the closing of the shunt circuit comprising resistance 31, and therefore the repeaters still will not sing, although the gain of repeater R'_3 has been increased to a value larger than was originally permissible. The resistance 31 is of course adjusted to a value sufficiently low to reduce the circulation of echo currents to the desired degree. Any repeater in line 2 between repeater R'_4 and station B will prevent transmission of current from station B to repeater R'_4 due to its unidirectional current transmitting property. The operation of the system in transmitting from line 7 to line 8 is similar to that in transmitting from line 8 to line 7, and needs no separate description.

In changing from the neutral condition of the circuit to the operating condition in either direction, or in changing from either operating condition to the neutral condition of the circuit, changes made on the repeater which is to have its gain reduced and the changes made on the other repeater should occur in such sequence as to always maintain the circuit in the non-singing condition.

It is noted that this type of circuit avoids circuit interruptions due to operation of relay contacts actually connected in the transmission circuit (such interruptions as would occur, for instance, if the gain decreases of the repeaters were accomplished by opening their input circuits), and that transmission in either direction over the circuit need never be entirely prevented although telephone currents will be attenuated more at one time than at another. If there are telephone currents passing over the circuit, at any time, of sufficient magnitude to be heard at the receiving station, no part of these currents will be lost due to switching operations in the repeater circuit. Moreover, no clicks due to changes of D. C. space current in the amplifiers are sent out on the lines as would be the case were the gain decreases of the repeaters produced by varying their filament currents or their D. C. plate voltages or their D. C. grid potentials.

It has been indicated above that in the system of Figs. 1 and 2, and also in the system of Fig. 3, the balancing networks 9 and 10 may be omitted, provided the transmission gains around the repeating paths are never greater than the transmission losses around these paths. As representing such a system minus the balancing networks, Fig. 4 shows a system which may be considered a modification of the system of Figs. 1 and 2 in that, as in Fig. 3, a different form of echo suppressor is employed and means is provided such that when normal transmission passes through one or the other of the repeater paths the gain of the repeating means in that path is increased, and moreover in that the networks 9 and 10 shown in Figs. 1 and 3 are omitted. Fig. 4 is like Fig. 3 except for the omission of these networks, and hence need not be further described.

The general principles herein disclosed may be embodied in many organizations widely different from those illustrated without departing from the spirit of the invention as defined in the appended claims.

Although the invention has been set forth with especial reference to its application to the repeating of voice frequency currents, it is of course also applicable to the transmission and repeating of currents of other frequencies, whether higher or lower, as for instance currents of the frequencies commonly used for radio and carrier currents.

The invention claimed is:

1. The method of operating a two-way repeating system including two two-wire circuits terminating at points geographically remote from each other and two oppositely directed repeatered paths joining said terminations, which comprises maintaining said paths operatively connected to transmit between said two-wire circuits in the absence of transmission through the system, and during transmission in the system, maintaining one of said paths at less than normal transmitting efficiency and the other path at a transmitting efficiency at least as great as normal, substantially regardless of the value of echo current entering said one path.

2. A two-way repeating system comprising two two-way wire circuits terminating at points geographically remote from each other and a four-wire repeating system joining said terminations, said four-wire system comprising two repeatered paths operatively connected to said two wire circuits, in the absence of transmisison, for repeating in opposite directions between said two-wire circuits, and two means, each responsive to transmission in only one direction over the system for substantially preventing the passage of current through either the other of said two means or the path in the other direction.

3. A two-way signalling system comprising paths adapted to transmit in opposite directions between two points, and a means connected to each path at a point remote from the ends of said path and responsive to transmission in the connected path for

rendering the other path and the other means inoperative.

4. A two-way signalling system comprising paths which include amplifying means and which are adapted to transmit in opposite directions, means tending to prevent circulating currents from one of said paths from flowing in the other of said paths, and two means, one associated with each of said paths and each responsive to transmission in the associated path for substantially preventing the passage of current through the other path and through the other of said two means.

5. A two-way signalling system comprising two two-wire circuits, paths operative to transmit in opposite directions between said circuits in the absence of transmission in said system, the net transmission loss around the loop comprising said paths being then greater than zero, a switch at a point in each of said paths for controlling the transmitting efficiency of the path, and a voice operated relay connected to each of said paths and adapted when energized by voice currents to control the switch in the other path, each of said relays being connected to its associated path at such a point, relative to the switch for that path, that when the switch for that path is operated by the other relay, current is substantially prevented from passing through the relay connected to that path.

6. A two-way signalling system comprising two two-wire circuits, paths operative to transmit in opposite directions between said circuits in the absence of transmission in said system, means tending to prevent circulating currents from each of said paths from flowing in the other path, a switch at a point in each of said paths for controlling the transmitting efficiency of the path, and a voice operated relay connected to each of said paths and adapted when energized by voice currents to control the switch in the other path, each of said relays being connected to its associated path at such a point, relative to the switch for that path, that when the switch for that path is operated by the other relay, current is substantially prevented from passing through the relay connected to that path.

7. In combination, two line sections, two unidirectional oppositely directed paths between said line sections, impedance elements substantially balancing the impedances of said line sections respectively, said unidirectional paths being so related to said line sections and to said balancing impedances that only a relatively small amount of current traversing one of said paths is fed back to the other of said paths, and a means associated with each path and operable by voice currents in that path for reducing the transmitting efficiency of the other of said paths and rendering the other means inoperable by said current fed back to said other path.

8. In a circuit having repeatered paths normally in condition to transmit signals in different directions, means tending to prevent circulating currents from each of said paths from flowing in the other of said paths and a means associated with each path and operable by signal currents in the other path for cutting off transmission through the associated path at such a point as to prevent operation of the corresponding means associated with the other path by said circulating currents.

9. A two-way signalling system comprising two two-wire circuits two paths which include amplifying means and are conditioned to transmit in opposite directions between said circuits in the absence of transmission in the system, the total transmission loss around the loop comprising said paths being greater than the total gain of said amplifying means, and means associated with each of said paths and responsive to transmission in the associated path for reducing the transmission efficiency of the other path and for preventing the other means from being operated.

10. A two-way signalling system comprising two line sections, two transmission paths connecting said line sections, said paths being normally conditioned to transmit in opposite directions, the net transmission loss around the loop comprising said paths being at least as great as zero, means operable by signalling currents in one of said paths for reducing the transmission efficiency of the other of said paths, and means operable by signalling currents in said other path to prevent the operation of said first mentioned means.

11. A two-way signalling system comprising two line sections, two transmission paths connecting said line sections, said paths being normally conditioned to transmit in opposite directions, amplifying apparatus in said paths, the total transmission loss around the loop comprising said paths being greater than the total gain of said amplifying apparatus, means operable by signalling currents in one direction over the system for reducing the transmission efficiency of the path in the other direction, and means operable by signalling currents in said other direction to prevent operation of said first mentioned means.

12. A two-way signalling system comprising two paths normally conditioned to transmit in opposite directions between two points, the net transmission loss around the loop comprising said paths being at least as great as zero, means operable by signalling currents in one direction for reducing the transmission efficiency of the path in the

other direction, and means operable by signalling currents in said other direction to prevent the operation of said first mentioned means.

13. A two-way signalling system comprising two line sections, two transmission paths connecting said line sections, said paths being normally conditioned to transmit in opposite directions, amplifying apparatus in said paths, the total transmission loss around the loop comprising said paths being greater than the total gain of said amplifying apparatus, means operable by voice currents in one of said paths for reducing the transmitting efficiency of the other of said paths, and means operable by voice currents in said other path to prevent operation of said first mentioned means.

14. A two-way signalling system comprising two line sections, two transmission paths connecting said line sections, said paths being normally conditioned to transmit in opposite directions, amplifying apparatus in said paths, the total transmission loss around the loop comprising said paths being greater than the total gain of said amplifying apparatus and being substantially equal to the sum of the transmission losses in the individual paths, means operable by voice currents in one of said paths for reducing the transmission efficiency of the other of said paths, and means operable by voice currents in said other path to prevent operation of said first mentioned means.

15. A two-way signalling system comprising paths which include amplifying means and which are adapted to transmit in opposite directions, apparatus tending to prevent circulating currents from one of said paths from flowing in the other of said paths, and two means, each responsive to transmission in only one direction over the system for substantially preventing the passage of current through either the other of said two means or the path in the other direction.

16. A two-way signalling system comprising two two-wire circuits, two paths operative to transmit in opposite directions between said circuits in the absence of transmission in said system, and means associated with said paths and responsive to a given transmission in said system for altering the tranmitting efficiency of each of said paths.

17. The method of operating a two-way repeater circuit including oppositely directed repeating paths operatively connected to transmit between two lines in the absence of transmission in the circuit, which comprises maintaining the transmission gains in said circuit at such valves in the absence of normal transmission in the circuit, that singing of the repeaters can not take place, and, whenever normal transmission in the circuit begins, increasing the transmission efficiency of the circuit in one direction.

18. The method of operating a two-way repeater system including two two-wire circuits and two oppositely directed repeatered paths connecting said two-wire circuits, which comprises maintaining the transmission gains in said paths sufficiently low to prevent singing of the repeaters in the absence of normal transmission in the system, and, whenever normal transmission in the system begins, increasing the transmitting efficiency of one of said paths and decreasing the transmitting efficiency of the other path sufficiently to prevent singing of the repeaters.

19. In a signalling system, a sending station, an outgoing path for signals, a return path for a portion of said outgoing path, said paths being so connected as to permit circulating currents in said return path, and signal responsive means for simultaneously increasing the transmitting efficiency of one of said paths and decreasing the transmitting efficiency of said other path.

In witness whereof, I hereunto subscribe my name this 30th day of January, A. D. 1923.

EDGAR D. JOHNSON.