Dec. 23, 1941. L. ESPENSCHIED ET AL 2,267,557

TWO-WAY REPEATING CIRCUIT

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FIG. 1

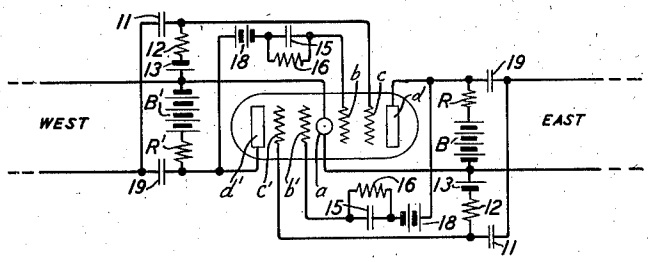

FIG. 2

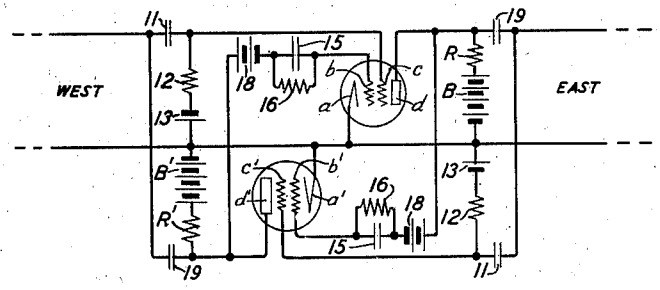

FIG. 3

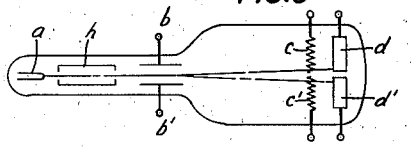

FIG. 4

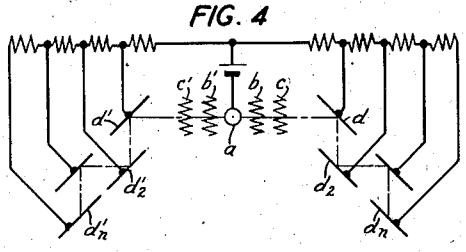

FIG. 5

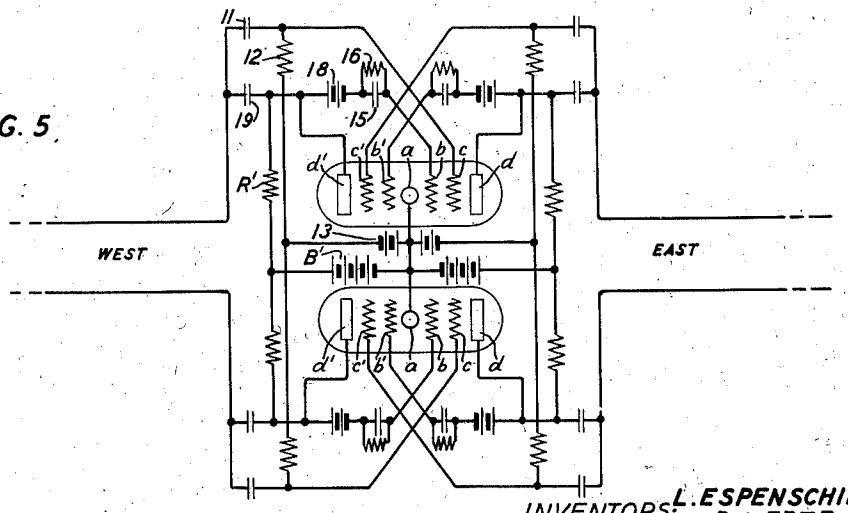

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FIG. 6

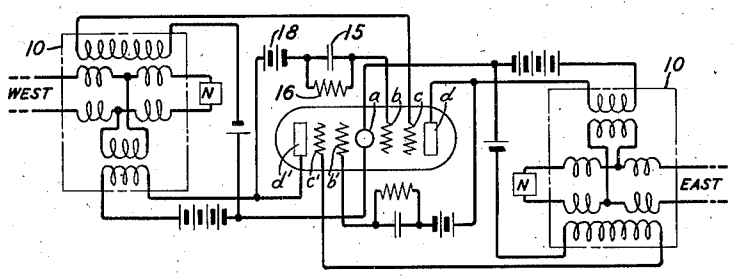


FIG. 7

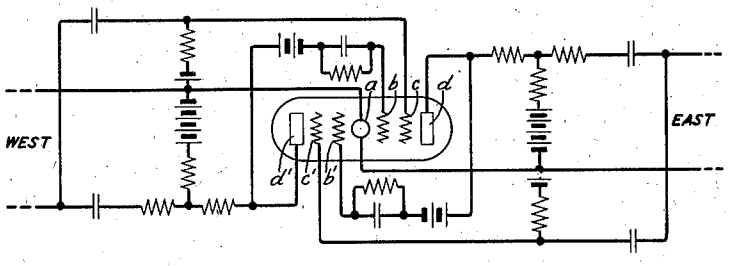


FIG. 8

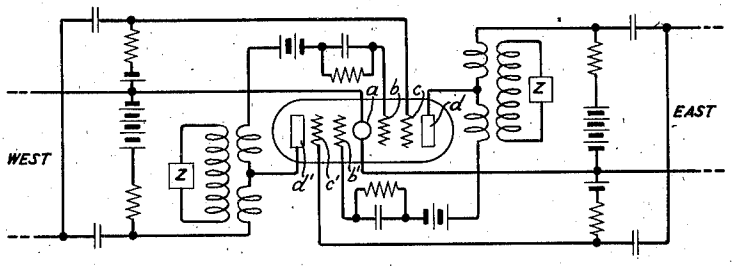
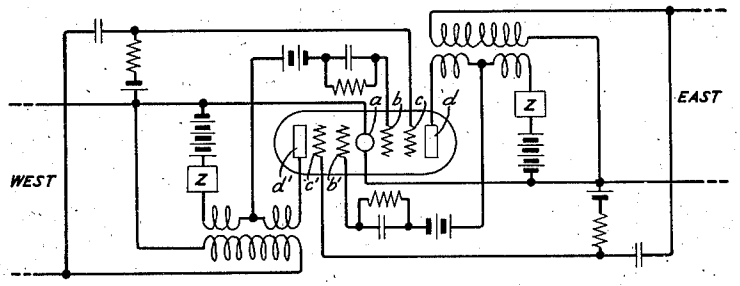


FIG. 9



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UNITED STATES PATENT OFFICE

2,267,557

TWO-WAY REPEATING CIRCUIT

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Application April 18, 1940, Serial No. 330,260

8 Claims. (Cl. 179—170)

This invention relates to the transmission of electric currents, and aims to provide simple and efficient means for accomplishing such transmission, especially over circuits used for two-way signaling over a single conductor pair.

In a form of the invention which is shown in the accompanying drawings, a two-way electron discharge repeater has the output of each of its oppositely directed amplifying paths so connected to the input of the other of these paths as to deliver to the grid of an electron discharge device in this other path a potential tending to prevent the transmission through this other path, to thereby prevent singing of the repeating elements due to currents from one of the amplifying paths circulating through the oppositely directed amplifying path. This is to be accomplished without requiring mechanical switching means at the repeater or other usual forms of singing suppressors. The repeater is connected in a line to which is connected means for sending alternating signal currents which initiate reactions for conditioning the repeater to faithfully repeat the alternating currents in the desired direction and to block transmission in the opposite direction. These and various other features of the invention will be pointed out by reference to the drawings in which:

Fig. 1 shows schematically a repeater embodying one form of our invention;

Fig. 2 is a modification thereof;

Fig. 3 is a modified form of repeater tube over that shown in Fig. 1 by which the objects of our invention may be attained;

Fig. 4 is a still further modification with certain circuit connections;

Fig. 5 is an extension of the circuit of Fig. 1;

Fig. 6 shows the introduction of the repeater of Fig. 1 in a transmission line; and

Figs. 7 to 9 are modifications of Fig. 6.

Referring more particularly to Fig. 1, there is shown the repeater point of a transmission line adapted for two-way communication from west to east and east to west. The repeater here shown consists of an electron discharge tube of special structure, all in one envelope, with a plurality of grids for performing functions described below. The tube structure is essentially a double vacuum tube amplifier, one of the tubes acting as an amplifier for transmission in the one direction and one acting as an amplifier for transmission in the reverse direction. The tube comprises an amplifier unit consisting of a common cathode *a*, plate *d* and grids *b* and *c*, which is being used for transmission from west to east. It also comprises an amplifier with the common cathode *a*, plate *d'* and grids *b'* and *c'*, for transmission from east to west. Bridged across the line on the output side of the first amplifier is the battery B and the load R. Similarly, B' and R' are connected to the output of the other amplifier. Across the input of the tube is connected the grid leak 12 and biasing battery 13. It will be noted that there is a cross-connection whereby the grid *b* is connected to the plate *d'* and the grid *b'* is connected to the plate *d*. In each of these connections there is a biasing battery 18 and a condenser 15 shunted by a resistance 16.

The operation of the circuit is as follows: The biasing of the amplifiers by the grids *b* and *b'* is such that a small, but a very small, current is flowing. When signal arrives from the west it is impressed on the grid *c*. Very early in the signal train a positive impulse will reach *c*, causing a substantial increase in the current to the plate *d*. This causes a drop in the potential of the plate, which is very quickly transferred to the grid *b'*. This lowering in the potential of *b'* decreases the current flowing to *d'*, whereupon the potential of *d'* rises. This increase in potential is very quickly transferred to the grid *b*. This increases the space current to the plate *d*, bringing the tube to a more favorable portion of its operating characteristic, resulting in a further drop in the potential of the plate *d* and a further drop in the potential of *b'*. When the positive impulse in the signal train gives way to a negative pulse the sequence of operations on the plate *d* reverses, but this time the effect of electron conduction from anode *d* to grid *b'* prevents a reversal of its potential about its bias point, and it retains a measure of the potential lowering incurred in the previous process. As a result of successive positive and negative impulses in the signal, therefore, there is a cumulative lowering of the potential of grid *b'*. This leads to a cumulative decrease in the current flowing to plate *d'*, and a corresponding cumulative rise in the potential of *d'*, a cumulative rise in the potential of grid *b*, and a rise in the space current to plate *d*. The cumulative process occurs at a greater rate as the rise in space current to *d* increases the gain from grid *c* to plate *d*, and rapidly places a bias on *b'* sufficiently large to suppress current to the plate *d'* so that its potential becomes substantially the same as the potential of the battery B' and this corresponds to a large positive bias of the grid *b*.

From the above it is seen that signal com-

ing from the west steps up the gain of the one repeater and suppresses the gain of the other, this suppression being so complete that even a strong signal arriving from the east or appearing at *d* is not able to activate the amplifier for transmission to the west. When signal waves from the west cease, the bias voltages on both *b* and *b'* return slowly to normal by virtue of current flow through the leak resistances 16 and the circuit is then ready for operation from either side. It is apparent that signals, if initiated first from the east, will be transmitted to the west and will block transmission of signal from the west to east. The size of the capacities and the resistances and the biasing batteries will be such that the speed of building up of amplification in the desired direction is very high but the rate at which the circuit returns to idle condition is relatively low. The speeds may be varied over a wide latitude, but preferably the decay time should be such as not to respond to the usual intervals between syllables but definitely be responsive to terminations of sentences.

From the above it will be observed that as the electron stream in the one path increases, that in the other decreases, or expressed in other terms, as the gain in the one tube increases, the gain in the other decreases. Normally, when no signal is being received, the gain of the tubes is so low that singing does not take place nor at any time during the reception of signals is the total gain around the total repeater section sufficient to permit singing. While a definite time is required to condition the repeater for full gain in one direction this time is very small, for the first positive impulse, arriving for example on the grid *c*, will increase the electron stream lowering the potential of *d* and *b'*. This is almost instantaneously accompanied by a raising of the potential of *d'* and *b*. After only a few of the initial waves of the wave train have been received the electron stream to *d'* will have been reduced to zero and the grid *b* will have reached its maximum value corresponding to a gain saturation in the electron path to *d*.

While in Fig. 1 the tube has been described as one of special construction with all elements included within one envelope, this disposition of elements is not necessary but the two parts of the tube may be made up separately. This is shown in Fig. 2 in which corresponding parts are correspondingly indicated. The operation of the circuit is precisely the same.

A modification of the tube circuit of Fig. 1 is shown in Fig. 3. The tube here is essentially of the cathode ray type of tube comprising an electron source *a* and anode *h* maintained at a constant potential giving rise to a stream of electrons going to the plates *d* and *d'*. The electron stream is sufficiently diffuse so that while most of the electrons pass through an aperture or space between electrodes *d* and *d'* some of them fall on each plate. Elements *b* and *b'*, in the form of deflecting plates, serve the same purpose as the grids *b* and *b'* of Fig. 1. If, for example, plate *b* is given a positive charge, the electron beam is so deflected as to increase the portion falling on the electrode *d* and to decrease the portion falling on *d'*. Control grids *c* and *c'* serve the same function as the corresponding grids in Fig. 1. The connections in circuit and the operation are identically the same as that for Fig. 1 with the exception of a fixed positive potential applied to the element *h*.

Fig. 4 shows a further modification of the circuit of Fig. 1, use here being made of the phenomenon of secondary electron emission. The common cathode, the grids *b* and *b'* and the grids *c* and *c'* operate in essentially the same manner as indicated in Fig. 1. The tube, however, instead of containing a single plate for each direction of amplification, is provided with a multiplicity of plates to which the electrons go successively, generating secondaries on each impact except the last. The external connections are made in the same way as Fig. 1, connection being made to the last plates d_n and d'_n instead of *d* and *d'*. It is apparent that additional three-element amplifiers in separate envelopes may be used instead of the series of plates.

Fig. 5 is an extension of the section of Fig. 1 into a push-pull combination. The analogous parts are clearly shown and the operation of the circuit will be evident. The first wave in the signal train will make the one side of the circuit positive and immediately start conditioning the repeater on that side of the line for transmission in the one direction. The next half of the wave will render the other side of the line positive and will start conditioning the repeater on that side for amplification in the correct direction. The object of the push-pull connection is to secure immunity to the listening subscriber from a click which is apt to be generated just at the beginning of transmission. This click is generated by the rapid rise in space current to the amplifying side of the tube while transmission is being established. With the push-pull connection a rise in space current occurs in each tube and the pulses balance each other in the output. Thus the subscriber will not hear the click.

One manner in which the repeater units may be introduced into the transmission line is shown in Fig. 6 which shows a manner of connection using the hybrid coil arrangement common in the telephone art for two-way signaling on one pair of wires. The standard type of hybrid coils is shown at 10, 10 and N, N are the usual balancing networks. The connection within the repeater unit itself are the same as for the figures already described.

The repeater unit may be connected directly to the line with a proper adjustment of biasing voltage, but in this case the transmission from plate *d'* is apt to be approximately the same as from line W to grid *b* and there will then be a tendency for the signal from W to operate on grid *b* in such a direction as to reduce the amplification in the W—E direction and tend to nullify in part the operation of the mechanism as a whole. To obviate this it is desirable to introduce more loss in the line W than in the line from the plate *d'* and to do this without inserting loss in the path from the line W to grid *c*. One arrangement for effecting this is shown in Fig. 7. This consists of building a pad around the battery-feed to plate *d'* as shown in Fig. 7. It will be noted, however, that this reduces the output power capacity of the tube in the direction E—W by the same amount that it introduces losses in the path line W—grid *b*. To avoid this, use can be made of a conjugate network to join their respective paths, as shown in Figs. 8 and 9.

In Fig. 8, for example, this is shown as a simplified hybrid coil. The impedance Z is adjusted to match the plate circuit. If the match were perfect and the coil were perfect and symmetrical, then infinite loss would be introduced from line W to grid *b* but only three decibels each in the paths from plate *d'* to line W and from plate

d' to grid b. In practice these ideal conditions will not obtain, but nevertheless it is possible to introduce substantially more loss from line W to grid b than from plate d' to line W and to grid b.

In Fig. 9 another arrangement of a simplified coil is shown. Here again the impedance Z is adjusted to match the plate circuit impedance and the losses introduced to the respective parts of the circuit are substantially the same as shown in Fig. 8.

Referring to Fig. 6, it should be noted that in view of the use of the hybrid coils there shown, no additional conjugate network such as shown in Figs. 8 and 9 is necessary. This is because the gain in the W—E direction through grid c and plate d can be made fairly large when the device is in the neutral-no-signal condition. It should be noted, however, that the situations in Fig. 6 and Fig. 8 are not quite identical. The hybrid coils in Fig. 6 are shown in the conventional two-wire repeater connection. In Figs. 8 and 9, however, the hybrid coils control transmission through the triggering grids b rather than through the amplifying grids c. This means that if any spurious voltage reaching a grid is sufficiently low to prevent its triggering wrongly, no effect whatever will be produced.

In all these arrangements it is necessary to proportion the circuit and apparatus constants such that when the circuit is idle in both directions there is a small loss in the circulating path in this condition. Where hybrid coils are used outside the amplifying element, as in Fig. 6, it is possible to have as much gain in this condition as in a conventional two-wire repeater, the gain then being raised above this value during actual transmission. It is desirable also that once the signals are received from one direction the repeater gains in the two directions should assume their proper respective values and not vary too much with the intensity of the signal once this is more than a given amount. This is evidently accomplished by the nature of the action in each circuit where the loss of gain in the suppressed direction causes increase of gain in the transmission direction and vice versa. Assuming transmission from west to east, the electron flow from cathode a to plate d' approaches zero, practically disabling transmission in this direction and the potential of plate d' approaches that of the positive plate of the supply battery and can go no higher. This fixes a maximum positive potential of the grid b and saturates the gain in this direction.

It is also, of course, necessary to prevent the device locking up completely in any one direction of transmission. This is accomplished by grid leaks 16 to grids b and b' which are cross-connected to the plates d' and d, respectively, which bring the amplifiers back to the idle condition when no speech is received in either direction.

What is claimed is:

1. A two-way repeater for insertion between two sections of a two-way line having only two conductors comprising space discharge apparatus including cathode means having connection to one conductor of each line section, two anodes connecting individually to the opposite conductor of the respective line sections, two control grids connected individually to the respective side of the line section such that one grid and cathode means are connected across each line section, a blocking grid for each cathode-anode space and means controlled by electron flow toward either anode for blocking electron flow toward the opposite anode comprising a bias transfer conductor conductively connecting each anode to the blocking grid of the opposite cathode-anode space.

2. A two-way repeater for insertion between two sections of a two-way line having only two conductors comprising space discharge apparatus including cathode means having connection to one conductor of each line section, two anodes connected individually to the opposite conductor of the respective line sections, two control grids connected individually to the respective side of the line section such that one grid and the cathode means are connected across each line section, two additional grids conductively connected individually, each to the anode of the other section, such that electron flow toward either anode applies a bias voltage over the corresponding conductive connection to the additional grid of the other section for blocking electron flow toward the opposite anode.

3. In a two-way amplifier repeater for insertion between two sections of a two-way line having only two conductors comprising a cathode means initiating an electron stream path to an anode in each section, a grid connection to each line section each adapted to control the electron stream in the other section in accordance with signal variations, and means associated with the electron paths for so conditioning the electron paths that signal from the one section builds up the amplification toward the other section and lowers the amplification toward its own section, said last means comprising an additional grid in each electron path and a bias conductor connecting such additional grid to the anode of the opposite section.

4. In a two-way amplifier repeater for insertion between two sections of a two-way line having only two conductors comprising cathode means initiating an electron stream path to an anode in each section, a grid connected to each section and adapted to control the electron stream in the other section in accordance with signal variations, and means associated with the electron paths so conditioning the electron paths that when idle the gain in each electron path is very low and when signal arrives from the one section the gain toward the other section is increased and the gain toward its own section is decreased, said last means consisting of an additional grid in each path conductively connected to the anode of the other section and means operating in response to the arrival of signal waves for progressively increasing the gain in the one path and reducing it to substantially zero in the other path.

5. The combination of claim 4 including elements for controlling the rate of progressive increase and decrease in the gain in said paths, said elements having such time constant that the progressive increase of gain to maximum in the one path and the reduction to zero in the other occur within the time of the first few vibrations of the signal.

6. In a two-way amplifier repeater for insertion between two sections of a two-way line comprising cathode means initiating an electron stream path to an anode in each section, a grid connected to each section and adapted to control the electron stream in the other section in accordance with signal variations, and means associated with the electron paths so conditioning the electron paths that when idle the gain in each electron path is very low and when signal ar-

rives from the one section the gain toward the other section is increased and the gain toward its own section is decreased, said last means consisting of an additional grid in each path and means operating in response to the arrival of signal waves for progressively increasing the gain to maximum in the one path and reducing it to substantially zero in the other path, means including elements for controlling the rate of progressive increase and decrease in the gain in said paths, said elements having such time constant that the progressive increase of gain to maximum in the one path and the reduction to zero in the other occur within the time of the first few vibrations of the signal and said elements having such time constant that the restoration to normal condition of said electron paths upon cessation of signal occurs at a substantially slower rate.

7. A two-way amplifier repeater for insertion between two sections of a two-way line comprising a cathode ray tube having a cathode, beam forming means and two targets located one on each side of the beam in its position when no signals are received, one of said targets being connected to each section of the repeater, a pair of deflecting plates one connected to each section and means operatively associated therewith and operative when signal is being transmitted in one direction to deflect the beam to the proper target for that direction of transmission, a grid connected to each section and positioned to control the strength of the beam in accordance with signal variations received from one of said sections to cause an amplified replica of the signal variations to be passed on to the other section.

8. In a two-way amplifier repeater for insertion between two sections of a two-way line, the repeater being in the form of a cathode ray tube having a cathode, means at one end initiating an electron stream, a focusing electrode through which the electron stream passes thereby being made narrower and caused to travel centrally along the length of the tube, two targets representing the anodes located equidistant from the center of the other end of the stream so as to allow the stream to pass between them when the repeater is inoperative, one of the targets being connected in each section of the repeater, a grid connection in each section adapted to control the electron stream in accordance with signal variations when said stream is directed toward the target of the other section, two deflecting plates adjacent to the electron stream one connected to each section of the repeater and acting under control of signals received from the one section to deflect the stream to the target of the other section thereby building up the amplification toward the other section and reducing the amplification toward its own section.

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