Jan. 5, 1926. 1,568,891

L. ESPENSCHIED

REPEATER CIRCUITS

Filed July 2, 1921 2 Sheets-Sheet 1

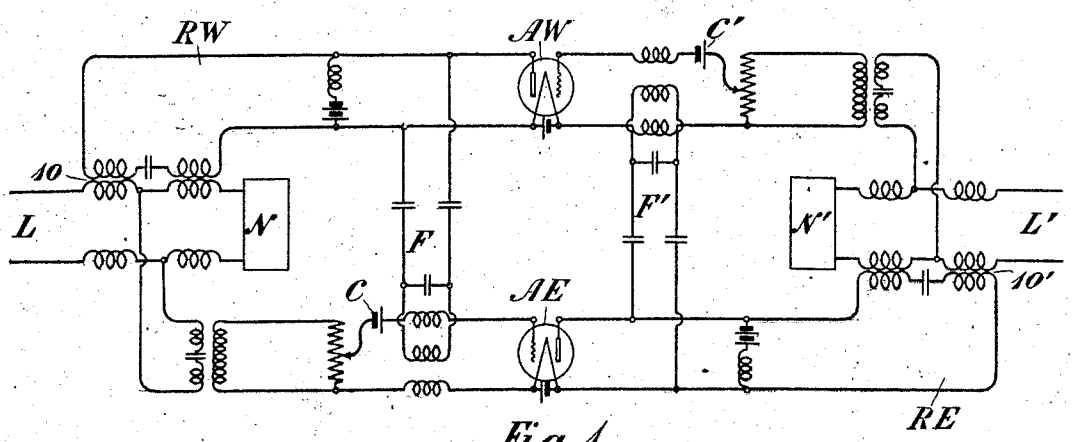


Fig. 1

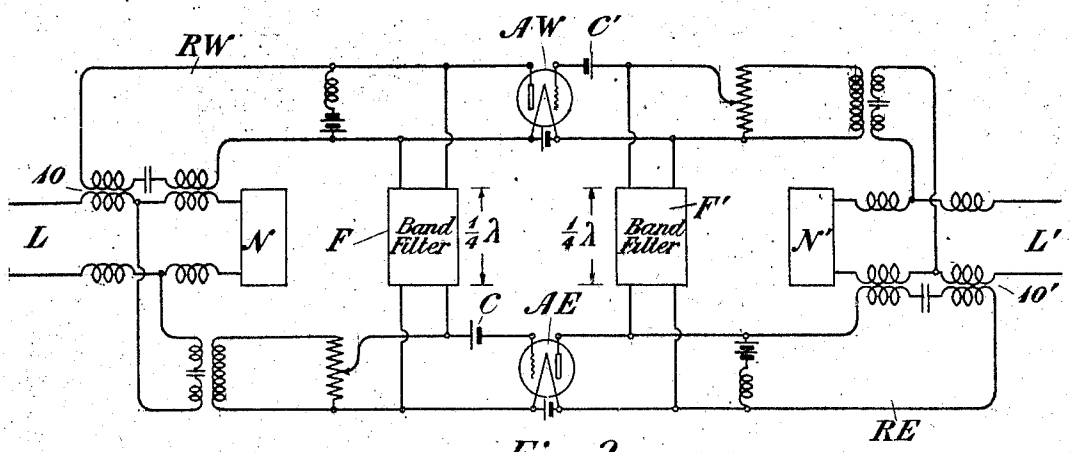


Fig. 3

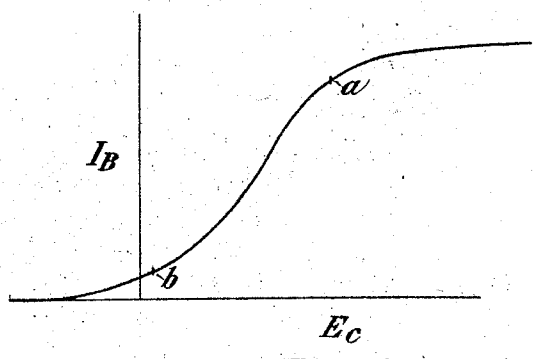


Fig. 2

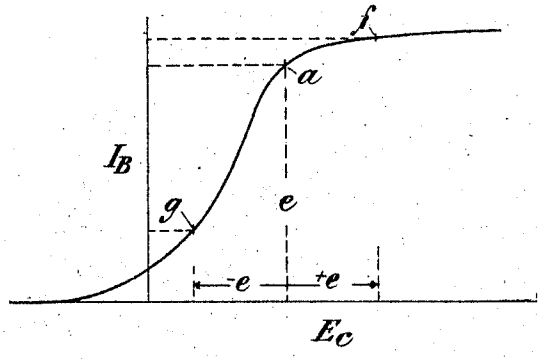


Fig. 4

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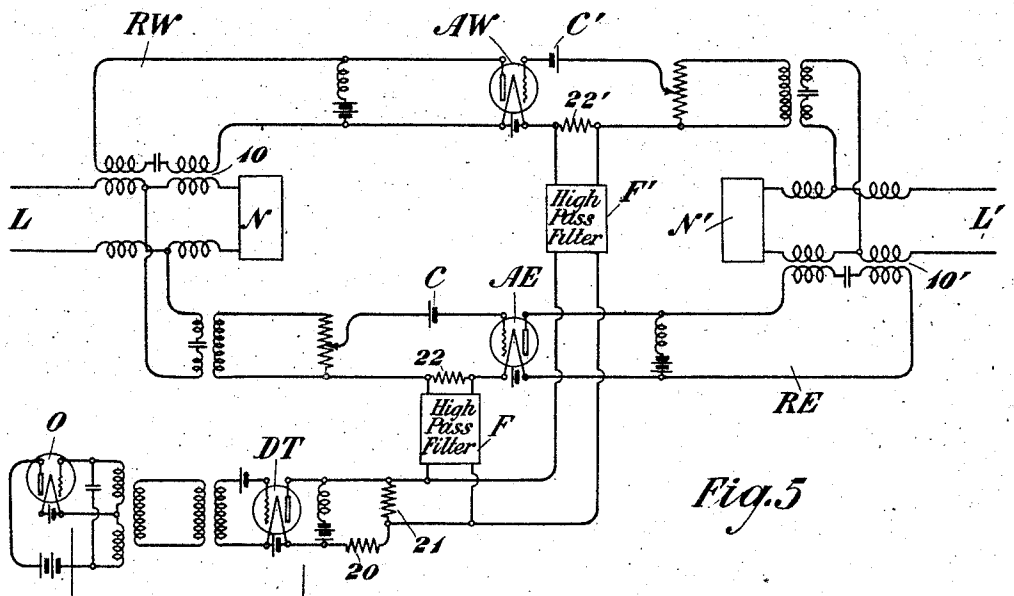


Fig. 5

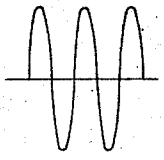


Fig. 6

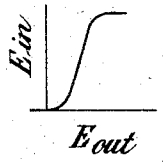


Fig. 7

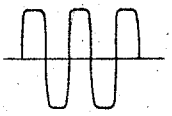


Fig. 8

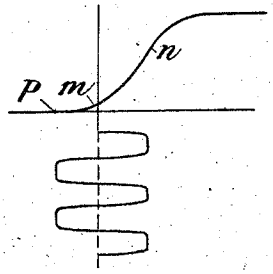


Fig. 9

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Patented Jan. 5, 1926. 1,568,891

UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF QUEENS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

REPEATER CIRCUITS.

Application filed July 2, 1921. Serial No. 482,243.

To all whom it may concern:

Be it known that I, LLOYD ESPENSCHIED, residing at Queens, in the county of Queens and State of New York, have invented certain Improvements in Repeater Circuits, of which the following is a specification.

This invention relates to transmission circuits, and more particularly to transmission circuits of the general type exemplified by two-way repeater circuits.

In repeater circuits of the so-called 22-type, it has been customary to differentiate between the sending and receiving channels by balancing the channels with respect to the line sections, the well-known hybrid coil and artificial line or network being employed for this purpose. The problem of balancing a line involves grave difficulties, however, and frequently the degree of balance is so poor that the amplification must be maintained quite low to prevent singing.

In accordance with the present invention, it is proposed to effect two-way transmission by differentiating between the sending and receiving channels on a time basis,—that is, by associating the channels with the line alternately at a frequency high as compared with the signaling frequency. This results in switching the line at both ends of the repeater at a rapid rate between the sending and receiving terminals of the repeater. This will obviously permit of operating the repeater at very high gain without encountering difficulties due to singing, since the problem of repeater singing is essentially one of discriminating between the oppositely directed channels. This method of switching may be used either to supplement the discrimination due to balance or may be substituted for the balancing method.

An important feature of the present invention resides in the employment of vacuum tubes for performing the switching function, the vacuum tubes having in this connection the characteristic advantage, as compared with mechanical switching means, of substantial absence of inertia, thereby permitting of high speed switching and absence of contacts with their attendant troubles.

More specifically considered, the invention involves an arrangement whereby the vacuum tube amplifiers in the oppositely directed channels of the 22 repeater circuit are alternately rendered operative at a high frequency rate by impressing proper operating potentials upon the grids of the tubes. These potentials may be applied by so connecting the circuits of the two tubes that singing will be set up and the alternating current pulses of the singing oscillations will alternately render the tubes capable of amplification. As an alternative, the alternating impulses for rendering the tubes operative may be applied from some external source. In either case, the circuits connecting the two channels should be arranged to discriminate against currents of signaling frequencies so as to prevent singing at a signaling frequency.

In order that the commutating action of the pulses applied to the grids of the amplifiers may be made to involve as short a time as possible for the switch-over operation, it is proposed to distort the wave which is applied to the amplifier so that it becomes a flat topped wave. This will permit of the tube amplifying during the period that one flat topped alternation is being transmitted, while the tube will be rendered non-amplifying by the flat topped alternation of opposite polarity.

Further details of the invention will be clearly understood from the following description, when read in connection with the accompanying drawing, Figures 1 and 3 of which illustrate two forms of the invention in which the amplifiers themselves are caused to oscillate to supply the commutating currents, and Figs. 2 and 4 of which are curves illustrating the operation of the circuits of Figs. 1 and 3, while Fig. 5 is a modified arrangement in which the commutating currents are supplied from an external source, Figs. 6, 7, 8 and 9 all representing curves for illustrating the operation of the circuit of Fig. 5.

Referring to Fig. 1, the usual form of 22 repeater circuit is shown, in which line sections L and L′ are associated with repeater channels RE and RW through hybrid coils 10 and 10′, artificial lines or networks N and N′ being provided to balance the line sections. Amplifiers AE and AW are included in the repeater channels RE and RW, respectively. While these amplifiers may be of any well-known type, they are preferably of the vacuum tube type. In order that both amplifiers may not function to amplify with efficiency at the same time, but may be rendered operative as amplifiers alternately, the

amplifiers AE and AW are connected mutually in tandem through a high frequency circuit including filtering or tuning devices F and F'. The tuned circuit F interconnects the plate circuit of the amplifier AW with the grid circuit of the amplifier AE, and the tuned circuit F' likewise connects the output or plate circuit of the amplifier AE with the grid circuit of the amplifier AW. The grid batteries C and C' are normally adjusted so that the amplifying tubes operate on the non-linear portion of the characteristic curve. The amplification of the tubes at telephone frequencies will, therefore, vary in accordance with the amplitude and polarity of the high frequency waves which oscillate in the tuned circuits F and F' due to the singing connection established between the two tuned circuits and the amplifying tubes. The amplifications of the amplifiers AE and AW are consequently varied alternately by the high frequency singing, first one and then the other of the amplifiers coming into play to amplify the telephone currents. By means of this arrangement, the total amplification around the repeater circuit, (that is, around the path in which low frequency singing tends to occur as the result of line impedance unbalances), is kept at a relatively low value so that audio frequency singing is minimized. The action of the repeater may be described as one in which the repeater gives continuously a small gain around the telephone repeater circuit while intermittently, but in very rapid succession, relatively large gains are alternately given to the channels east and west.

In order that the operation above described may be obtained, the grid batteries of the amplifying tubes may be adjusted in either of two ways depending upon their phase relation in the oscillating circuit. If, for example, the selective circuits F and F' are of such a character as to give little or no phase difference between the amplifiers AE and AW, then one amplifier may be operated on one knee of the characteristic curve, as for example, on the point *a* of the characteristic curve of Fig. 2, and the other amplifier may be operated upon the opposite knee of the curve, as, for example, at the point *b* in Fig. 2. For this condition, a half-wave of the high frequency passing substantially simultaneously through the two tubes will diminish the amplification of one tube and increase the amplification of the other, and vice versa for the opposite half of the high frequency wave.

If, on the other hand, the feed-back selective circuits F and F' are connected in the reverse manner so that a positive half-wave in the tube AE corresponds to a negative half-wave in the tube AW, then both tubes should be operated on the same knee of the characteristic curve, as, for example, at the point *a*. One amplifier will then have its gain as regards telephonic transmission increased, while that of the other will be decreased.

Instead of using sharply tuned circuits for obtaining the singing action described in connection with Fig. 1, band filters of the Campbell type may be employed as illustrated in Fig. 3, these filters having the advantage that they may be utilized in controlling the phase relations. The band filters F and F' in Fig. 3 should be so designed as to transmit a sharply defined predominant natural frequency above the telephone range. This may be accomplished by making the band of free transmission of the filters quite narrow. If the filters are further so designed as to have an electrical length of one-quarter wave length, a phase difference of 180 degrees will exist between the tubes AE and AW. In this case both tubes should be operated on the same knee of the characteristic curve. For example, as illustrated in the characteristic curve of Fig. 4, the grid batteries C and C' should be adjusted to apply a potential E_c to the grid of each tube, thereby causing the tubes to operate at the point *a* on the characteristic curve. If now a positive half-wave of amplitude *e* is superposed upon the normal potential E_c, the tube will operate at the point *f* of the characteristic curve, at which point the tube is substantially non-amplifying. If, on the other hand, a negative half-wave of amplitude *e* is superposed upon the normal grid potential, the tube will be caused to operate about the point *g*, which is the point of greatest amplification of the tube. Since these two actions in the tubes AE and AW occur at phase intervals of 180 degrees, the tubes will alternate in their amplifying action. It will be understood, of course, that this phase difference may be brought about by making the filters F and F' of other electrical lengths than one-quarter wave length each, as above described.

In the arrangements disclosed in Figs. 1 and 3, the high frequency control current for the amplifiers was generated by the amplifier tubes themselves. The general scheme involved would probably be more practical for telephone use if the high frequency control current were generated separately from the amplifiers themselves by means, for example, of a high frequency oscillator. This would eliminate the complication of causing the repeaters to function simultaneously as oscillators while functioning alternately as amplifiers. The provision of a separate high frequency source would, furthermore, not involve any considerable additional expense, as the same source might be used for a plurality of repeaters. Fig. 5 illustrates an amplification control system in which the controlling high frequency current is

generated separately from the repeaters themselves. This figure introduces a further feature of importance in that it provides means for minimizing the distortion of the telephone currents which would normally be occasioned by the action of running the repeater up and down its non-linear characteristic.

Referring to Fig. 5, two amplifiers AE and AW are supplied from a common vacuum tube oscillator O, which applies currents to the tubes in opposite phase relation. The general action is the same as in Figs. 1 and 3, the amplifier AE being caused to operate upon the portion of its characteristic curve giving minimum amplification, while at the same time the amplifier AW is caused to operate upon the portion of its characteristic curve corresponding to maximum amplification.

If the current supplied to the amplifiers from the source O were of sine wave form, the amplifiers would be continually shifted in position on their characteristic curves. As a consequence, during the greater part of the time the repeaters would be operating on portions of their characteristic curves other than the straightest or most linear part, so that the voice currents traversing the tubes would be subjected to distortion. In accordance with the present invention, this difficulty due to distortion may be overcome by supplying to the amplifiers waves having square tops instead of sinusoidal waves. By using a square topped wave, the amplifier may be shifted from maximum to minimum amplification in the shortest time possible so as to minimize the distortion of the voice currents which arises during the time that the repeater is being shifted on its characteristic curve.

In order to accomplish this result, the waves supplied by the oscillator O are passed through a distorting tube DT having a resistance 20 in its output circuit. The tube DT and its associated circuits are arranged in a well-known manner so that the tube will have a characteristic curve such as is indicated in Fig. 7, the change from the flat part of the curve at saturation and at the no-current points being relatively abrupt. If, therefore, a sinusoidal current such as is indicated in Fig. 6 is generated by the oscillator O, such current, in passing through the tube DT, will be distorted so that the waves will have flat tops, as indicated by the curve of Fig. 8.

The circuits including the filters F and F′, which associate the output circuit of the distorting tube DT with the grid circuits of the amplifying tubes AE and AW, respectively, are conductively associated with the output circuit of the distorting tube by being bridged across a resistance 21, so that the direct current pulses of the waves of Fig. 8 will be permitted to flow into these circuits without rounding off the tops of the waves. For the same purpose the connections to the grid circuits of the amplifiers AE and AW are established through resistances 22 and 22′, respectively. The high pass filters F and F′ should be designed so that their lower cut-off point will be below the fundamental frequency of the square topped wave of Fig. 8, but the cut-off should be sufficiently high so as to exclude audible frequencies. The suppression of audible frequencies by these filters will eliminate any possibility of the establishment of a singing connection at audible frequencies for either amplifying tube over the output circuit of the tube through a hybrid coil and through the filters F and F′ to the input circuit. By making the lower cut-off point low enough to include the fundamental frequency of the wave of Fig. 8, the square topped form of the wave may be transmitted through the filters without any rounding of the tops of the waves owing to the fact that the square topped form of wave may be considered to comprise a fundamental frequency upon which are superposed successive harmonics. As the high pass filter will pass the fundamental wave and all of its harmonics, the square topped form of the wave will not be disturbed.

If the grid batteries of the amplifiers are adjusted to operate normally at the point m, which corresponds to the lower knee of the characteristic curve of Fig. 9, the superposition of the alternating square topped wave of Fig. 8 upon the grid will result in shifting the operating point along the curve to the point n during one-half cycle and to the point p during the other half-cycle. At the point n, the tube will be operating at its greatest amplifying efficiency and at the point p will be operating at substantially no amplification. The time of shifting between points n and p will be very short, owing to the square topped form of the wave.

As in the case of Fig. 3, the filters F and F′ may be employed to determine the phase relations of the two tubes. Considerable latitude is also possible in the design of the detailed arrangements for generating the high frequency, for distorting the high frequency to produce a flat topped wave, etc.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a repeater system, line sections, amplifiers for repeating in opposite directions associated with said line sections, a circuit

interconnecting said amplifiers in tandem independently of said line sections, and means to prevent the transmission of audible frequencies over said circuit.

2. In a repeater system, line sections, amplifiers interconnecting said line sections for repeating in opposite directions, means for impressing upon said amplifiers currents to alternately render the amplifiers operative and substantially inoperative, said means comprising a high frequency circuit interconnecting said amplifiers independently of said line sections, and means for preventing the transmission of audible frequencies over said circuit.

3. In a repeater system, line sections, amplifiers interconnecting said line sections for repeating in opposite directions, means for impressing upon said amplifiers currents to alternately render the amplifiers operative and substantially inoperative, said means comprising an oscillating circuit interconnecting said amplifiers independently of said line sections, and means in said oscillating circuit for preventing the transmission of audible frequencies over said oscillating circuit.

4. In a repeater system, line sections, vacuum tube amplifiers interconnecting said line sections for repeating in opposite directions, means to alternately vary the amplification of said amplifiers from an operative to a substantially inoperative condition comprising a circuit arrangement interconnecting the grids of said amplifiers for the transmission of high frequency controlling currents, and means to prevent the transmission of audible frequencies over said circuit arrangement.

5. In a repeater system, line sections, vacuum tube amplifiers for interconnecting the line sections for repeating in opposite directions, an oscillator, a connection from said oscillator to the grid circuits of each of said amplifiers whereby controlling currents supplied by said oscillator may be alternately applied to the amplifiers to alternately render the amplifiers operative and substantially inoperative, and means in said connection for preventing the transmission of audible frequencies over said connection.

6. In a repeater system, line sections, vacuum tube amplifiers interconnecting the said line sections for repeating in opposite directions, an oscillator, connections from said oscillator to the grid circuit of each of said amplifiers for applying controlling currents supplied by said oscillator to the grid circuits of the amplifiers to alternately render the amplifiers operative and substantially inoperative, and phase controlling elements in said connections for determining the phase relations with which the controlling currents are applied to the amplifiers.

7. In a repeater system, line sections, vacuum tube amplifiers interconnecting said line sections, a circuit arrangement interconnecting the said amplifiers independently of said line sections for supplying to said amplifiers high frequency currents to alternately render the amplifiers operative and substantially inoperative, and filters in said circuit arrangement for determining the phase relation of the high frequency currents applied to the amplifiers.

8. In a repeater system, line sections, vacuum tube amplifiers for interconnecting the line sections for repeating in opposite directions, a source of high frequency current, connections from said source to the grid circuits of each vacuum tube amplifier to alternately apply to each tube controlling currents for determining the amplification thereof, and means for determining that the controlling waves supplied to the amplifiers will be flat topped.

9. In a repeater system, line sections, vacuum tube amplifiers for interconnecting the line sections for repeating in opposite directions, a source of high frequency current connections from said source to the grid circuits of each vacuum tube amplifier to alternately apply to each tube controlling currents for determining the amplification thereof, and means for distorting the waves supplied by said source so that the waves will be flat topped.

10. In a repeater system, line sections, vacuum tube amplifiers interconnecting said line sections for repeating in opposite directions, means to supply square topped waves, circuits interconnecting said means with the grid circuits of the amplifiers, the connection of said circuits with said grid circuits and said means for supplying square topped waves being of such a character as to transmit direct currents, and high pass filters in said circuits having a cut-off point below the fundamental frequency of the square topped wave and above the voice frequencies.

In testimony whereof, I have signed my name to this specification this 29th day of June 1921.

LLOYD ESPENSCHIED.