May 2, 1933. H. W. DUDLEY 1,907,147

TRANSMISSION CIRCUITS

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FIG. 1-A

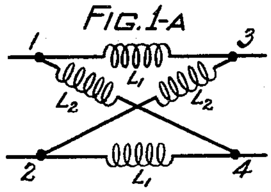

FIG. 1-B

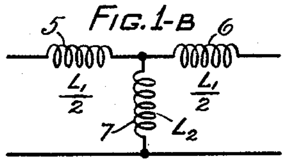

FIG. 1-C

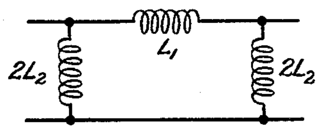

FIG. 2-A

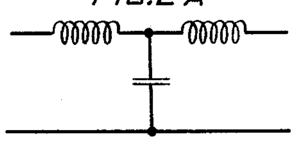

FIG. 2-B

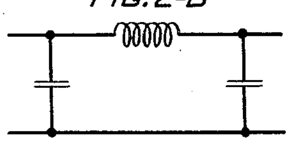

FIG. 3-A

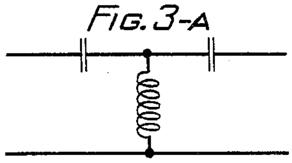

FIG. 3-B

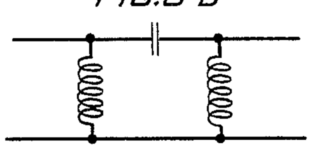

FIG. 1-D

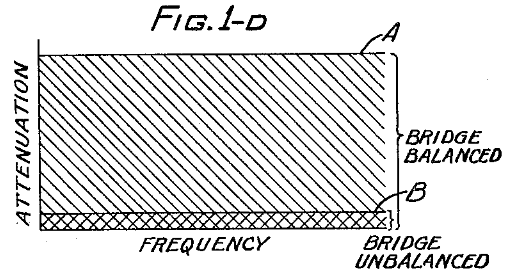

FIG. 2-C

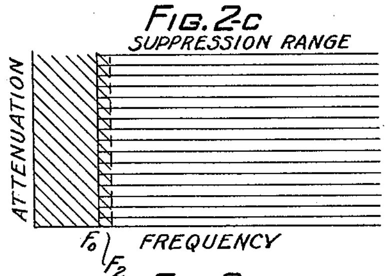

FIG. 2-D

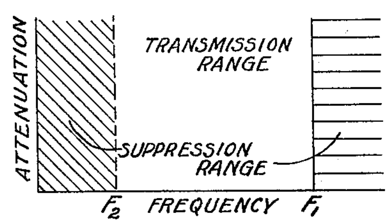

FIG. 3-C

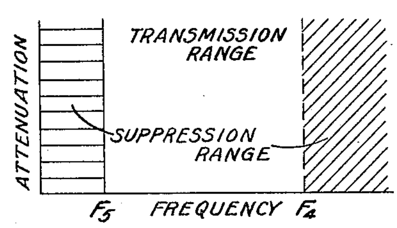

FIG. 3-D

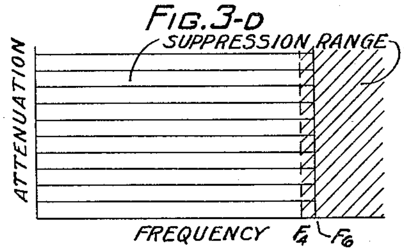

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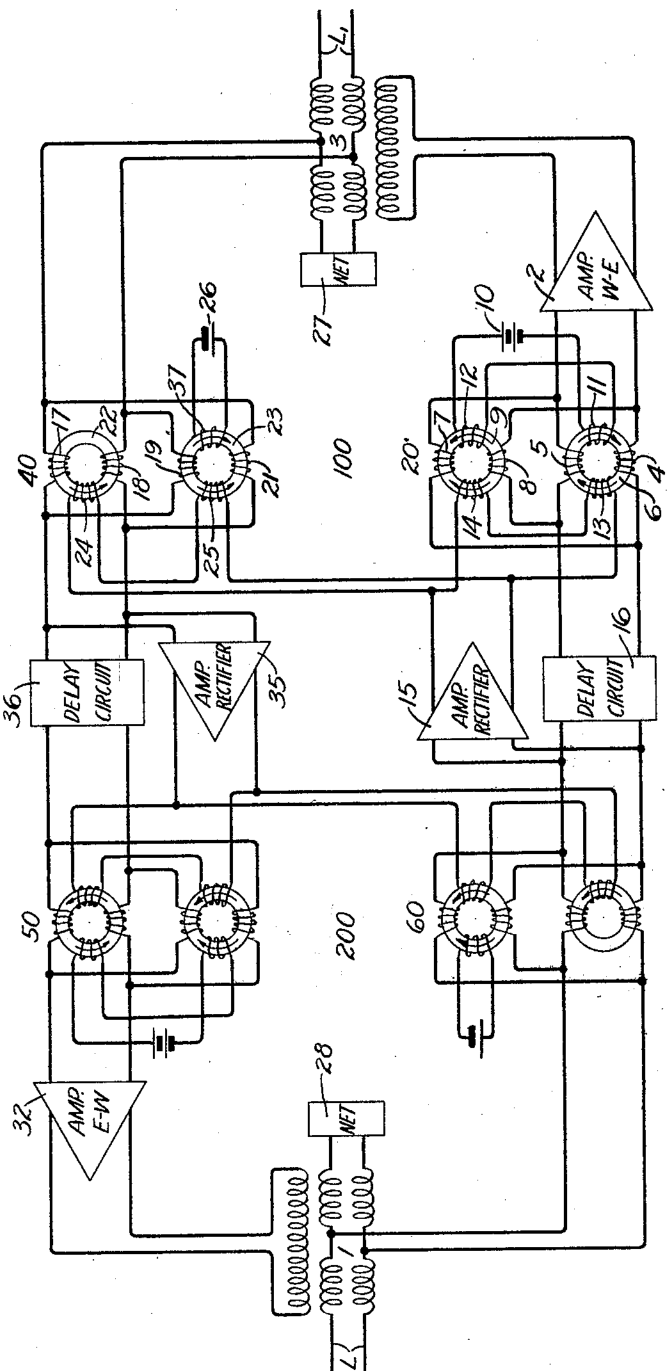
FIG. 4



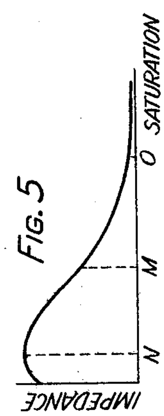


FIG. 5

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UNITED STATES PATENT OFFICE

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TRANSMISSION CIRCUITS

Application filed January 15, 1929. Serial No. 332,728.

This invention relates to echo suppressing and singing prevention circuits, and more particularly to those utilizing saturation of magnetic coils as a means of control.

Heretofore echo suppressing circuits have comprised in part electromechanical elements such as relays, which require appreciable time to operate and have contacts which may cause chattering or become inoperative or of high resistance.

An object of the invention is to speed up the transmission of signals through a repeater equipped with echo suppressing and singing prevention devices.

Another object of the invention is to increase the efficiency of operation and at the same time to simplify and economize on necessary apparatus.

A feature of the invention resides in the use, in a two-way repeater circuit, of magnetic coils having the property of becoming highly saturated to control transmission. It is well known that saturating a coil is equivalent to making it of low impedance and to decreasing transmission loss if it is in series and to increasing loss if it is in shunt. Removing saturation has the opposite effects, respectively. In accordance with the objects of this invention, a portion of the current being transmitted through a repeater is utilized to vary the saturation of coils in both branches of the repeater in such a manner that the branch repeating in the direction of the signals is made transparent to the signals, whereas the branch repeating in the opposite direction is made opague thereto, thus preventing the return of echoes to the transmitting end.

Other features of the invention comprise the various types of circuits for associating the coil with the repeater circuit. In one type of circuit the loss increment is determined by the saturation conditions of the cores, although for any given condition the loss for all frequencies is the same. Another type of circuit includes a filter which gives different loss increments at different frequencies and cuts out as completely as desired the frequencies that should be eliminated.

A better understanding of the invention may be had from the following description together with the accompanying drawings of which Figs. 1—A, 1—B and 1—C are circuits which give constant loss increments at all frequencies both before and after a change of saturation conditions. Fig. 1—D illustrates the transmission characteristics of this type of circuit for different conditions of saturation. Figs. 2—A and 2—B are low pass filter circuits which give different loss increments at different frequencies. Figs. 2—C and 2—D are the transmission characteristics of these circuits for different conditions of saturation. Figs. 3—A and 3—B are high pass filters which also give different loss increments at different frequencies, while Figs. 3—C and 3—D illustrate the transmission characteristics of these circuits for different conditions of saturation. Fig. 4 illustrates a repeater circuit equipped with the loss circuit of Fig. 1—A and Fig. 5 shows the variation of the impedance of the coils with saturation.

Before describing a repeater circuit employing the invention several typical circuits will be described in which the loss may be efficiently controlled by varying the saturation of the coils. With some of the nickel iron alloys at present available the saturation properties are so remarkable that their use in these circuits produce an effect which is somewhat equivalent to opening a series or closing a shunt switch and to closing a series or opening a shunt switch. The effect is not obtained to the same degree as with an actual switch, but by using sufficient inductance any amount of loss increment desired may be obtained and it becomes a question of choosing the most economical point of operation for the particular circuit used.

If the transmission losses must be fairly constant over a large frequency range, both before and after the change, circuits such as those shown in Figs. 1—A, 1—B and 1—C may be used. Fig. 1—A is a Wheatstone bridge with like inductances L_1 in opposite arms of the bridge. This circuit has its maximum effect, that is, the greatest change of impedance for a given change of saturation, when L_1 equals L_2 and when one is in the saturated condition and one is not. Suppose the inductances L_1 in the opposite branches of the bridge are in the unsaturated condition, while the inductances L_2 in the other branches of the bridge are saturated and that under these conditions of saturation L_1 equals L_2. This will give the high loss condition represented by A in Fig. 1—D, as the bridge will be balanced and no difference of potential will exist across the terminals 3 and 4 regardless of the voltage impressed upon 1 and 2. If the reverse conditions of saturation obtain, namely, L_1 saturated and L_2 unsaturated, the impedance of the coils L_1 will be considerably decreased, whereas the impedance of the coils L_2 will be increased. A maximum unbalance of the bridge will result causing a difference of potential across terminals 3 and 4 corresponding to the potential impressed upon the terminals 1 and 2. This gives the low loss condition represented by line B in Fig. 1—D.

If the coils represented by L_1 and L_2 have equal inductances under like conditions, the above effect may be obtained by biasing both coils so that they are in a semi-saturated condition when the bridge is balanced. By reducing the saturation of one of the coils and increasing the saturation of the other, the maximum unbalanced condition of the bridge may be obtained. If pure inductances were available the attenuation at all frequencies would be the same and under a balanced condition where $L_1=L_2$ the loss presented by the bridge would be infinite. If the resistance increments of the coils have values that do not appreciably change the phase angle, there is negligible variation of inserted loss with frequency and the infinite loss condition is closely approached. By making the D. C. resistances equal, the attenuation for D. C. and extremely low frequencies may be made infinite since perfect balance of the bridge may be secured. This is a condition desirable in many telephone circuits.

Similar loss conditions may be obtained by means of the T network of Fig. 1—B and the π network of Fig. 1—C. In both these circuits, the low loss condition represented by the line B of Fig. 1—D occurs when L_1 is saturated and L_2 is unsaturated, whereas the high loss condition represented by line A in Fig. 1—D results when L_2 is saturated and L_1 unsaturated.

Throughout the specification the coils are treated as if maximum impedance obtains at zero saturation. In many coils, however, it occurs at a finite saturation so that in such cases the operating range would lie between a point of heavy saturation and the saturation for maximum impedance. When maximum impedance occurs at a small saturation, a choice exists of using the saturation curve above or below this point. In general, it is desirable to use it above this point since much lower impedance can be obtained at points of heavy saturation and also more nearly constant inductance for slight changes of current. By properly biasing the coils the operating range may be confined to the portion of the curve desired.

In Figs. 1—A, 1—B and 1—C, it is necessary that the impedance terminations resemble closely the characteristic impedance of the networks or at least that there is a fixed impedance ratio for all frequencies in order for constant loss to exist with all frequencies.

Other desirable embodiments of the invention comprise filter circuits of the types shown in Figs. 2—A, 2—B, 3—A and 3—B. In the low pass filters 2—A and 2—B, saturating the coils decreases their inductance and changes the filter cut-off frequency from an original value of F_0, Fig. 2—C, to some higher value F_1, Fig. 2—D. A small frequency range from zero to F_0 is a pass region in both conditions. However, if a high pass filter is used to cut out the region from zero to F_2, then with the non-saturated coils nothing is transmitted as shown in Fig. 2—C, while with the saturated coils, the frequency range F_2 to F_1, Fig. 2—D is transmitted. For ordinary commercial telephony F_2 would probably be about 300 cycles and F_1 around 3000.

If high pass filters such as those shown in 3—A and 3—B are used, the conditions obtaining under different conditions of saturation are shown in Fig. 3—C and Fig. 3—D. In this case a fixed low pass filter (non-saturating) is used which transmits all frequencies below F_4. In the saturated condition, filters 3—A and 3—B have a cut-off corresponding to F_5, Fig. 3—C. Under these conditions a transmission band from F_5 to F_4 exists. Upon removing saturation the cut-off frequency is increased to F_6, Fig. 3—D, so that transmission through the circuit is effectively prevented. The range included between F_5 and F_4 would probably be the same as between F_2 and F_1. There are, of course, a large number of other filter circuits which may be used to carry out the invention, other than the specific circuits shown.

A voice control repeater circuit in which the invention may be used is shown in Fig. 4. This is a two-way repeater having separate paths for repeating signals in opposite directions. The line L is terminated in balancing network 28 and the hybrid coil 1 which aids in separating the waves received from and impressed upon the line L. The line L_1 is similarly terminated by the network 27 and hybrid coil 3. Amplifiers 2 and 32 of the usual type are connected, respectively, in the oppositely directed paths for amplifying respectively the west to east and the east to west signals. The west to east and the east to west paths are equipped respectively with the voice controlled loss circuits 100 and 200.

The loss circuit 100 has a loss element 20 which may be any of the specific types heretofore described or which may be equivalent thereto. The circuit 200 in the other branch of the circuit has a similar loss element 50. The impedance which the loss element presents to the signals traversing the paths is dependent upon the saturation of the loss element coils. The saturation of the coils of the loss element 20 is controlled by the amplifier-rectifier 15 which rectifies a portion of the signal current, while that of the coils of element 50 is controlled by a corresponding rectifier 35.

Since the purpose of the invention is to prevent singing of the repeater and to suppress echoes, an effect which would be produced for example if some of the amplified repeater energy which is impressed upon the line through the hybrid coil should get into the oppositely directed path due to poor balancing of networks against lines or to other impedance irregularities, the elements 20 and 50 are in the high loss condition, that is, opaque to signaling energy during the periods of non-transmission.

However when energy to be amplified is impressed upon any paths, a portion of it is rectified, and applied to the loss element in that path, placing it in the low loss condition so that the signals are readily transmitted. Thus for example when signals from the line L are impressed upon the west to east path, a portion of their energy is rectified by the rectifier 15, and applied to the element 20. This places the element in the low loss condition so that signals are readily transmitted and amplified by the amplifier 2. During transmission over the west to east path the loss element 50 in the other path is in the high loss or opaque condition.

When signals are being transmitted in the east to west direction over the other path similar conditions exist in the loss control circuit 200.

In order that the loss elements be in the proper transmission condition at the beginning of the signaling period, it may be necessary to delay the signals slightly until the rectifier places the coils in the proper condition of saturation. The delay circuits 16 and 36 are used for this purpose although these circuits are not always essential.

If sufficient loss is not obtained by the elements 20 and 50, additional loss elements 40 and 60 may be used. During the periods of non-transmission these elements are in the low loss or transparent condition. Element 40 is controlled from the rectifier 15 while element 60 is controlled by the rectifier 35. When signals are being transmitted over the west to east path the element 40 is changed to the high loss condition thus introducing additional loss in the idle path. Element 60 operates similarly during transmission over the east to west path. These additional loss elements are advantageous if very large gains are desired, or if only poor balances are attainable between networks and lines.

For purposes of illustration the loss elements 20, 40, 50 and 60 have been shown as adaptations of the loss circuit of Fig. 1A although any of the types of circuits illustrated in Figs. 1 to 3 or any others within the spirit of the invention may be used.

The element 20 comprises the series coils 4 and 5 on the core 6, corresponding to the L_1 coils of Fig. 1A, and the shunt coils 7 and 8 on the core 9, corresponding to the L_2 coils of the same figure. Cores 6 and 9 are equipped with biasing windings 11 and 12 supplied respectively with current from a source 10, and with windings 13 and 14 supplied with current from the amplifier rectifier 15. When no current is flowing in the windings 13 and 14 the windings 11 and 12 maintain the cores 6 and 9 in a semi-saturated condition corresponding to M in Fig. 5. Under these conditions all the coils have equal impedance. This is the balanced or high loss condition. As coils 11 and 12 are oppositely poled a current flowing in the windings 13 and 14 poled in the same direction on the cores 6 and 9 respectively cause the coils on one core to become more saturated and the coils on the other less saturated. Under these conditions the coils on one core will have a high impedance corresponding to N in Fig. 5 while the coils on the other core will have a low impedance corresponding to O. This corresponds to the low loss or unbalanced condition. The windings 13 and 14 are energized from the amplifier rectifier 15 which rectifies and amplifies a portion of the incoming signal energy. The delay circuit 16 mentioned heretofore may be of the type illustrated in Patent 1,607,687 to H. Nyquist issued November 23, 1926.

The loss element 40 comprises the coils 17 and 18 on the core 22 and coils 19 and 21 on the core 23. These coils correspond to the coils 4, 5, 7 and 8 of the loss element 20 respectively. Cores 22 and 23 are also equipped with biasing windings 24 and 25, which are in parallel with the coils 13 and 14 and energized from the same amplifier rectifier 15. However, as element 40 in this path is in the unbalanced or transparent condition during periods of non-transmission, one core must be in the unsaturated condition corresponding to high impedance, while the other core must be highly saturated or of low impedance. Consequently only the core 23 is equipped with a biasing winding 37 energized from the source 26 so that during periods of non-transmission over the west to east path or in other words when coils 24 and 25 are deenergized, the coils 17 and 18 on the core 22 have an impedance corresponding to N in Fig. 5, while coils 19 and 21 on the core 23 have an impedance corresponding to O. The coil 37 is oppositely poled with respect to the coil 25. When the windings 24 and 25 are energized by current from the amplifier rectifier 15, during periods of transmission over the west to east path, the coils 17 and 18 become saturated to a point corresponding to M in Fig. 5, while the saturation of coils 19 and 21 on account of the polarity of coil 37 is decreased to the same point. This represents the balanced or high loss condition.

The amplifier element 32, loss element 50, loss element 60, the amplifier detector 35 and the delay circuit 36 are identical with and function in a manner similar to the elements 2, 20, 40, 15 and 16, when signals are being repeated in the east to west direction, and consequently will not be described in detail.

The operation of the circuit may be readily understood by supposing that signals from line L are to be amplified and repeated to the line L_1. If the line L_1 is not exactly balanced by the network 27, or if there are other unbalance conditions or impedance irregularities in the circuit, a portion of the west to east energy may be transmitted back over the east to west branch, amplified by the amplifier 32 and impressed upon line L through the hybrid coil 1, producing undesirable echo effects and possibly also causing singing of the repeater. By use of the loss circuits, however, in accordance with the invention, the lower branch of the repeater, in Fig. 4 amplifying in the direction of the signals, is rendered transparent, whereas the upper branch repeating in the opposite direction is made opaque to these signals, thus eliminating the undesired effects heretofore mentioned.

When no signals are being repeated in either direction the loss elements 40 and 60 are in the low loss or transparent condition, whereas the elements 20 and 50 are in the high loss or opaque condition. When signals are being transmitted from the line L in the west to east direction a portion of the energy is amplified and rectified by the amplifier-rectifier 15 and applied to windings 13 and 14 of the loss element 20 and to windings 24 and 25 of the loss element 40. The element 20 thereby is placed in the low loss condition, permitting the signals to be readily amplified and transmitted to the line L_1, whereas the element 40 is placed in the high loss condition and is opaque to any of the energy of the west to east signals which may tend to be transmitted back in the reverse direction. The loss circuit 200 operates in a similar manner when the signals are being repeated in the east to west direction.

Although but one circuit has been shown in which the various types of loss circuits may be utilized, the invention is not to be restricted thereto, but is to be limited only by the scope of the appended claims.

What is claimed is:

1. In a transmission system, means for controlling the amount of energy transmitted through said system, said means comprising a plurality of coils connected in series and in shunt of the line and having properties of high saturation, and means for changing in opposite senses the degree of saturation of certain of said coils by a current derived from the current to be transmitted through said system.

2. In a transmission system, two one-way transmission paths for transmitting signals in opposite directions, a plurality of coils having high saturation properties connected in series and in shunt to each of said paths, and means responsive to signals in one of said paths to render the other of said paths opaque to signals transmitted over said first path, said means being adapted to vary the degree of saturation of said coils in said other path.

3. In a transmission system, two one-way transmission paths for transmitting signals in opposite directions, a plurality of coils connected in each of said paths having high saturation properties, and means responsive to the signals in one of said paths for varying the amount of saturation of said coils so as to decrease the impedance and to make said one transmission path transparent to signals and simultaneously to increase the impedance of and render said other path opaque thereto.

4. In a transmission system, two one-way transmission paths for transmitting signals in opposite directions, a network comprising a plurality of coils in each of said paths, one of said networks being transparent and the other opaque to signaling currents during periods of non-transmission and means for reversing the transmission conditions of said networks during periods of transmission, said means comprising saturating windings for said coils energized from a source of rectified signal energy.

5. In a transmission system, two one-way transmission paths for transmitting signals in opposite directions, a low pass filter and a high pass filter in at least one of said paths, one of said filters having means dependent upon the current in said path for changing the saturation of the filter coils so that for some conditions of transmission the suppression ranges of said filters overlap causing complete suppression whereas for other conditions of transmission an appreciable transmssion range exists for transmitting the desired signals.

6. In a transmission system, two one-way transmission paths for transmitting signals in opposite directions, a plurality of filters in each of said paths, at least one of the filters in each of said paths having a variable suppression range, means for rectifying a portion of the energy from one of said paths to

vary the saturation of the coils in said filters having variable suppression ranges, so that during periods of non-transmission the suppression ranges of the filters in said one path overlap causing it to be opaque to signal currents, while a suitable transmission range exists between the suppression ranges of the filters in said other path, but during periods of transmission over said one path the transmission conditions of said variable filters are reversed.

7. In a two-way system of transmission comprising two oppositely directed one-way paths, an inductive impedance device in each path for controlling transmission over the path, each such device having a magnetic core, and means operating in response to currents in one path for varying the saturation of the cores of the inductive impedance devices in opposite paths in respectively opposite directions to vary the impedance of the paths oppositely.

In witness whereof, I hereunto subscribe my name this 14th day of January, 1929.

HOMER W. DUDLEY.