June 28, 1927.

H. C. SILENT

1,633,615

DELAY CIRCUITS FOR VOICE OPERATED DEVICES

Filed Oct. 24, 1925

2 Sheets-Sheet 1

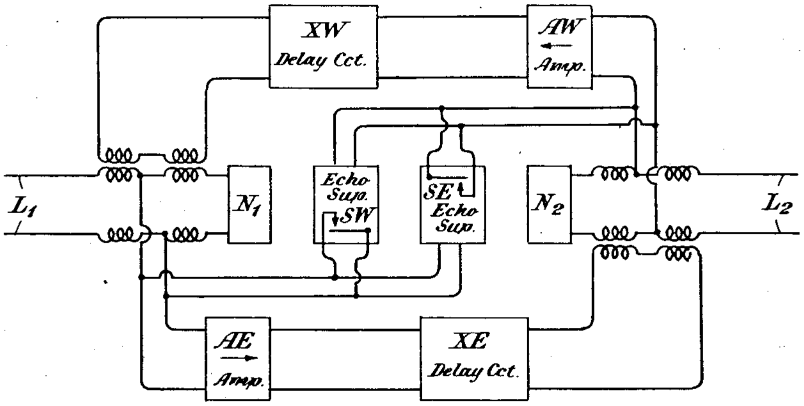

Fig. 1

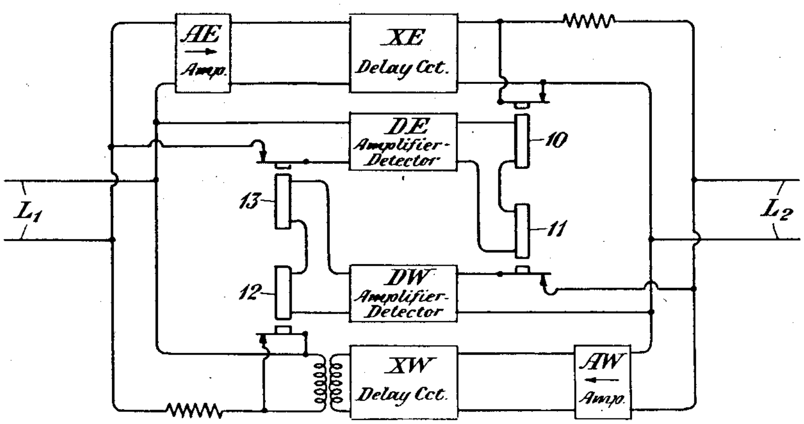

Fig. 2

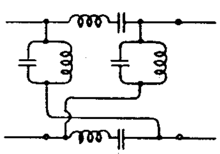

Fig. 3

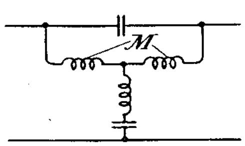

Fig. 4

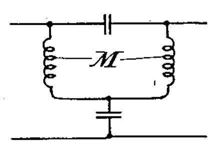

Fig. 5

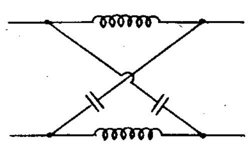

Fig. 6

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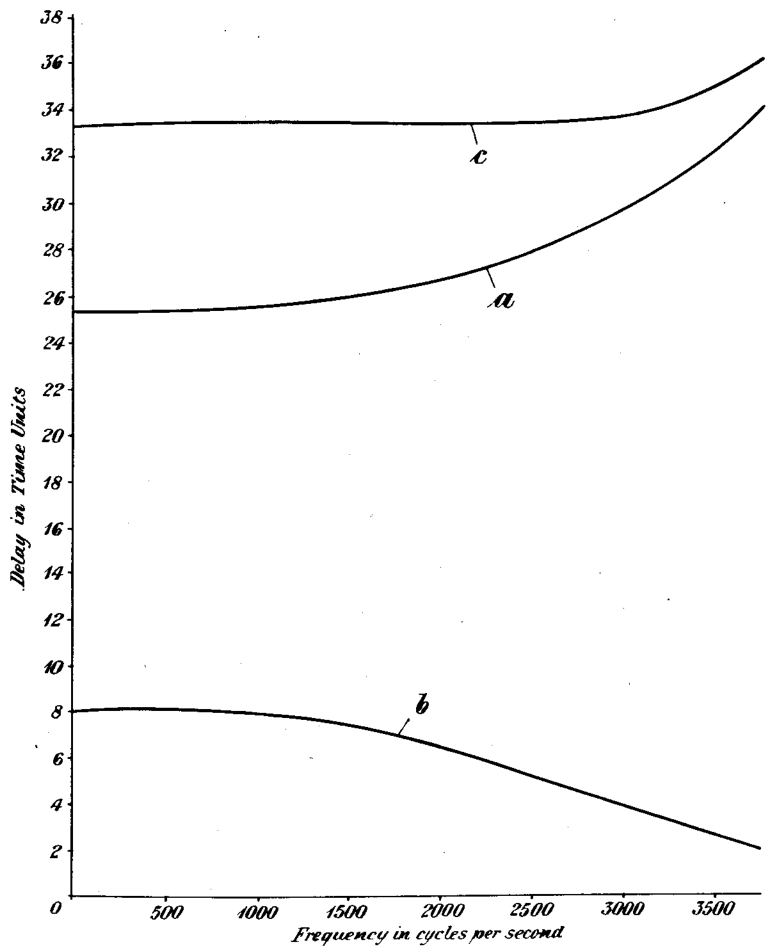

Fig. 7

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UNITED STATES PATENT OFFICE.

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DELAY CIRCUITS FOR VOICE-OPERATED DEVICES.

Application filed October 24, 1925. Serial No. 64,682.

This invention relates to delay circuits for use in connection with the voice operated devices of echo suppressors and voice operated repeater systems.

In connection with 22-type repeaters employing voice operated devices either for suppressing echoes or for controlling the direction of transmission of the repeater, it has been proposed to utilize delay networks for the purpose of delaying the transmission of the signaling currents over a part of the path until the voice operated device has had time to actuate its contact. Such delay networks heretofore have been of the filter type. In accordance with the present invention it is proposed to use a lattice type of network to attain the desired amount of delay, so that the lattice network in addition to performing its delay function may also be used to compensate for the variation of the time constant of the transmission circuit with respect to frequency.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, Figure 1 of which illustrates a typical form of echo suppressor circuit employing a delay circuit, Fig. 2 of which illustrates a typical form of voice operated repeater circuit employing a delay circuit, Figs. 3, 4, 5 and 6 of which illustrate different types of lattice networks which may be employed for delay circuits, and Fig. 7 of which is a series of curves illustrating the characteristics of the delay circuit employed in connection with the present invention.

It has long been recognized that a transmission line produces two kinds of distortion. One type of distortion involves the attenuation of the higher frequencies to a greater extent than the lower frequencies, so that the higher frequencies arrive at the receiving point with lower amplitude. The other type of distortion involves the variation in the time of transmission of different frequencies over the circuit. Here, again, the discrimination is most marked at the high frequencies, which take a much longer time for transmission than the lower frequencies.

Attenuation equalizers have been developed to compensate for the first type of distortion, and more recently lattice type networks have been developed to compensate for the variable delay of the line with respect to frequency, so that when the network is employed in connection with the line the over-all delay will be substantially the same regardless of frequency. These lattice type networks structurally resemble wave filters, since they are made up of a plurality of sections, each section comprising series and shunt impedance elements consisting of inductances and capacities. The lattice type network differs structurally from the filter network in that its shunt impedance elements are connected diagonally across the terminals of the series elements of each section, thus forming a so-called lattice.

Functionally the lattice type of network is entirely different from the filter type. The filter has the peculiar characteristic that it will transmit a band of frequencies of uniform and substantially negligible attenuation, but will suppress all frequencies lying outside of the band. Its impedance is not a pure resistance and can only be made a pure resistance by utilizing special terminating arrangements. The impedance of the lattice type of network, on the other hand, is a pure resistance, and its attenuation characteristics are entirely different from that of the filter in that it offers substantially negligible attenuation at all frequencies. In actual practice, due to the fact that the inductance and capacity elements of the lattice network involve a slight amount of resistance and leakage, there is a small amount of attenuation due to the network, and this attenuation is not quite uniform for all frequencies. If, however, the network were constructed of pure inductances and perfect capacities, there would be no attenuation at any frequency.

While the lattice type of network does not substantially discriminate between different frequencies so far as attenuation is concerned, it does discriminate or may be made to discriminate with respect to different frequencies so far as its time of transmission is concerned. Therefore it has been employed to compensate for the variation in delay of an ordinary transmission line with respect to frequency.

Notwithstanding the fact that, as above pointed out, the function of the lattice type network is intimately concerned with the delay of transmission, the delay networks heretofore employed have been of the filter type. There are two principal types of transmission systems which involve the use of delay circuits. One is the echo suppressor circuit of which a typical example is illustrated in Fig. 1. In this figure is shown a 22-type of repeater interconnecting the line sections L_1 and L_2, the repeater involving one path for transmitting from east to west and another path for transmitting from west to east. The former path includes an amplifier AW and the latter path an amplifier AE of well known type. Bridged across the input side of the amplifier AW is an echo suppressor unit conventionally indicated at SW. This unit, as is well known, comprises a suitable amplifier and rectifier which amplifies and rectifies the voice currents in order to operate a mechanical relay to short-circuit the opposite transmission path. Similarly an echo suppressor unit SE is bridged across the input side of the amplifier AE to short-circuit the path transmitting west. When either echo suppressor unit short-circuits the path controlled thereby, it at the same time short-circuits the opposite echo suppressor unit to prevent it from functioning.

If this circuit is analyzed, it will be seen that voice currents coming in from the line L_2, for example, to operate the echo suppressor SW will also pass through the hybrid coil and back into the path transmitting from west to east due to unbalance between the line L_1 and its network N_1. Since a certain amount of time is necessary to enable the echo suppressor to close its contact, the unbalance currents might enter the echo suppressor SE and thereby cause a false operation. In order to prevent this possibility, a delay circuit XW is provided, so that the voice currents are delayed in transmission from the input of the amplifier AW to the hybrid coil, thereby giving the echo suppressor SW an opportunity to close its contact before the unbalance currents arrive on the input side of the amplifier AE. A similar delay circuit XE is provided in the path transmitting from west to east to permit the other echo suppressor to function.

Another type of system employing delay circuits is the voice operated repeater of which a typical example is illustrated in Fig. 2. Here the transmission paths including the amplifiers AE and AW are normally short-circuited by the contacts of relays 10 and 12 to prevent the repeater circuit from singing. These relays are controlled by means of amplifier-detector arrangements similar to those employed in the echo suppressors above described, and the amplifier-detector arrangements DE and DW have their input circuits bridged across the input side of amplifiers AE and AW, respectively. Normally the circuit is not in condition to transmit in either direction. If voice currents come in over the line L_1, however, they operate the amplifier-detector combination DE, so that the relay 10 opens a short-circuit across the path from the amplifier AE to the line L_2 permitting transmission to take place from west to east. At the same time the relay 11 is controlled by the apparatus DE to open the input circuit of the corresponding voice operated arrangement DW to prevent false operation thereof. Similarly, if voice curents come in over the line L_2 the amplifier-detector DW is actuated to remove the short-circuit from the east to west path by means of relay 12 and to disable the amplifier-detector DE of the relay 13.

In either case it will be obvious that a certain amount of time is necessary to enable the relay 10 or the relay 12, as the case may be, to open the short-circuit controlled by its contacts. This would result in clipping the initial syllable of each word or group of words unless some means is provided to prevent the voice currents from arriving at the point at which the short-circuit occurs until the voice operated relay has had an opportunity to actuate its contact. Accordingly delay circuits XE and XW are provided at the positions indicated to delay the transmission of the voice currents through the repeater path until the short-circuit has been removed.

As already stated, the delay networks employed in these typical systems have been of the filter type. In accordance with the present invention, however, it is proposed to substitute lattice type networks instead. The lattice type network has many advantages over the filter type even when considered merely for the purpose of introducing the desired delay in the repeater circuit. In the first place the desired delay may be introduced with a fewer number of sections of the network than are required for the same delay with the loaded line type of circuit. Furthermore, owing to the flat transmission frequency characteristic of the lattice type network which has already been referred to, practically no distortion due to attenuation is introduced into the circuit. The network introduces no cut off beyond which the circuit will fail to transmit. Aside from these advantages, the use of the lattice type network enables the same network to accomplish the desired delay in the repeater circuit and to compensate for variations of the time of transmission of the line circuit with frequency of transmission, as will appear later.

The sections of the delay circuit may be of several different types of lattice structures. For example, in Fig. 3 is shown the general type of lattice network section comprising series resonant combinations of inductance and capacity in series with the line and anti-resonant combinations of induction and capacity bridged across the line in criss-cross fashion, as indicated. As is well known in the art, a circuit of this type may be adjusted to increase the delay at some special frequency or range of frequencies, and, in general, by properly proportioning the parts, the delay-frequency characteristic may be made to assume practically any desired form. In Fig. 4 and Fig. 5 two modified arrangements are shown which are known to be electrically equivalent in their operation to the arrangement shown in Fig. 3. In each of these figures a capacity is included in series with the line and two coils wound upon the same core so as to have a certain amount of mutual inductance are bridged about the capacity. The midpoints of these coils are connected to the opposite conductor of the line circuit through an inductance and capacity in the case of Fig. 4 and through a simple capacity in the case of Fig. 5. Another general type of lattice network is illustrated in Fig. 6 in which the series element of each section is an inductance and the shunt elements comprise capacities connected criss-cross to either terminal of the series inductance.

The effect of a network made up of latticed sections to compensate for the variations in the delay-frequency characteristic of a transmission circuit will be clear from the curves shown in Fig. 7. In these curves, frequency in cycles per second is plotted horizontally, and delay in suitable time units is plotted vertically. The curve *a* represents the delay at different frequencies of a typical telephone circuit. As will be seen, the delay gradually increases with frequency so that at frequencies in the neighborhood of 2,000 cycles and upwards the delay becomes very marked. This means that if a square topped wave be impressed upon the circuit (such a wave being equivalent to a fundamental wave having an infinite series of harmonics), the higher harmonics will not be built up at the distant end of the circuit until some time after the fundamental and the lower harmonics have arrived. This results in the well known "transient" phenomenon, which has been a source of considerable difficulty in transmission circuits.

Curve *b* represents the variation of delay with frequency for a network built up of three sections of the type shown in Fig. 3. As will be seen, the delay reaches a maximum in the neighborhood of 500 cycles, and somewhere in the neighborhood of 1,500 or 2,000 cycles the delay begins to fall off very rapidly as the frequency increases. If, then, a network consisting of three sections of the type of Fig. 3 be superposed on the transmission line whose characteristics are represented by the curve *a*, the delay-frequency characteristic of the entire combination will be as represented by the curve *c*. As will be seen, the delay is practically constant for all frequencies from 0 to 3,000 cycles. Therefore, all frequencies ordinarily useful in telephone transmission may be transmitted without any substantial transient effect.

On the other hand, it will be seen from an inspection of the curve *b* that for frequencies up to about 2,000 cycles the delay due to the network is fairly uniform and quite substantial in amount. This delay can therefore be utilized if the network is introduced into the repeater paths, as shown in Fig. 1 and Fig. 2, to give the necessary delay in transmission to enable the essential voice frequencies to operate the voice operated relays of the echo suppressor circuit or the voice operated repeater circuit, as the case may be. Since the frequency delay curve of which *b* is an example may be varied in shape to a considerable extent, particularly in the direction of producing a hump in the curve at a particular frequency, the network may be designed so as to introduce a large delay at some particular frequency or group of frequencies, this being especially useful in the case of an echo suppressor.

It should be noted that while the delay networks of the present invention exercise a considerable degree of discrimination as between frequencies so far as delay in transmission is concerned (see curve *b*), this discrimination is not accompanied by an attenuation discrimination. So far as amplitude is concerned, the networks treat all frequencies substantially alike. Consequently the delay circuits may be used to perform the dual function of equalizing the delay in the transmission line and of allowing time for the operation of the voice operated relay contacts without introducing any substantial attenuation into the repeater paths.

It will, of course, be understood that the lattice type of network per se is not a part of the present invention, except in so far as it is used as one of the elements of a combination to produce the dual result already set forth. It will likewise be clear that types of lattice networks other than those disclosed may be used when such networks have the desirable characteristics of controlling the delay for particular frequencies without introducing any variation in attenuation.

It will also 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 transmission circuit, a voice operated relay for controlling the transmission over a part of said circuit, and a delay cir-

cuit operating to delay the transmission of signaling currents over said part of said circuit until the voice operated relay has had time to function, said delay circuit comprising a network so designed as to compensate for the variation in the delay of the transmission circuit with respect to frequency.

2. In a transmission system, a transmission line, a transmission path interconnecting sections of said line, a voice operated relay responsive to signaling currents for controlling the transmission over said path, and a delay circuit associated with said path for delaying the transmission of signaling currents until the voice operated relay has had time to function, said delay circuit comprising a network so designed as to compensate for the variation in delay of the transmission line with respect to frequency.

3. In a signaling system, a transmission line, a two-way repeater connecting sections of said line, a voice operated relay arrangement associated with said repeater to control its ability to transmit in a given direction, and a delay circuit associated with said repeater to delay the transmission of signaling currents to a part of said repeater until said voice operated relay has had time to function, said delay circuit comprising a network so designed as to compensate for the variation in the delay of the transmission line with respect to frequency.

4. In a signaling system, a transmission line, a repeater interconnecting sections of said line, said repeater comprising amplifying paths, one for transmitting in one direction and the other for transmitting in the opposite direction, a voice operated relay arrangement associated with each path for controlling transmission over the opposite path, and a delay circuit in each path to delay the transmission of signaling currents until the corresponding voice operated relay has had time to function, said delay circuit comprising a network so proportioned as to compensate for the variation in delay of the transmission line with respect to frequency.

In testimony whereof, I have signed my name to this specification this 23rd day of October, 1925.

HAROLD C. SILENT.