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VACUUM TUBE ECHO SUPPRESSOR

Filed Sept. 18, 1925

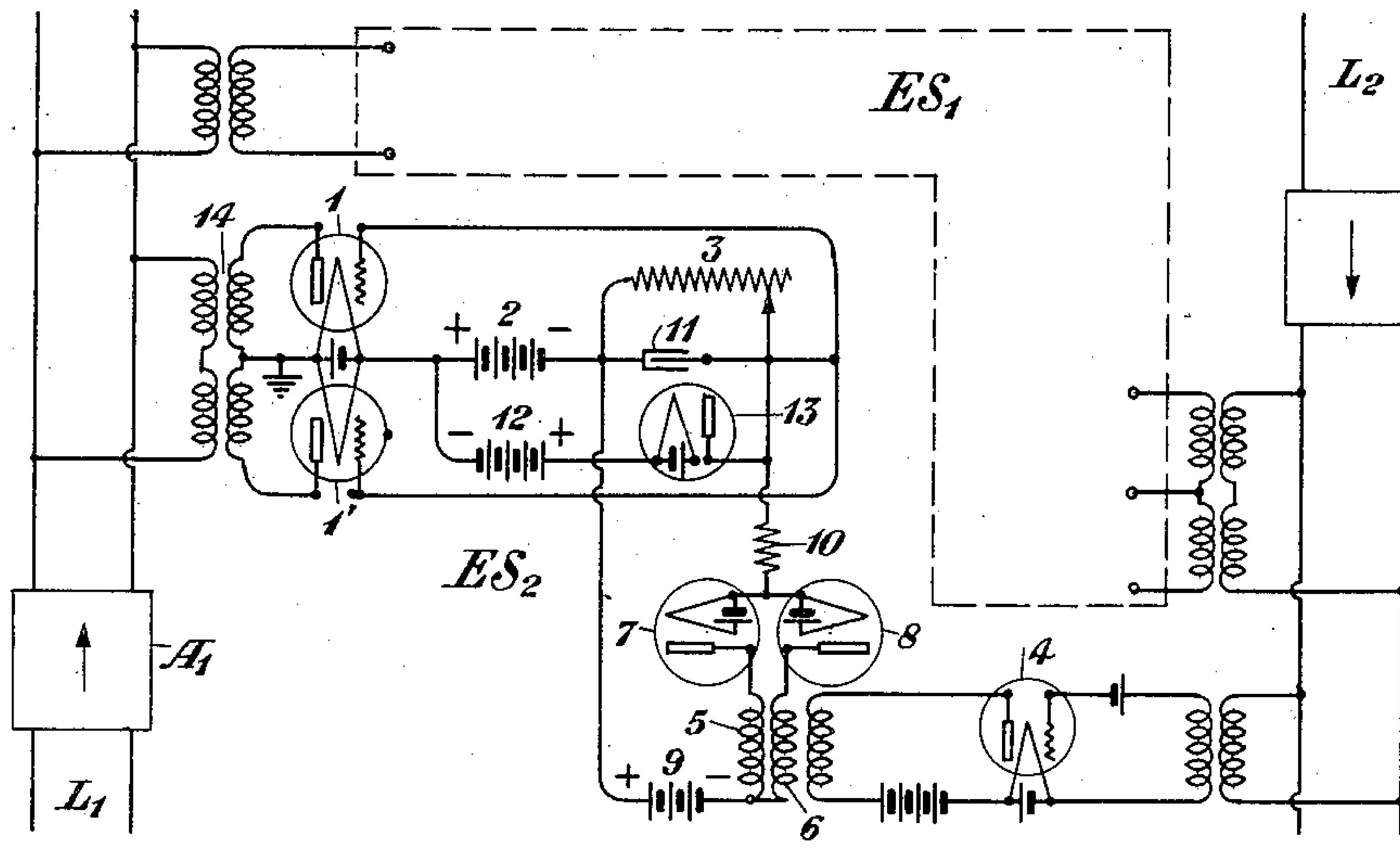

Fig. 1

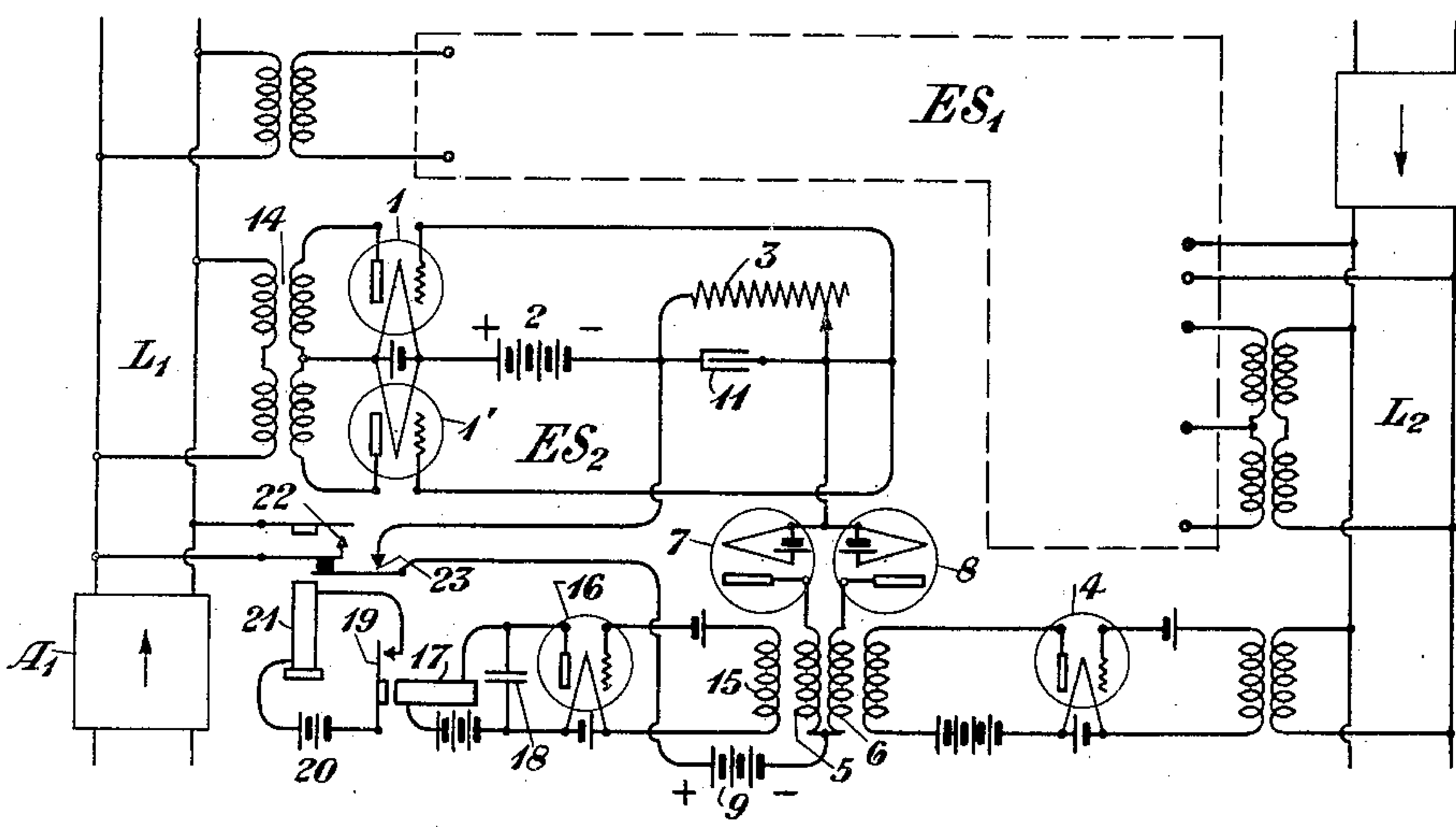

Fig. 2

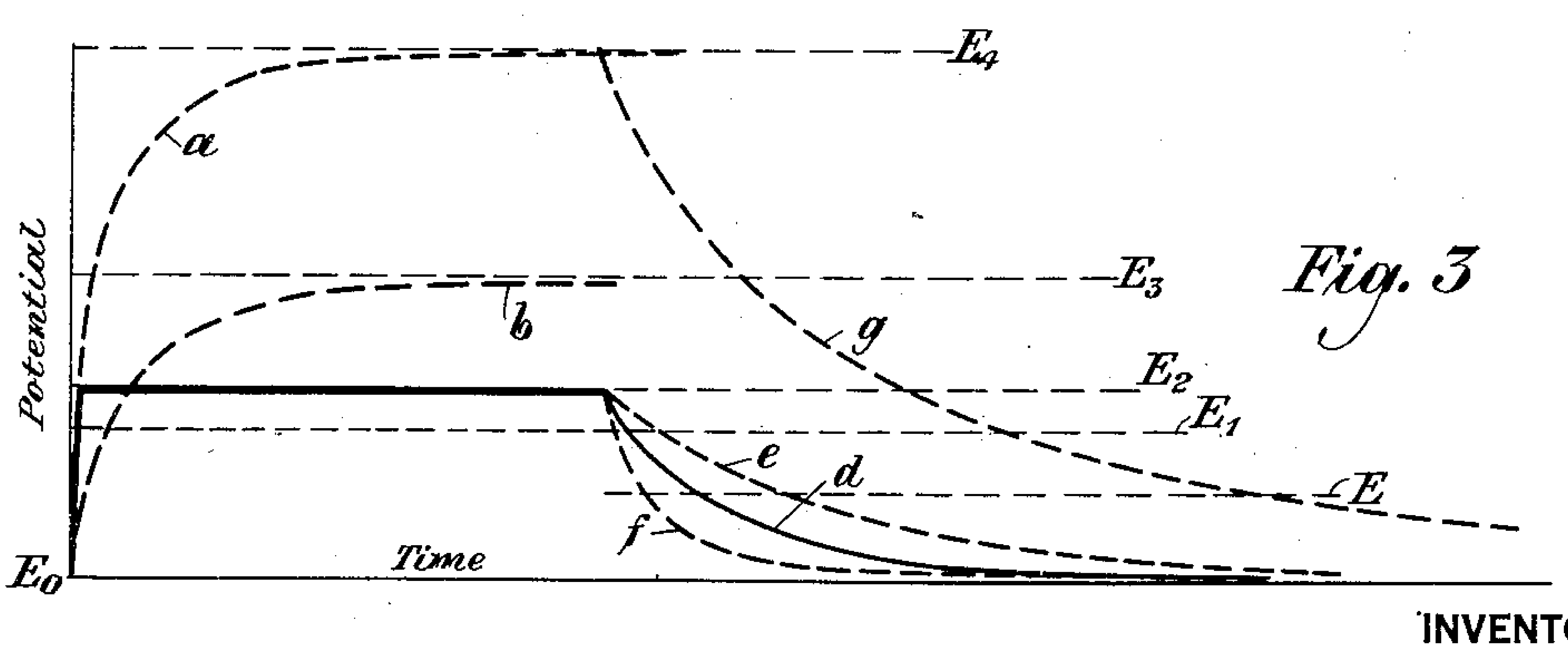

Fig. 3

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VACUUM-TUBE-ECHO SUPPRESSOR.

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This invention relates to vacuum tube relays and more particularly to transmission circuits in which vacuum tube relays are employed for the suppression of echoes.

When a subscriber talks over a transmission circuit, echo currents are transmitted back in the reverse direction due to reflection either at the terminal points or at points where balancing arrangements are provided in connection with repeaters. The echo currents may be prevented from arriving at the originating subscriber's set by employing echo suppressors at points where the transmission circuit involves individual paths for transmitting in each direction. An echo suppressor unit is associated with each path and when transmission occurs over one path the suppressor unit associated with that path operates to disable the path transmitting in the reverse direction.

Echo suppressor units as heretofore constructed have usually comprised an amplifier detecting arrangement with a high impedance input which is bridged across one of the transmitting paths and operates in response to voice currents or other signaling currents to produce rectified currents to operate a relay. The relay is a mechanical relay arrangement whose contacts are arranged to disable the opposite transmitting path when the rectified current flows through the relay winding.

While it has also been proposed to use vacuum tube relay arrangements as echo suppressors, such arrangements have heretofore been impractical for a number of reasons. The disabling operation resulted in clicks in the talking circuit. Furthermore the hangover time could not be made sufficiently long and both the operating and hangover periods were dependent on the magnitude of the operating voice currents. Moreover no discrimination between noise currents and voice currents was possible in the operation of the circuit. Therefore an object of the present invention is to provide a voice operated echo suppressor employing vacuum tube relays which will operate quickly and without clicks to disable the path of transmission not being used, which will have a definite and controllable hangover interval substantially independent of the magnitude of the voice currents operating the device, and which will so discriminate against noise currents as to permit its action to be very sensitive to voice currents greater in magnitude than the noise currents.

Other and further objects of the invention will be clear from the following detailed description when read in connection with the accompanying drawing, Figures 1 and 2 of which are circuit diagrams illustrating two embodiments of the invention and Fig. 3 of which is a series of curves illustrating the operation of the circuit.

Referring to Fig. 1, L_1 and L_2 designate two transmission paths including amplifiers A_1 and A_2. These paths may be the two sides of a four-wire circuit or they may be the two transmission paths of a 22 repeater. An echo suppressor combination ES_2 is bridged across the path L_2 on the output side of the repeater A_2 and operates in response to voice currents transmitted over the path L_2 to practically short-circuit the output side of the amplifier A_1 of the path L_1. A similar echo suppressor combination ES_1 is bridged across the path L_1 to disable the path L_2. This echo suppressor combination is merely indicated symbolically and will be understood to be identical in all respects with the combination ES_2 which is illustrated in detail.

The relay member of the echo suppressor combination ES_2 comprises two vacuum tubes 1 and 1′ which are connected in push-pull relation. The two plates are connected to the ends and the two filaments to the middle of one winding of a transformer 14, whose remaining winding is bridged across the line L_1 as indicated. The grids of the two tubes are connected to each other and between the grids and the filament is placed an arrangement for varying the voltage normally impressed upon the grids so that the impedance of the combination which is bridged across the circuit L_1 can be controlled.

Without, for the moment, going into the details of the arrangement for varying the potential upon the grids, let us assume that this potential may be varied at will. Now, if the potential be normally set so that both grids are sufficiently negative, no current can flow between the filaments and plates of the tubes 1 and 1′. The impedance looking from the line L_1 through the transformer 14 will then be very high and the bridge across the line L_1 will be without substantial effect. If the potential on the grids be adjusted so that it is less negative, current can flow between the filaments and plates of the tubes so that the impedance of the plate circuits of the tubes will be relatively low. The minimum impedance will, of course, depend upon the character of the tubes employed but for the case of an ordinary vacuum tube such as is used for telephone repeater purposes, it might be in the neighborhood of 2,000 ohms. As an impedance of 2,000 ohms will not, in general, constitute a sufficient shunt across the circuit L_1 to disable it, this impedance may be stepped down to a very low value by means of a step-down transformer 14. Consequently, when the potential of the grids is so changed as to permit a maximum current to flow in the output circuits of the tubes, the line L_1 will, in effect, be shunted by an impedance which constitutes practically a short circuit, although it will be understood that this impedance may be given a somewhat higher value if desired.

The arrangement for controlling the potential upon the grids of the tubes 1 and 1′ comprises a battery 2 connected between the filaments of the tubes 1 and 1′ and the grids thereof through a resistance 3 so that normally the grids have a high negative potential with respect to the filament and no appreciable current is shunted away from the line L_1 when speech currents pass over it. In order to vary the potential applied to the grid when transmission takes place over the line L_2 a vacuum tube amplifier 4 is arranged with its input circuit bridged across the line L_2. This amplifier is shown as comprising a single vacuum tube, but obviously any combination of tubes or any other type of amplifying device might be used to secure the desired result. The secondary winding of the output transformer of the amplifier tube comprises two parts 5 and 6 which are connected through rectifiers 7 and 8 and a resistance 10 to one terminal of a condenser 11 which is connected in parallel with the resistance 3 of the grid filament circuit of the vacuum tubes 1 and 1′. The common point of the windings 5 and 6 is connected to the opposite terminal of the condenser 11 through a battery 9, whose purpose will be described later. The rectifiers 7 and 8 may be of any well known type but are shown as two-element vacuum tubes.

When an alternating voltage is impressed upon the amplifier 4 it sets up electromotive forces in the windings 5 and 6 which cause a direct current to flow through the rectifiers to charge the condenser 11 through the resistance 10. The windings 5 and 6 are so connected that the half waves of one polarity are sent through rectifier 7 while the other half waves are sent from the winding 6 through the rectifier 8, but both tend to charge the condenser 11 in the same direction. The use of two windings and two rectifiers is not essential to the operation of the system but tends to make the charging of the condenser more rapid, thereby increasing the speed of operation of the system. The rectified potential is applied to the condenser 11 in such a direction as to make the potential of the grids less negative with respect to the filament so that the apparatus comprising the tubes 1 and 1′ operates as previously described to shunt the line L_1 and thus reduce and substantially extinguish transmission over this line. In other words, the windings 5 and 6 and the rectifiers 7 and 8 are so connected that the potential applied across the terminals of the condenser 11 tends to oppose the normal negative potential due to the battery 2.

It is desirable and is, in fact, one of the objects of the invention that the shunt be placed upon the line L_1 as nearly instantaneously as possible. It therefore becomes desirable to arrange the condenser 11 so that it will be charged as quickly as possible. If the resistance 10 were not present the condenser 11 would be instantaneously charged to the full rectified voltage and hence the operation of the echo suppressor to apply the shunt to the line L_1 would be instantaneous. It is necessary to provide the resistance 10, however, in order to enable the use of the rectifier 13 and battery 12, which serve to limit the potential to which the condenser 11 may be charged, as will be described later. The presence of the resistance 10 prevents the condenser 11 from attaining its full charge immediately, although the time required for the condenser to attain the necessary charge for satisfactory operation may be cut down in a manner to be described later.

The resistance 3 is made large so that the charge in the condenser 11 will be retained for a sufficient time after the transmission over the line L_2 has ceased, to take care of the fact that it requires a definite time for the last wave of voice current from the line L_2 to pass back over the line L_1 as an echo and arrive at the point where the shunt is applied through the transformer 14. This so-called "hangover" interval is required in all echo suppressor systems. The speed with which the condenser 11 discharges, and consequently the effective length of this hangover interval, can be adjusted by changing the magnitude of the resistance 3. With given values of resistance 3 and with a given capacity of the condenser 11 the time required for the condenser to discharge and hence for the system to be restored to the free transmitting condition depends upon the charge in the condenser 11. In other words, the hangover interval will be long when loud volumes of speech are passing over the line L_2 and shorter when the volume of speech is low. The reason that this is so will be explained later but it is this fact that necessitates the provision for the rectifier 13 and battery 12 to limit the potential to which the condenser 11 is charged.

It will be noted that the rectifier 13 and the batteries 12 and 2 in series are connected in parallel with the condenser 11. The batteries 2 and 12 are series-aiding and are so poled with respect to the rectifier 13 that they oppose current flowing through this rectifier from the rest of the circuit. On the other hand, the rectifier 13 is so connected with respect to the circuit including the windings 5 and 6 and the rectifiers 7 and 8 that the rectified potential which charges the condenser 11 is in such a direction as to tend to cause a current to flow through the rectifier 13. Consequently, as soon as the rectified potential is raised high enough to overcome the opposing potential of the batteries 2 and 12 in series, current flows through the rectifier 13 and through the batteries 12 and 2 in series, thereby shunting the condenser 11 and preventing the potential applied to its terminals from rising appreciably higher. The combined potential of the batteries 2 and 12 is so set that the rectifier 13 will come into play at a potential somewhat greater than that which is necessary to cause the proper operation of the tubes 1 and 1′ to shunt the line L_1. It will be obvious, of course, that if the resistance 10 were not present the rectifier 13 could not exercise any shunting effect on the condenser 11, but the full rectified potential would be applied to said condenser in any case.

It will be recalled that the resistance 3 was provided to regulate the hangover time required for the capacity 11 to discharge, and that the resistance 10 was provided to enable the by-pass circuit through the rectifier 13 to limit the potential applied to the condenser 11. It is, of course, desirable that the condenser 11 be charged to the limited value as quickly as possible and that the time of discharge shall be independent of the rectified potential supplied by rectifiers 7 and 8 so that the hangover time will always be the same. In order to understand how the condenser 11 and its associated apparatus accomplish this result, reference may be had to the curves of Fig. 3.

In this figure, let E_1 represent the potential which must be applied across the terminals of the condenser 11 in order to bring the potential of the grids of the tubes 1 and 1′ to the desired value to disable the circuit L_1. If, now, a rectified potential E_4 is applied to the circuit leading to the terminals of the condenser 11 and this circuit includes no resistance, it will be obvious that the condenser would be fully charged to the potential E_4 instantly. If, however, resistance 10 is included in series with the condenser and a rectified potential E_4 is applied to the circuit, it will take a definite time to build up to approximately the full potential E_4 across the terminals of the condenser. Now, the time required to build up to substantially the final voltage across the terminals of the condenser will be the same regardless of the magnitude of this voltage, but the time to build up the charge to some definite lesser value such as E_1 will vary with the applied voltage the time required becoming smaller as the voltage becomes greater. This is illustrated by the curves *a* and *b* of Fig. 3 which show the building up of the potential difference between the terminals of the condenser 11 for two different values of applied voltage, E_3 and E_4. These curves both approximately reach their asymptotes E_3 and E_4 in the same length of time, but curve *a* crosses the line corresponding to E_1 in much less time than curve *b*. It is therefore apparent that in the case of the higher applied potential the charge across the condenser is built up to E_1 much more quickly than in the case of the lower potential represented by curve *b*. With a high resistance 10 in the circuit, the amplifier 4 should amplify the voice currents sufficiently to produce a much higher rectified potential than is actually necessary to produce the desired charge across the condenser 11.

Let us now suppose that the potential to which the condenser is charged is limited so that it does not rise above the value E_2. If, when the applied potential ceases, the condenser were short-circuited the potential would instantly drop from E_2 to zero. As already stated, however, it is desirable to have a definite hangover time; consequently the resistance 3 is provided and it may be adjusted to give any desired hangover time. The curves *d*, *e* and *f* represent the manner in which the condenser discharges with different values of the resistance 3. The time required for the charge to drop to value E (at which it may be assumed that the relay tubes 1 and 1′ no longer disable the line L_1) will be much less when the resistance 3 is small, as represented by the curve *f*, than when the resistance is large, as represented by the curve *e*. The resistance 3 alone determines the time required to discharge the condenser to a given minimum value as there is no discharge path through the rectifier 13 due to the opposing voltage of the batteries 2 and 12, or through the rectifiers

7 and 8 owing to the fact that these rectifiers are non-conductive for the direction in which the discharge would take place.

The desirability of preventing the condenser 11 from being charged above a predetermined maximum limit such as E_2 will be evident from a comparison of the curves *d* and *g*. The curve *d* represents the discharge of the condenser from a value E_2 for a given adjustment of the resistance 3. Similarly, the curve *g* represents the discharge of the condenser from a value E_4 with the same resistance. Now, obviously, the time required for the condenser to discharge to the value E in the two cases is markedly different. Since it is necessary to apply a large rectified potential in order to produce a quick charge of the condenser to the operating value, the desirability of preventing the condenser from charging to a value materially greater than the operating value becomes at once apparent, because satisfactory behavior of the suppressor requires that the hangover interval be substantially constant.

A further feature of the circuit of Fig. 1 resides in the provision of the battery 9, which is for the purpose of making the system discriminate against noise and enable a larger gain to be used in the amplifier 4. The battery 9 is so poled that its electromotive force is opposed to the current which will pass through the rectifiers 7 and 8. Consequently, before any current can pass through the rectifiers the applied potential must be greater than the electromotive force of the battery 9 and, of course, it must be in the opposite direction. The battery 9 is so adjusted that the normal noise on the line L_2 will be insufficient to pass current through the rectifiers 7 and 8 and consequently the noise will produce no charge in the condenser 11. When, however, the speech volume becomes great enough to override the noise, condenser 11 is charged and the transmission over the line L_1 is interrupted. Since the influence of the line noise is counteracted by the electromotive force of the battery 9, the gain of the amplifier 4 may be made as great as necessary in order to produce the prompt charging of the condenser 11 and the proper operation of the vacuum tubes 1 and 1′. Of course, if the gain of the amplifier 4 is increased the voltage of the battery 9 must also be raised to offset the larger effect of noise but the excess of speech over wire will also be increased.

A modified arrangement is shown in Fig. 2 in which the vacuum tube relay operates to disable the echo path, but the hangover time is determined by a mechanical relay. The vacuum tube relay comprises vacuum tubes 1 and 1′ as before, the operation of these tubes being controlled by building up a charge across the terminals of the condenser 11. The circuit for charging the condenser includes the rectifiers 7 and 8 and transformer windings 5 and 6, just as in the case of Fig. 1, but in the present instance the limiting arrangement comprising the rectifier 13 and the battery 12 is not necessary since the resistance 3 will be made sufficiently low to cause a quick discharge of the condenser, and the hangover time will be determined by the slow-release relay 21, to be described later. As no limiting device is required, the resistance 10 may be omitted and consequently when voice currents are applied to the input of the amplifier 4 the rectified potential produced by the rectifiers 7 and 8 charges the condenser 11 rapidly, with the result that the relay comprising the tubes 1 and 1′ promptly disables the line L_1.

An additional winding 15 is provided for the transformer in the output circuit of the amplifier 4 and a rectifier tube 16 is connected to this additional winding so that the amplified voice currents from the amplifier 4 will be rectified and the direct current component of the rectified current will be passed through the winding of a relay 17. A condenser 18 is bridged across the output circuit of the rectifier 16 to by-pass the alternating component of the rectified current. The relay 17 closes, by means of its contact 19, a local circuit including a battery 20 and the slow-release relay 21. The relay 21 does not pull up its armature instantly, but when it does pull up its armature, closes contact 22 to short circuit or otherwise disable the line L_1 independently of the shunt through the transformer controlled by the vacuum tube relay. An instant later the contact 23 opens and removes the rectified charging current from the condenser 11. The condenser then discharges through the resistance 3 and removes the effective shunt through the transformer 14. The line L_1 is now held disabled at contact 22 as long as the voice currents are applied through the amplifier 4 to the rectifier 16. When the voice currents cease the relay 21 releases after a hangover interval determined by its time of release and the short circuit is then removed from the line L_1.

It will be noted that here the vacuum tube relay arrangement operates to disable the line L_1 rapidly. After an interval the line is held in a disabled condition by the mechanical relay 21 and the vacuum tube relay is released, the disabling of the line being thereafter under the control of the mechanical relay. The hangover time being determined by the slow-release relay will always be the same for a particular adjustment of said relay and will not be determined by the potential required to charge the condenser 11.

It will be obvious that the general principles herein disclosed may be embodied in many other forms and arrangements without departing from the spirt and scope of the appended claims.

What is claimed is:

1. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its plate circuit bridged across one of said paths, means to apply a normal potential to the grid of said tube to maintain the impedance bridged across said path large, and means responsive to signaling currents transmitted over the other path to change the grid potential to reduce the output impedance of said tube, thereby disabling said first mentioned path.

2. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its plate circuit bridged across one of said paths, means to apply a normal potential to the grid of said tube to maintain the impedance bridged across said path large, means responsive to signaling currents transmitted over the other path to produce a potential determined by said signaling currents, and means to apply said potential to the grid of said tube in such a direction as to reduce the output impedance, thereby disabling said first mentioned path.

3. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its plate circuit bridged across one of said paths, means to apply a normal potential to the grid of said tube to maintain the impedance bridged across said path large, means to apply a rectified potential corresponding to signaling currents from the other transmission path to the grid of said vacuum tube in such a direction as to reduce the output impedance, thereby disabling said first mentioned path.

4. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its plate circuit bridged across one of said paths, means to apply a normal potential to the grid of said tube to maintain the impedance bridged across said path large, a storing device associated with said grid circuit, and means to apply a rectified potential corresponding to signaling currents from the other path to charge said storing device in such a direction as to reduce the output impedance of the tube and disable said first mentioned path.

5. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its plate circuit bridged across one of said paths, means to apply a normal potential to the grid of said tube to maintain the impedance bridged across said path large, a storing device associated with said grid circuit, means to apply rectified potential corresponding to signaling currents from the other path to charge said storing device in such a direction as to reduce the output impedance of the tube and disable said first mentioned path, and means to limit the rectified potential applied to said storing device.

6. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its plate circuit bridged across one of said paths, means to apply a normal potential to the grid of said tube to maintain the impedance bridged across said path large, a storing device associated with said grid circuit, means to apply rectified potentials corresponding to signaling currents from the other path to charge said storing device in such a direction as to reduce the output impedance of the tube and disable said first mentioned path, and means to prevent the application of rectified potential to said storing device in response to weak currents of the order of noise currents transmitted over said second transmission path.

7. A transmission system comprising a pair of transmission paths for transmitting in opposite directions, a disabling relay associated with one of said paths comprising a pair of vacuum tubes connected in a push-pull circuit with the plate circuits of said tubes bridged across said path, means to apply a normal potential to the grids of said tubes such that the impedance of the plate circuit will be substantially infinite, and means responsive to signaling currents transmitted over the other path to change the potential of said grids to reduce the output impedance, thereby disabling said first mentioned path.

8. A transmission system comprising a pair of transmission paths for transmitting in opposite directions, a disabling relay associated with one of said paths comprising a pair of vacuum tubes connected in a push-pull circuit with the plate circuit of said tubes bridged across said path, means to apply a normal potential to the grids of said tubes such that the impedance of the plate circuit will be substantially infinite, means responsive to signaling currents transmitted over the other path to produce a potential determined by said signaling currents, and means to apply said potential to the grids of said tubes to reduce the output impedance and thereby disable said first mentioned path.

9. A transmission system comprising a pair of transmission paths for transmitting in opposite directions, a disabling relay associated with one of said paths comprising a pair of vacuum tubes connected in a push-

pull circuit with the plate circuits of said tubes bridged across said path, means to apply a normal potential to the grids of said tubes such that the impedance of the output circuit will be substantially infinite, means to apply a rectified potential corresponding to signaling current from the other transmission path to the grids of said tubes in such a direction as to reduce the output impedance, thereby disabling said first mentioned path.

10. A transmission system comprising a pair of transmission paths for transmitting in opposite directions, a disabling relay associated with one of said paths comprising a pair of vacuum tubes connected in a push-pull circuit with the plate circuits of said tubes bridged across the said path, means to apply a normal potential to the grids of said tubes such that the impedance of the plate circuit will be substantially infinite, a storing device included in the common path of the grids of said tubes, and means to apply rectified potential corresponding to signaling currents from the other path to charge said storing device in such a direction as to reduce the output impedance of the tubes and disable said first mentioned path.

11. A transmission system comprising a pair of transmission paths for transmitting in opposite directions, a disabling relay associated with one of said paths comprising a pair of vacuum tubes connected in a push-pull circuit with the plate circuits of said tubes bridged across said path, means to apply a normal potential to the grids of said tubes such that the impedance of the plate circuit will be substantially infinite, a storing device included in the common path of the grids of said tubes, means to apply rectified potential corresponding to signaling currents from the other path to charge said storing device in such a direction as to reduce the plate impedance of the tubes and disable said first mentioned path, and means to limit the rectified potential applied to said storing device.

12. A transmission system comprising a pair of transmission paths for transmitting in opposite directions, a disabling relay associated with one of said paths comprising a pair of vacuum tubes connected in a push-pull circuit with the plate circuit of said tubes bridged across the said path, means to apply a normal potential to the grids of said tubes such that the impedance of the plate circuit will be substantially infinite, a storing device included in the common path of the grids of said tubes, means to apply rectified potential corresponding to signaling currents from the other path to charge said storing device in such a direction as to reduce the plate circuit impedance of the tubes and disable said first mentioned path, and means to prevent the application of rectified potential to said storing device in response to weak currents of the order of noise currents transmitted over said second transmission path.

13. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a three element vacuum tube having its circuit so associated with one of said paths as to disable said path without producing clicks therein when said tube is operated, means to normally apply a potential to the controlling electrode of said tube to prevent said tube from disabling said path, and means responsive to signaling currents transmitted over said other path to cause said tube to quickly disable said first path.

14. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a three element vacuum tube having its circuit so associated with one of said paths as to disable said path without producing clicks therein when said tube is operated, means to normally apply a potential to the controlling electrode of said tube to prevent said tube from disabling said path, means responsive to signaling currents transmitted over said other path to cause said tube to disable said first path, and means to maintain said first path disabled for a predetermined time after said signaling currents have ceased.

15. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its circuit so associated with one of said paths as to disable said path without producing clicks therein when said tube is operated, means to normally prevent said tube from disabling said path, means responsive to signaling currents transmitted over said other path to cause said tube to disable said first path, and means to maintain said first path disabled after said signaling currents have ceased for a predetermined time which is substantially independent of the strength of said signaling currents.

16. In a transmission system, two one-way transmission paths for transmitting in opposite directions, a vacuum tube having its circuit so associated with one of said paths as to disable said path without producing clicks therein when said tube is operated, means to normally prevent said tube from disabling said path, means responsive to signaling currents transmitted over said other path to cause said tube to disable said first path, and means to prevent said tube from responding to weak currents of the order of noise curre ts.

In testimo whereof, I have signed my name to this s ecification this 17th day of September 1925.

GEORGE CRISSON.