Aug. 8, 1933. H. A. AFFEL 1,921,063

TREATMENT OF ECHOES IN TRANSMISSION SYSTEMS

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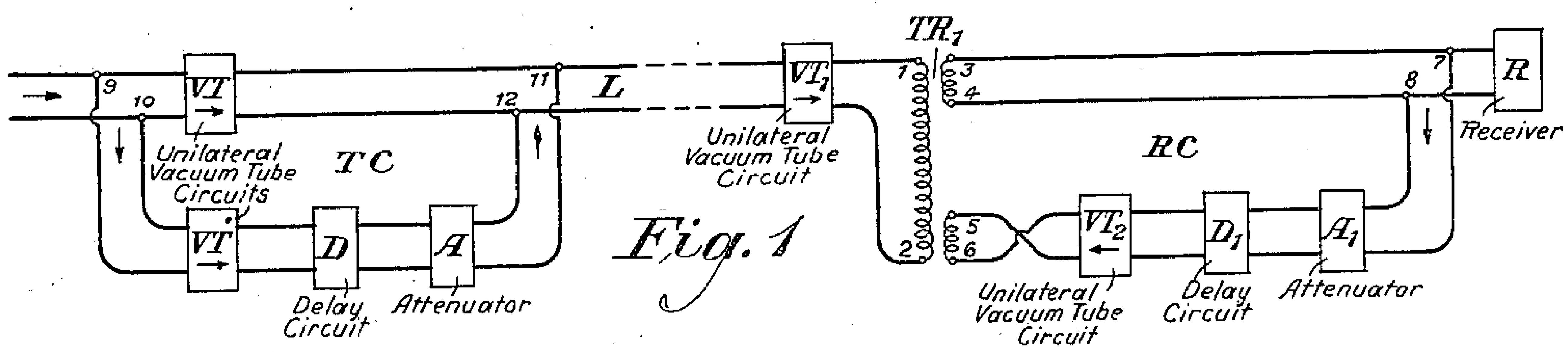

Fig. 1

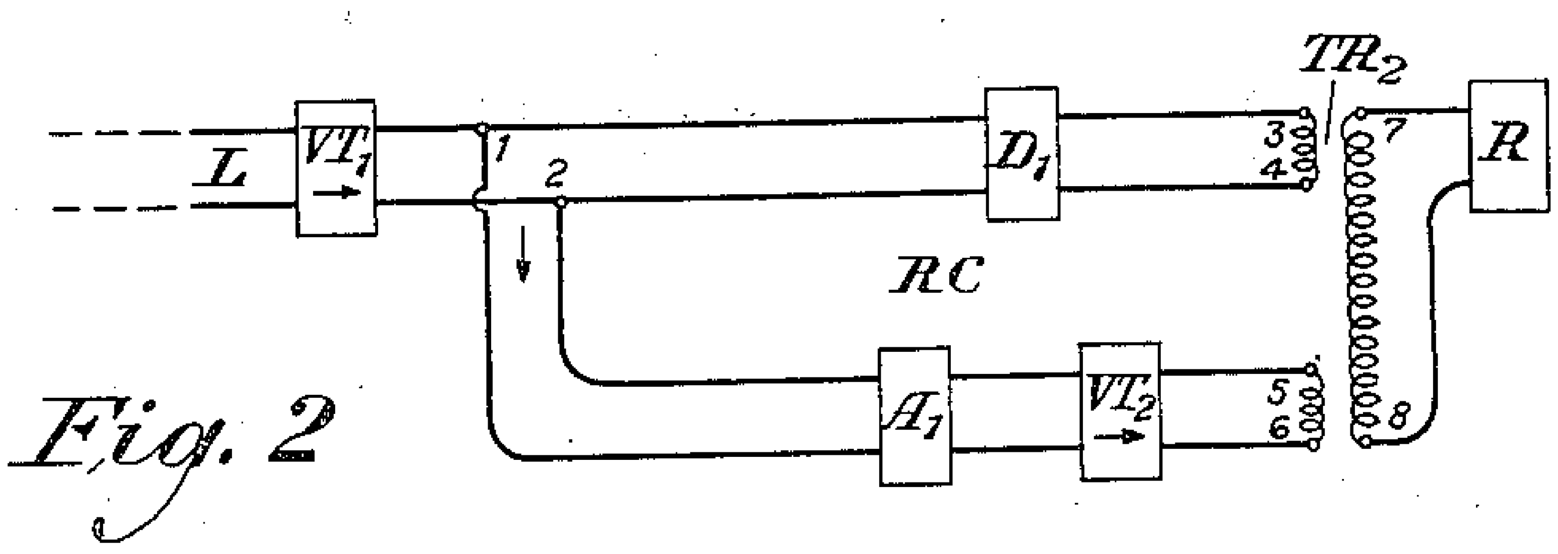

Fig. 2

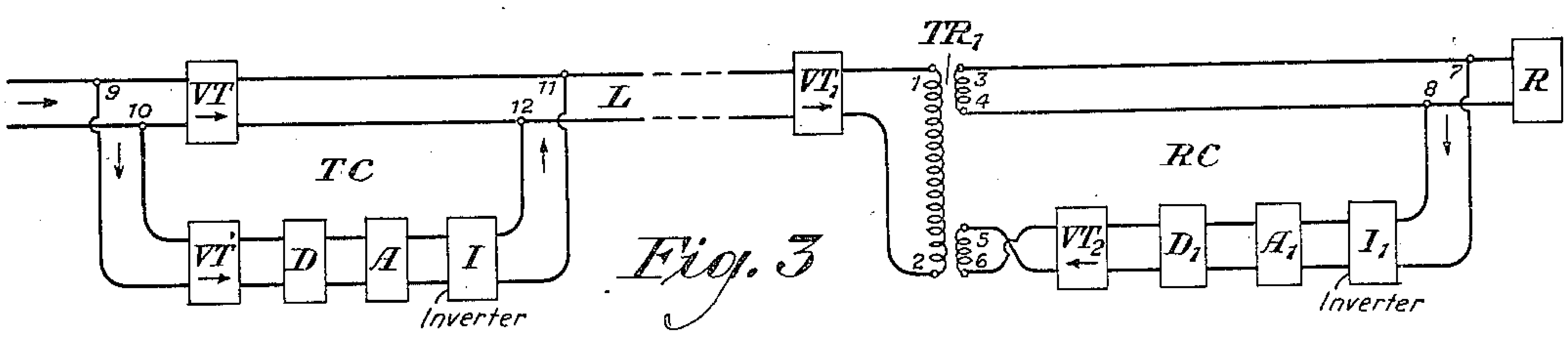

Fig. 3

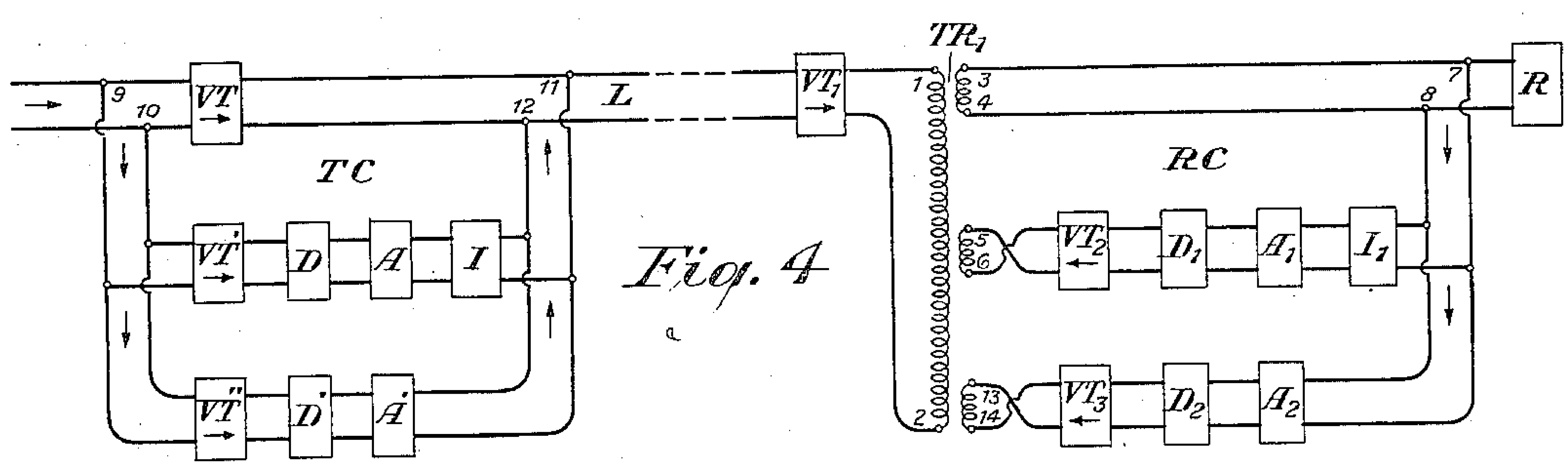

Fig. 4

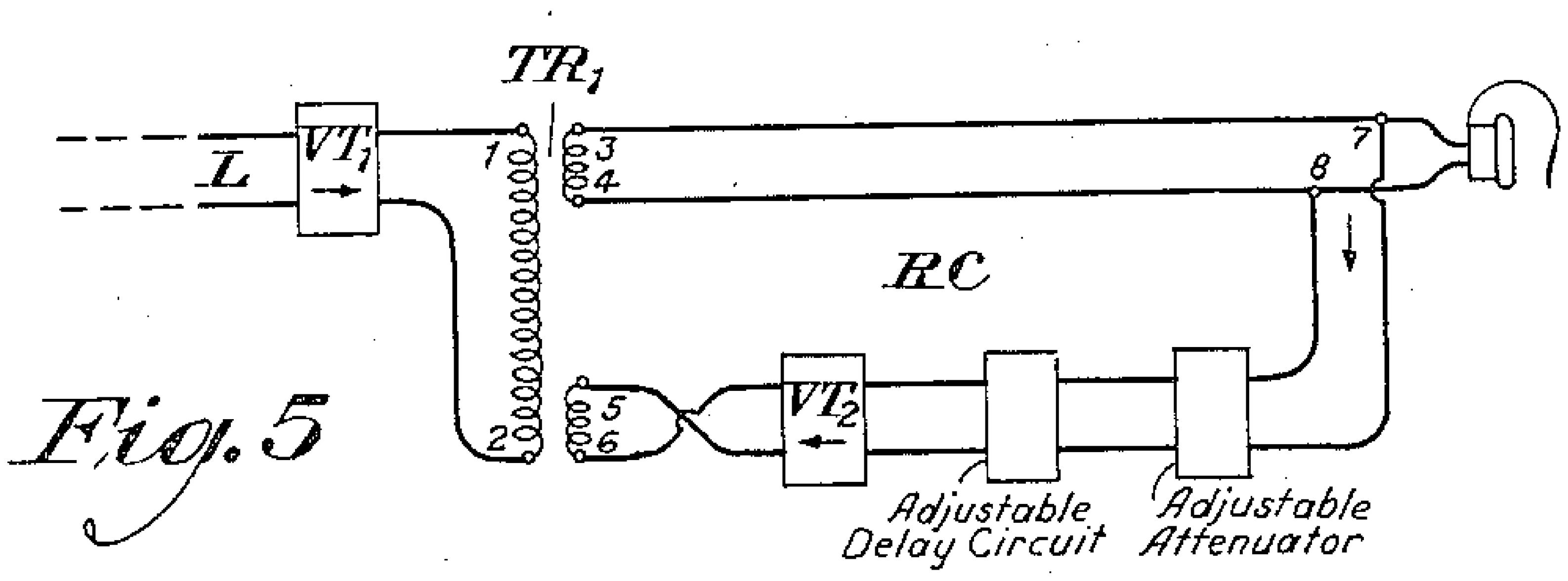

Fig. 5

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TREATMENT OF ECHOES IN TRANSMISSION SYSTEMS

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18 Claims. (Cl. 178—44)

This invention relates to transmission systems, and more particularly to signaling systems in which echoes of the original waves are introduced.

One of the objects of the invention is the elimination or reduction of echo effects at the receiving end of a transmission system.

Another object of the invention is the decrease of intelligibility of the signals during transmission.

The fundamental idea involved in the invention is the balancing out of the echoes transmitted to the receiving circuit by echoes artificially produced in that circuit. This canceling operation permits the elimination of echoes unavoidably transmitted; it also permits the artificial introduction at the transmitting end of the system of echoes which serve to decrease the intelligibility of the signals during transmission, since these distorting echoes can be removed in the receiving circuit.

Other objects and features of the invention will appear from the following discussion and from the following detailed description of specific applications of the inventive ideas.

The descriptive matter appearing hereinafter is to be read with reference to the accompanying drawing, which presents a series of schematic disclosures of applications of the invention.

Figure 1 of the drawing indicates the generation of echoes at the transmitting end of a system, which generation may be artificial and for the purpose of introducing secrecy, and shows at the receiving end of the system an arrangement for balancing out the transmitted echoes when the echo energy is attenuated with relation to the original energy.

Fig. 2 shows a modified arrangement for offsetting the echo effects in a receiving circuit when the echo energy is of greater magnitude than the original energy.

Fig. 3 shows an arrangement for producing secrecy, in which distortion is introduced at the transmitting end additional to that indicated in Fig. 1 and in which the distorted waves are canceled out at the receiving end of the system.

Fig. 4 shows a somewhat more complex arrangement for producing secrecy in the transmission of signals.

Fig. 5 indicates the application of the applicant's fundamental idea to the measurement in the receiving circuit of echoes transmitted over the system.

Like characters of reference in the several figures of the drawing designate corresponding elements.

The origin of echoes in accoustical and electrical transmission systems and the desirability of eliminating the effects of echoes in such systems are well understood in the art. In an auditorium, for instance, the voice of a speaker may be heard over the direct air path to the listener and also over indirect paths involving the reflection of the sound waves from the walls or the ceiling of the auditorium. Again, speech or music may be received from two or more radio transmitters simultaneously, and the transmitters may be connected to the microphone by transmission circuits having different electrical distances. Furthermore, the introduction of appreciable echoes in long two-wire and four-wire telephone circuits has been for some time a problem calling for treatment and solution by telephone engineers.

The appreciable result of an echo is that the original sound is repeated with a time delay of considerable length. The seriousness of the echo effect depends, of course, on the length of the delay and on the magnitude of the echo energy. Since, in practically all cases, echo effects in a receiving circuit are undesirable, various measures are employed either to eliminate the source of the echoes or to reduce the delay interval or the magnitude of the reflected energy, or both, as far as is possible.

As has been stated above, the central idea of the present invention is to balance out the transmitted echoes in the receiving circuit by locally produced echoes of like characteristics. With reference first to Fig. 1 of the drawing, let it be assumed that at the transmitting end TC of a system over which are transmitted waves representing sound, echoes of the original waves are in some manner introduced. The energy transmitted from the transmitting circuit TC over a line L to the distant receiving circuit RC will include not only the original energy but the echo waves. These echo waves are like the original waves in form but are delayed by a certain time interval with relation to the original waves, and it will be assumed that the echo energy is considerably attenuated with relation to the original energy. Thus, the composite wave transmitted may be broken up into components corresponding to time intervals equal to the echo delay. The components corresponding to the consecutive time intervals may be termed *a*, *b*, *c*, *d*, *e*, etc. It will be understood that until the expiration of the first unit of time, the energy received in the receiving circuit RC will represent only the original energy free of echo; that is, during this first time interval there is impressed on the receiving circuit only the component a. In the second time interval there will arrive the second component b, and along with it there will arrive the echo of a multiplied by some factor x, which in the case assumed is a fraction. Similarly, during the third time interval the component c will have added to it xb, which is the echo of the original component b, etc. Thus, the received energy may be represented according to time intervals by the following table:

Time interval	1	2	3	4	5
Composite wave	a	$b+xa$	$c+xb$	$d+xc$	$e+xd$

In the arrangement of Fig. 1 the applicant passes the energy transmitted over line L through a unilateral vacuum tube circuit VT_1 to a transformer TR_1. An output path leads on to a receiver R and a branch circuit is provided for feeding energy back to the transformer TR_1 at the input of the receiving circuit. The terminals of the input winding are designated as 1 and 2, the terminals of the output winding as 3 and 4 and the terminals of the feed-back winding as 5 and 6. In this feed-back circuit are included an attenuator A_1, a delay circuit D_1, and a second unilateral vacuum tube circuit VT_2. The potential applied to the terminals 1—2 follows the table given above. Thus, during the first time interval the wave a is received and is passed on to the receiver R unaffected by the feed-back arrangement. A part of this energy, however, is diverted at point 7—8 and is returned to the input circuit through winding 5—6, is attenuated by x in A_1, and is subjected to a delay in D_1 which is equal to the delay of the transmitted echo with relation to the original wave. It will be understood that the unilateral device VT_2 introduces neither gain nor loss. It will now be understood that just as the energy of the second time interval $b+xa$ reaches the transformer TR_1, the artificially produced wave xa is fed back to the terminals 5—6 of the transformer; it will be understood further that if this fed back energy is opposed to the incoming energy, as indicated in Fig. 1, the transmitted echo xa and the locally produced echo xa oppose each other, and since the potentials are of equal magnitude the two echoes are balanced out and the resultant wave which passes on to the receiver R is b, free of the echo xa.

Similarly, a part of b is diverted at the point 7—8, is attenuated and delayed in the feed-back circuit, and serves to balance out the echo xb which accompanies the wave c corresponding to the third time interval, etc. It is thus seen that while the energy which is transmitted and received represents the signal accompanied by a substantial echo, the energy finally passed on to the receiver R is free of echo.

It will be understood that the unilateral device VT_1 prevents the echo balancing currents from returning to the line L, and that the unilateral device VT_2 serves to permit the balancing currents to pass in only one direction.

It is evident to those skilled in the art that unless the feed-back circuit of Fig. 1 involves a net loss, there will be a tendency toward singing in the receiving circuit RC. Thus, it is seen that the arrangement of Fig. 1 will function well if the echo attenuation factor x represents a considerable difference of magnitude between the original energy and the reflected energy. Since, however, there are echoes which exceed the original energy in magnitude, it becomes desirable to provide a modification of the arrangement of Fig. 1, which is not subject to the hazard of singing. Such an arrangement is indicated in Fig. 2.

In the case of Fig. 2, the energy coming in over line L from a distant transmitting point is passed through a unilateral vacuum tube circuit VT_1 and is caused to divide at point 1—2. A portion of the energy passes over the upper branch through a delay circuit D_1 to the terminals 3—4 of a transformer TR_2. The other portion of the energy passes over the lower branch and through an attenuator A_1 and a unilateral device VT_2 to the terminals 5—6 of the transformer TR_2. These two portions of the incoming energy are then combined so as to oppose each other and to produce a resultant potential across the winding 7—8 of the transformer TR_2. This output is then passed on to the receiver R.

The incoming energy which is divided according to time intervals equal to the delay time, may be represented by the following table:

Time interval	1	2	3	4	5
Composite wave	a	$b+ya$	$c+yb$	$d+yc$	$e+yd$

It is understood that y may be greater than unity. Since the delay introduced in D_1 is equal to the echo delay, the wave appearing at terminals 3—4 of the transformer TR_2 may be represented as follows:

Time interval	1	2	3	4	5
Composite wave	O	a	$b+ya$	$c+yb$	$d+yc$

In other words, the transmitted wave is delayed by one time unit. The energy which is passed through the attenuator A_1 will appear at terminals 5—6 of the transformer as follows:

Time interval	1	2	3	4	5
Composite wave	$\frac{a}{y}$	$\frac{b}{y}+a$	$\frac{c}{y}+b$	$\frac{d}{y}+c$	$\frac{e}{y}+d$

When these two branch path outputs are combined in opposition in the transformer TR_2, there results across the terminals 7—8 of the transformer a wave which may be represented as follows:

Time interval	1	2	3	4	5
Composite wave	$\frac{a}{y}$	$\frac{b}{y}$	$\frac{c}{y}+ya$	$\frac{d}{y}+yb$	$\frac{e}{y}+yc$

It is seen that the arrangement of Fig. 2 fails to produce the echo elimination of the arrangement of Fig. 1. There is, however, a considerable improvement introduced with a large reduction of the echo effect. It will be seen from the last tabular picture that there is some distortion of the original signal but that the distorting components are greatly attenuated. This is, of course, a favorable condition as compared with that in which the signal is accompanied by an echo of greater intensity than the original energy.

With reference again to Fig. 1 of the drawing, it has been stated that the arrangement therein disclosed—and also the arrangement disclosed in Fig. 2—serves to improve the reception in the receiving circuit RC of signals transmitted from the distant transmitting circuit TC. In the normal case, of course, the echoes generated in TC are unavoidable and the only thought is to eliminate or reduce the objectionable effect at the receiving end of the system. However, the applicant's balancing arrangement at the receiving end permits the artificial distortion of the transmitted energy at the transmitting end, for the purpose of reducing the intelligibility of the signals during transmission with a view to secrecy. In the arrangement of Fig. 1, the energy traveling over the line L is divided at the point 9—10. The portion of the energy passing over the upper branch reaches the point 11—12 without distortion. The portion which passes through the lower branch, however, is subjected to a delay in the delay circuit D and preferably to an attenuation in the attenuator A. Accordingly, when this portion of the energy is recombined with the other at points 11—12, the energy sent on over the line L has the form of the original signal accompanied by an echo. It will be understood that the unilateral vacuum tube circuits VT and VT' are included to insure the unilateral action of the branch paths and may introduce gain or loss if desired for other purposes. When the distorted energy reaches the distant receiving circuit RC, it is, of course, desirable to restore the normal intelligibility of the signal, and the above-described technique is employed whereby echoes are produced in the receiving circuit and are opposed to the incoming echoes transmitted from the transmitting end.

The idea just discussed can, of course, be carried to a further point as indicated in the arrangements of Figs. 3 and 4. In Fig. 3 at the transmitting circuit TC there is introduced not only the distortion of the artificially introduced echo but also the distortion of frequency inversion. In the lower branch path of the circuit TC, along with the delay circuit D and the attenuator A, is included an inverter I. As is well understood in the art, this device is a modulator-like circuit in which the high frequencies of the signal apppear as low frequencies, and the low frequencies as high. For instance, the inversion may be arranged to take place over a frequency range of about 3000 cycles: a speech frequency of 300 cycles, for instance, will appear in the output of the inverter as 2700 cycles and, similarly, a high speech frequency of 2500 cycles, for instance, will appear in the output as 500 cycles. At the receiving circuit RC the feed-back arrangement of Fig 1 is employed, and to the attenuator A_1 and the delay circuit D_1 is added an inverter I_1. The distorted wave produced at the terminals 5—6 of the transformer TR_1 is opposed to the distorted wave transmitted for the purpose of secrecy, and the two are canceled out, leaving the signal of normal intelligibility to be passed on to the receiver R.

In the arrangement of Fig. 4, the energy in the transmitting circuit TC is divided between three branch paths. The first branch path includes merely the unilateral device VT. The second branch includes the unilateral device VT', a delay circuit D and an attenuator A. The third branch path includes a unilateral device VT'', a delay circuit D' and an attenuator A'. It will be understood that the delays introduced by D and D' are different and that the attenuations introduced by A and A' are different. At the receiving end two feed-back circuits are provided, the first including an attenuator A_1 and a delay circuit D_1, and the second including an attenuator A_2 and a delay circuit D_2. In this receiving circuit RC there are differences of delay and attenuation corresponding to those introduced at the transmitting end, and accordingly, waves resulting at the terminals 5—6 and 13—14 of the transformer TR_1 serve to remove the distortion introduced at the transmitting end.

With reference to Fig. 4, it will be understood that the inversion idea of Fig. 3 may be combined with the multiple echo idea of Fig. 4. If this is desired, an inverter I is included in one of the branch paths, for instance, of the circuit TC, and correspondingly, an inverter I_1 is included in one of the feed-back circuits of the circuit RC.

In general, the transmission loss and the phase shift of the echo path vary with the frequency. Such variations, if known, can be imitated to make the elimination of the echoes complete. Thus it will be understood that in the arrangements of Figs. 3 and 4 forms of distortion other than frequency inversion might well be used.

The fundamental idea of creating artificial echoes in the receiving circuit and causing them to balance out the transmitted echoes, may be applied for the purpose of measuring received echoes. The arrangement of Fig. 5 corresponds to the receiving circuit arrangement of Fig. 1. The original energy components of the received wave are passed on to a receiver, while a portion of each component is diverted at the point 7—8 and after being subjected to attenuation and delay is fed back to the input of the circuit RC in opposition to the incoming echo energy. For the purpose of measuring echoes, the attenuator and the delay circuit of the feed-back circuit should be adjustable. The operator will listen at the receiver and will adjust the attenuator and the delay circuit until the reception is free of echo effect. He will then read or otherwise determine the degree of attenuation introduced in the feed-back circuit and the degree of delay in the delay circuit therein. Since the absence of echo means that there is a balance in the input of the circuit, these determined amounts of attenuation and delay will represent the magnitude and the delay of the received echo.

While the invention has been disclosed in certain embodiments for the purpose of illustration, it is to be understood that such disclosure is not entirely limiting but that the true scope of the invention is to be determined from the appended claims.

What is claimed is:

1. In a system in which waves are transmitted to a receiving circuit and in which echoes are introduced, the method of dealing with the echoes which consists in producing in the receiving circuit echoes having the same characteristics as those previously introduced, and op-

posing to each other in said circuit the transmitted and the locally produced echoes.

2. In a system in which waves representing sound are transmitted to a receiving circuit and in which waves which are echoes of the original waves, delayed with relation thereto, are introduced in the course of the transmission, the method of eliminating the echo waves in the receiving circuit which consists in producing therein echo waves like those produced in the course of the transmission, and opposing to each other in the receiving circuit the transmitted and the locally produced echo waves.

3. In a system in which waves are transmitted to a receiving circuit and in which echoes of said waves are introduced, the method of improving the reception of the waves at the receiving end of the system which consists in dividing the incoming energy into two portions, subjecting one of said portions to a delay, subjecting one of said portions to an attenuation, and combining the two portions in opposition.

4. In a system in which waves representing sound are transmitted to a receiving circuit and in which echoes are introduced having the same forms as the original waves but delayed with relation thereto and having a difference of magnitude therefrom, the method of improving the reception of the sound at the receiving end of the system which consists in dividing the incoming energy into portions, delaying the transmission of one portion by a time equal to the delay of the transmitted echoes, attenuating one portion by the difference in magnitude between the original and the echo energy, and recombining the portions of the received energy in opposition.

5. In a system in which waves representing sound are transmitted to a receiving circuit and in which echoes are introduced having the same forms as the original waves but delayed with relation thereto by a certain time interval and having a difference of magnitude therefrom, the method of improving the reception of the sound at the receiving end of the system which consists in dividing the transmitted energy between branch paths, introducing in one of the branch paths an artificial delay equal to the certain time interval, introducing in one of the branch paths an artificial change of magnitude, and combining the outputs of the branch paths in opposition.

6. In a system in which waves are transmitted to a receiving circuit and in which echoes of such waves are introduced, means in the receiving circuit for producing echoes resembling those transmitted, and means in said circuit for opposing to each other the transmitted and the locally produced echoes.

7. In a system in which waves representing sound are transmitted to a receiving circuit and in which echoes of such waves are introduced in the course of transmission, means in the receiving circuit for producing echoes having equal attenuation and delay with the transmitted echoes, and means for balancing against each other the transmitted and the locally produced echoes.

8. In a system in which waves representing sound are transmitted to a receiving circuit and in which there are introduced echo waves having a certain attenuation and a certain delay with relation to the original waves, the method of eliminating the echo effects in the receiving circuit which consists in diverting a portion of the original energy which has passed the input of said circuit, subjecting the diverted energy to attenuation and delay equal to the attenuation and delay of the transmitted echo, and feeding the attenuated and delayed diverted energy back to said input so as to balance out the incoming echo energy.

9. In a system in which waves representing sound are transmitted to a receiving circuit and in which there are introduced echo waves having a certain attenuation and a certain delay with relation to the original waves, means in the output of the receiving circuit for diverting a portion of the energy passed thereto, means for subjecting the diverted energy to attenuation and delay equal to the attenuation and delay of the transmitted echo, and means for feeding the attenuated and delayed diverted energy back to the input of the receiving circuit in opposition to the incoming echo energy.

10. In a system in which waves representing sound are transmitted to a receiving circuit and in which echoes of said waves are introduced, the method of reducing the echo effects in the receiving circuit which consists in dividing the energy entering the receiving circuit into two portions, subjecting one portion to a delay, subjecting the other portion to an attenuation, and combining the two portions of the energy at the output of the receiving circuit in opposition.

11. In a system in which waves representing sound are transmitted to a receiving circuit and in which there are introduced echo waves like the original waves in form but differing therefrom in magnitude and delayed with relation thereto by a certain time interval, the method of reducing the echo effects in the receiving circuit which consists in dividing the energy entering the receiving circuit into two portions, subjecting one portion to a delay equal to the time interval separating the original waves and transmitted echoes, subjecting the other portion to an attenuation equal to the difference of magnitude between the original waves and the transmitted echoes, and combining the two portions of the energy at the output of the receiving circuit in opposition, substantially as described.

12. In a system in which waves representing sound are transmitted to a receiving circuit and in which there are introduced echo waves, means in the receiving circuit for dividing the incoming energy into two portions, means for delaying the transmission of one of said portions, means for attenuating the other of said portions, and means for combining the two portions in opposition thereafter.

13. In a signaling system, the method of decreasing the intelligibility of the signals during transmission and restoring the normal intelligibility at the receiving end of the system, which consists in producing echoes of the signal waves at the transmitting end, transmitting to the receiving end both the signal waves and the echoes, producing at the receiving end echoes like those produced at the transmitting end, and balancing out at the receiving end the transmitted and the locally produced echoes.

14. In a system for the transmission of signal waves, means at the transmitting end of the system for introducing echoes of the transmitted waves, means at the receiving end of the system for producing echoes of the transmitted waves, and means at the receiving end of the system for canceling out the transmitted and

the locally produced echoes, whereby the intelligibility of the signal waves is decreased during transmission and is restored to normal at the receiving end of the system.

15. In a system for the transmission of signal waves, means at the transmitting end of the system for introducing echoes of the transmitted waves, means at the receiving end of the system for producing echoes of the transmitted waves equal in delay and attenuation to the echoes introduced at the transmitting end, and means at the receiving end of the system for canceling out the transmitted and the locally produced echoes.

16. In a signaling system, the method of decreasing the intelligibility of the signals during transmission and restoring the normal intelligibility at the receiving end of the system, which consists in producing echoes of the signal waves at the transmitting end, inverting the frequency band of the echoes so produced, transmitting to the receiving end both the signal waves and the distorted echoes, producing at the receiving end echoes like those produced at the transmitting end, inverting the frequency band of the echoes so produced, and balancing out at the receiving end the transmitted and the locally produced distorted echoes.

17. In a system for the transmission of signal waves, means at the transmitting end for producing echoes of the signal waves, means for inverting the frequency band of the echoes, means at the receiving end for producing echoes like those produced at the transmitting end, means for inverting the frequency band of the echoes produced at the receiving end, and means at the receiving end for balancing out the transmitted and the locally produced distorted echoes.

18. In a system in which waves representing sound are transmitted to a receiving circuit and in which echoes are introduced, the method of measuring the echoes in the receiving circuit which consists in diverting a portion of the original energy which has passed the input of said circuit, subjecting the diverted energy to attenuation and delay, feeding the diverted energy back to said input so as to oppose the incoming echo energy, observing the sound output of said circuit, adjusting the attenuation and the delay to which the diverted energy is subjected until said output is free of appreciable echo, and determining the degree of attenuation and delay introduced to produce the echo-free result.

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