

Aug. 18, 1931.

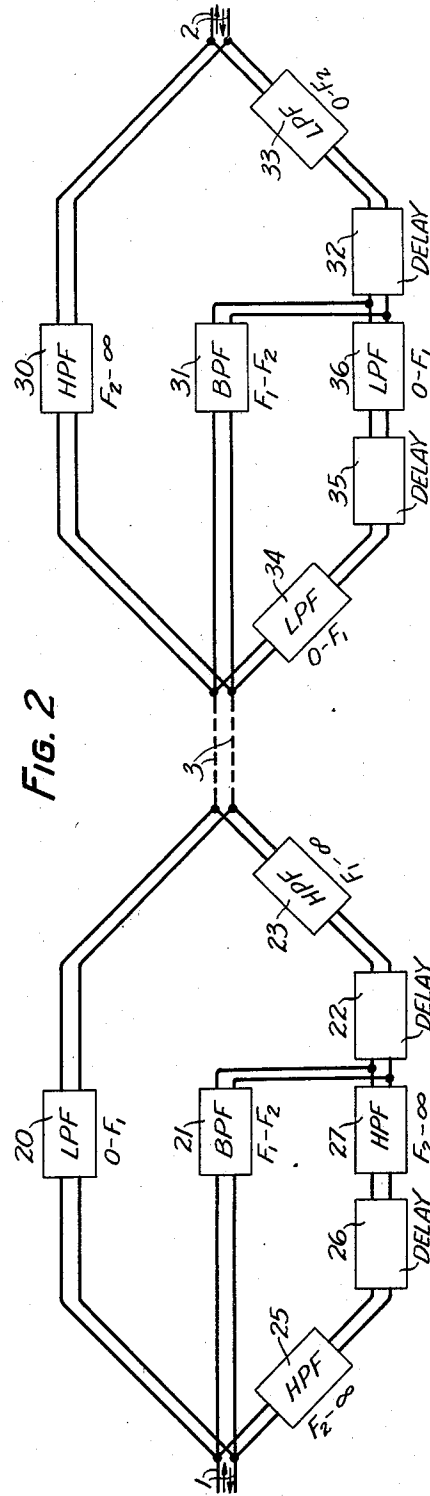
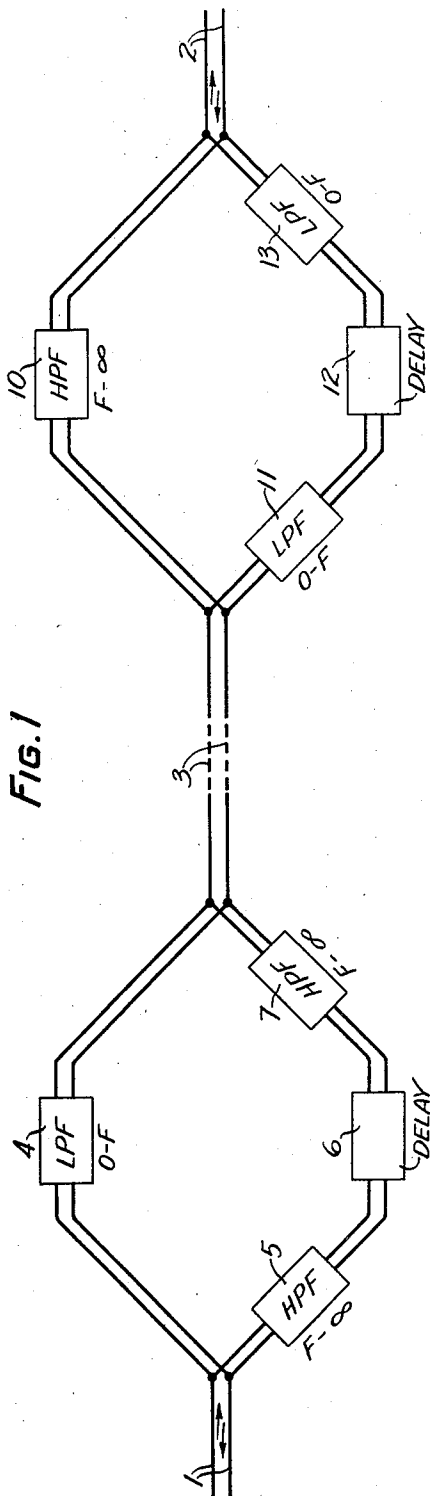
R. C. MATHES

1,819,614

WAVE TRANSMISSION SYSTEM

Filed March 30, 1929

4 Sheets-Sheet 1



INVENTOR
R. C. MATHES
BY *H. A. Burgess*
ATTORNEY

Aug. 18, 1931.

R. C. MATHES

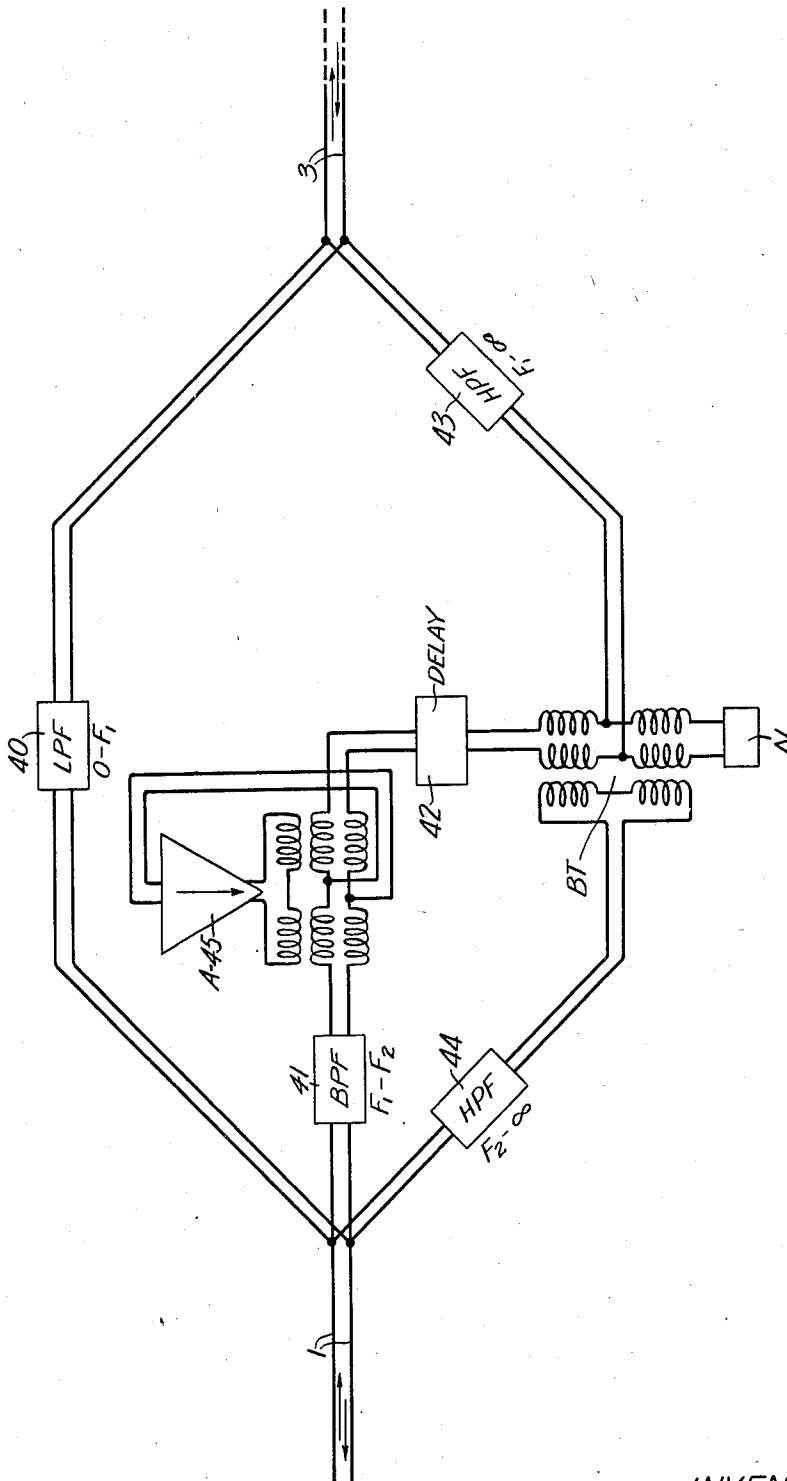
1,819,614

WAVE TRANSMISSION SYSTEM

Filed March 30, 1929

4 Sheets-Sheet 2

FIG. 3



INVENTOR
R. C. MATHES

BY *H. A. Burgess*
ATTORNEY

Aug. 18, 1931.

R. C. MATHES

1,819,614

WAVE TRANSMISSION SYSTEM

Filed March 30, 1929

4 Sheets-Sheet 3

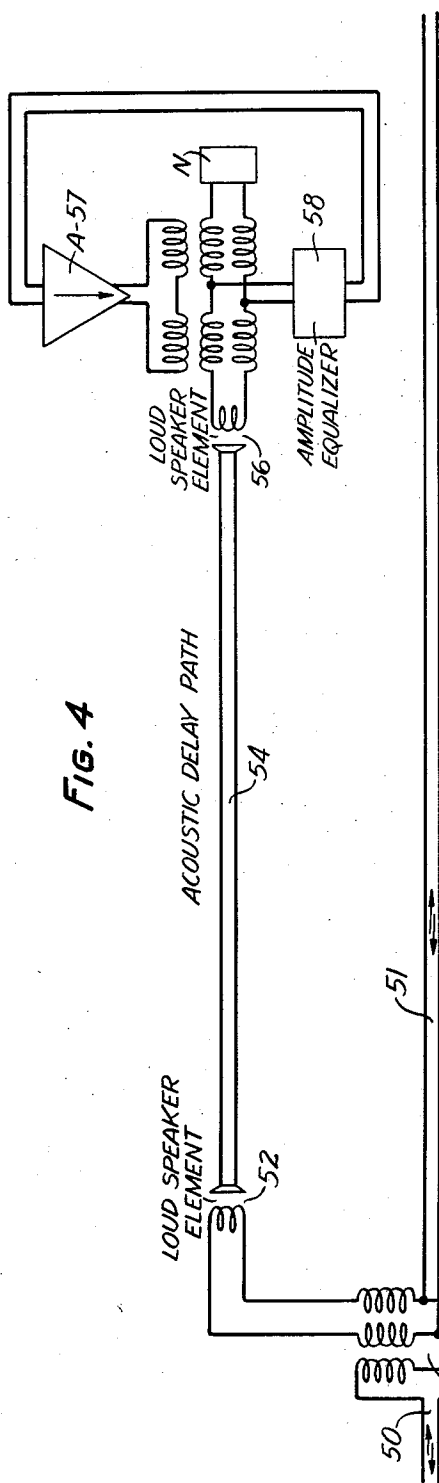


FIG. 4

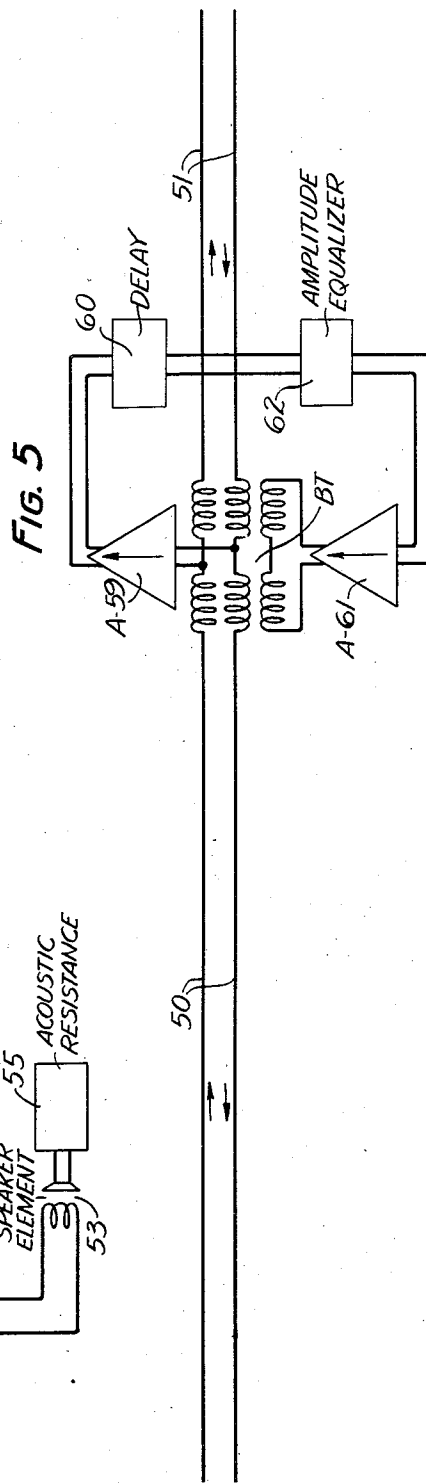


FIG. 5

INVENTOR

R. C. MATHES

BY

H. A. Burgess

ATTORNEY

Aug. 18, 1931.

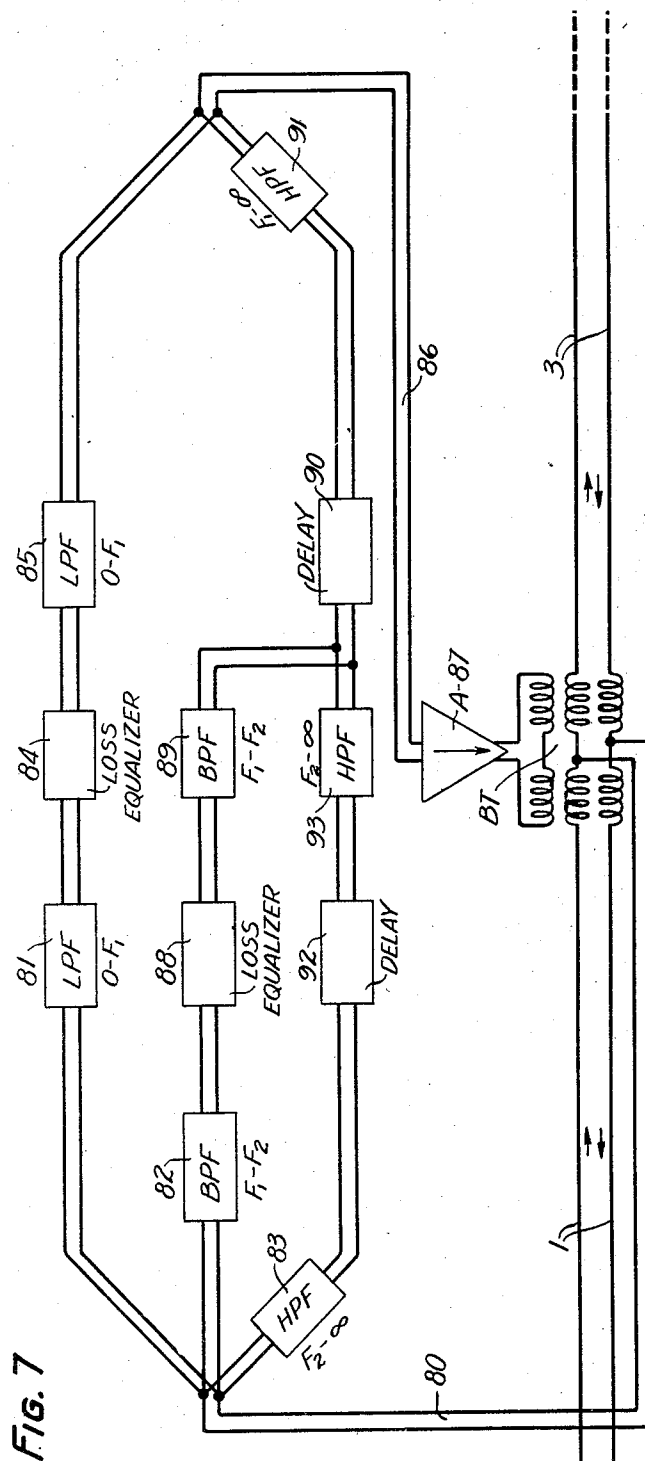
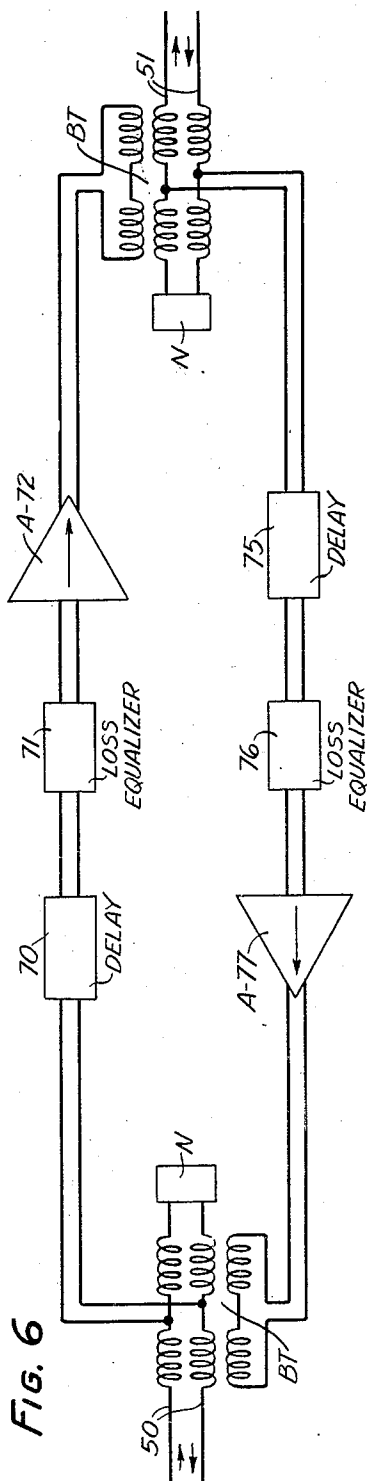
R. C. MATHES

1,819,614

WAVE TRANSMISSION SYSTEM

Filed March 30, 1929

4 Sheets-Sheet 4



INVENTOR
R. C. MATHES
BY *H. A. Burgess*
ATTORNEY

UNITED STATES PATENT OFFICE

ROBERT C. MATHES, OF WYOMING, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

WAVE TRANSMISSION SYSTEM

Application filed March 30, 1929. Serial No. 351,417.

This invention relates to wave transmission and especially to privacy systems of communication.

An object of the invention is economy of privacy apparatus.

A further object is to obtain greater privacy for signals transmitted in a given direction in a two-way signaling system than is obtained by merely the alteration of these signals which occurs before they are sent from their transmitting station.

In one specific form of the invention in which privacy in radio telephony results from relatively delaying frequency bands of speech energy in the general manner disclosed in Mathes Patent 1,542,566, June 16, 1925, privacy apparatus at each of two transmitting and receiving stations in a two-way radio telephone system includes filters for separating the frequency bands of speech energy to be received or transmitted and transmission delay means for relatively delaying the bands transmitted in either direction, and this privacy apparatus is connected in a portion of the system in which waves of the same frequency, transmitted in opposite directions over the systems, pass through the same path. In this system not only does the same delay apparatus serve for both directions of transmission, but the total length of delay paths is economized by having one of two mutually exclusive frequency bands of speech energy that are transmitted in the same direction over the system pass through two portions of a delay path in tandem relationship and having the other band pass through one only of the two portions instead of through a separate delay means of delay time equal to that of the one portion, and moreover, privacy is augmented by delaying the high frequencies more than the low frequencies in sending in one direction and delaying the low frequencies more than the high frequencies in sending in the other direction. This dissimilarity in the kinds of alteration introduced in sending signals from the two intercommunicating stations to reduce their intelligibility as sent out, requires that a listener-in have two separate receiving systems, and if the same frequencies be

transmitted in both directions, each of the receiving systems will need to have a sharp directional selectivity, a requirement very difficult to meet except in limited areas in relation to the two transmitting stations.

Other objects and features of the invention will be apparent from the following description and claims.

Fig. 1 shows a secret transmission system embodying one form of the invention; Fig. 2 shows a secret transmission system embodying a second form of the invention; Fig. 3 shows one terminal of a secret transmission system embodying a third form of the invention; Figs. 4, 5 and 6 show each a different delay means embodying a form of the invention and suitable for use in the systems of Figs. 1, 2 and 3; and Fig. 7 shows a form of secret transmission system embodying still another form of the invention.

In Patent 1,542,566, mentioned above, is shown a method for securing secrecy in telephone conversations for transmission and reception over a radio system. This method consists in dividing the speech energy into frequency bands and displacing these bands relatively to one another in time.

Fig. 1 of the attached drawings shows how, with two-way delay circuits, economy in the use of delay apparatus in practicing that method may be secured in a two-way transmission system, as for example a two-way radio or wire telephone system, by using the same delay circuits for transmission in both directions. In this system, secrecy is augmented by delaying the high frequencies more than the low frequencies in sending in one direction and the low frequencies more than the high frequencies in sending in the opposite direction. The system transmits speech in both directions between line 1 at one terminal, which for convenience may be referred to as the west terminal, and line 2 at the other or east terminal, through a transmission line or channel 3. The use of dashes to represent channel 3 indicates that it may be of considerable length and/or may include any desired apparatus, as for example a radio link. This system illustrates

a case where speech is divided into only two frequency bands which are sent at different relative times. The pass ranges of the filters shown in all of the figures of the drawing are indicated on the drawing. Starting at line 1 at the west terminal the lower speech band passes directly through a low pass filter 4 on to the secrecy part 3 of the circuit, whereas the high frequency band passes from line 1 through high filter 5, delay circuit or path 6, and high pass filter 7, and thus is given a time delay in passing to the secrecy part 3 of the circuit. At the other end of the system in passing from the secrecy part 3 of the circuit to the two-wire line 2 at the east terminal, the high frequency band passes directly through a high pass filter 10, whereas the low frequency band is passed through a low pass filter 11; a delay circuit 12 which introduces a relative time lag equal to that introduced by element 6 at sending and in such a way as to restore the normal time relations between the two frequency bands and a low pass filter 13 on to line 2. In the case of speech passing from east to west, at the east terminal the high frequency band passes through directly and the low-frequency band is delayed, while at the western end of the circuit reversion to normal is secured by exactly the same process as that which converts to secrecy when transmitting from the western terminal.

The attenuation losses in the delay circuit may be eliminated by use of two-way repeaters, but this will involve accurately balancing the impedance of the delay circuit. This is probably most easily done if electric delay circuits are used. The delay circuit can be set up on the reflection basis, as disclosed in Nyquist Patent 1,607,687, November 23, 1926, if desired; and then a simple way in which to insert amplification is by a 21 type repeater at the reflection point, as disclosed in Clark Patent 1,672,057, June 5, 1928.

To secure a greater degree of secrecy than is obtained by division of speech into two frequency bands only, a corresponding division into three bands may be employed in the manner shown in Fig. 2. In this case two delay circuits for each terminal are used, each introducing a delay of time T . Starting from line 1 at the west terminal the low frequency band, $0-F_1$, passes through the low pass filter and on to line 3 with no delay. The mid-frequency band, F_1-F_2 , passes from line 1 through band pass filter 21, delay circuit or path 22 and high pass filter 23 on to line 3 and so is given a delay of time T relative to the low frequency band in getting to the secrecy part 3 of the circuit. The high frequency band, $F_2-\infty$, passes from line 1 through high pass filter 25, delay circuit or path 26 of delay time T , high pass filter 27, delay path 22 and filter 23 on to line 3, and so is given a delay of $2T$ relative to the low frequency band. In receiving at the east end the

high frequency band passes from line 3 through high pass filter 30 to line 2, and so is given no additional delay; the mid-frequency band passes through band pass filter 31, delay circuit or path 32 of delay time T , and low pass filter 33 on to line 2, and so is given a delay of T ; and the low frequency band passes through low pass filter 34, delay circuit or path 35 of delay time T , low pass filter 36, delay path 32 and filter 33 on to line 2 and thus is given a delay of $2T$, so that all three bands have been given the same overall delay of $2T$ and are back in normal time relation with respect to one another. In the case of transmission from east to west the same delays are introduced in reversed order with respect to the three bands at the transmitting and receiving ends. The following table shows how, when (as in the system of Fig. 2) the speech energy is divided into three bands and the higher bands are delayed most on transmission from the west end while the lower bands are delayed most on transmission from the east end, the amount of confusion caused to an outside listener adjusted for listening to west to east transmission would be increased for the transmission from east to west.

Sending band	Transmission west to east			Outside listener adjusted for west to east transmission	
	Sending delay at west end	Receiving correction at east end	Total delay	Receiving correction	Total delay
$0-F_1$	0	$2T$	$2T$	$2T$	$2T$
F_1-F_2	T	T	$2T$	T	$2T$
F_2-F_3	$2T$	0	$2T$	0	$2T$

Sending band	Transmission east to west			Outside listener adjusted for east to west transmission	
	Sending delay at east end	Receiving correction at west end	Total delay	Receiving correction	Total delay
$0-F_1$	$2T$	0	$2T$	$2T$	$4T$
F_1-F_2	T	T	$2T$	T	$2T$
F_2-F_3	0	$2T$	$2T$	0	0

A listener-in would therefore need two separate receiving systems, each with a sharp directional selectivity (which could probably be operated successfully only in limited areas in relation to the sending and receiving stations) so that the transmission from each terminal could be individually picked up and corrected for; and in, for example, a radio telephone system sending the same frequencies in both directions, each of those two receiving systems would need to have sharp directional selectivity, which, as noted above, is a requirement very difficult to meet except in limited areas in relation to the two transmitting stations. If the delay circuit is op-

erated on a reflection basis the two delay circuits for each terminal may further be combined into one as shown in Fig. 3 for the west terminal.

In this Fig. 3 but a single delay circuit is shown which for equivalent results should introduce a time delay equal to that of any one of the delay circuits shown in Fig. 2. Only the west terminal of the system is shown, as the construction and operation of the east terminal is similar and will be apparent from the description of the west terminal. As shown the low frequency band passes from line 1 directly through low pass filter to the secrecy part 3 of the circuit with no delay. The mid-frequency band passes through band pass filter 41, a 21 type repeater A—45, the delay path or circuit 42 of delay time T and out through the bridge terminals of a hybrid coil or bridge transformer BT and a high pass filter 43 on to the secrecy part 3 of the circuit. Part of its energy is lost in the series branch of the hybrid coil circuit. The high frequency band passes from line 1 through high pass filter 44 to the series winding of the hybrid coil, half of its energy being lost in the balancing network N and half of it entering the delay circuit. The latter energy after passing through the delay circuit is amplified by repeater A—45 and traverses the delay circuit a second time. Arriving again at the hybrid coil half of it passes on to the secrecy part 3 of the system and half of it goes back through the series winding and is lost. The mid-band frequencies traverse the repeater, delay circuit, and hybrid coil once whereas the upper band frequencies traverse them all twice. The repeater compensates for the delay circuit losses. However, if desired the repeater can be omitted. Then, with filter 41 designed to appear to the delay circuit substantially as either a short circuit or an open circuit for the upper band frequencies, the upper band energy will be reflected therefrom and made to traverse the delay circuit a second time.

In applications of delay circuits such for example as the application just mentioned or the applications considered above in connection with Figs. 1 and 2, it is desirable to have two-way delay circuits of zero loss, or with gain. Figs. 4, 5 and 6 show some ways of securing such circuits. One such circuit is that of Clark Patent 1,672,057 mentioned above, which involves the addition of a 21-type telephone repeater to the system of Nyquist Patent 1,607,687 mentioned above for getting twice the delay out of the particular delay circuit by a reflection process. Fig. 4 shows a similar system using an acoustic delay circuit of the general type disclosed in Mathes Patent 1,696,315, December 25, 1928, instead of an electrical delay circuit. The delay path is shown connected between sections 50 and 51 of a two-way two-wire circuit or line.

Speech energy comes from line section 50 into the hybrid coil or bridge transformer circuit BT and divides between two loud speaker elements 52 and 53, one coupled to an acoustic delay path 54 and the other coupled to an acoustic resistance 55. This acoustic resistance, which is to imitate or simulate the impedance of an infinite length of the acoustic delay path, might consist of a substantially infinite pipe, or a pipe decreasing exponentially in diameter, or a composite group of open and short-circuited pipes as disclosed in the copending application of W. P. Mason, Serial No. 221,261, filed Sept. 22, 1927, which issued as Patent No. 1,795,874, March 10, 1931. At the far end of the acoustic delay path the speech energy is reconverted to the electrical form by another loud speaker element 56 after which it is amplified by a 21-type telephone repeater A—57. Half of the amplified energy is sent on and lost in the balancing network N, the other half returning via the acoustic delay path 54 to the hybrid coil BT where half of it goes to the two-wire line section 51 and half is fed back to the two-wire line section 50. The process for transmission from line section 51 to line section 50 is exactly similar. This system not only has the property of a 21-type repeater circuit that energy is fed back to the subscriber talking as well as on to the subscriber listening, but furthermore has the property that a certain amount of direct transmission will pass between line sections 50 and 51 through the hybrid coil BT, its magnitude depending upon the degree of balance obtainable, and travel on down the circuit ahead of the delayed transmission. The system shown has been devised with a view to keeping this unbalance component as small as possible compared to the delayed main component. If desired, an amplitude equalizer 58, which compensates for non-uniform frequency-response characteristics of the loud speaker elements 52 and 56 and the delay path 54, can be included in circuit with amplifier A—57, as shown.

When the savings to be made by the use of the reflection methods are not sufficient to warrant its use, the circuit Fig. 5 may be used which has the advantage of cutting the load requirement on the amplifying apparatus in half, as but one hybrid coil BT is involved in the circuit. Transmission from either line section 50 or 51 passes from the hybrid coil through one-way amplifier A—59, delay circuit or path 60, one-way amplifier A—61 and the hybrid coil on to the other line section. If desired, amplifier A—59 can be omitted; but then this circuit like the last one, will have an unbalance current travelling ahead of the delay component. When amplifier A—59 is used, the magnitude of the unbalance component depends upon the degree of balance between the impedance of the in-

put to the amplifier A—59 and the impedance output of the amplifier A—61, and can be made negligible, inasmuch as these impedances can be made substantially resistances that balance each other.

By this system a two-way delay circuit can be obtained either from those delay devices which in themselves function in but one direction, such as phonograph or telegraphophone devices, or from a two-way electrical or acoustic or mechanical delay path, for example. Although the delay circuit indicated in this figure can be made of the reflection type, that introduces the disadvantage that a second unbalance current, or "inverted echo," travelling ahead of the delay component is set up which is amplified as much as the main transmission. If desired, an amplitude equalizer 62, which compensates for non-uniformity of the frequency-response characteristic of the delay path, can be connected in circuit with the amplifier A—61, as shown.

Circuits such as those of Figs. 4 and 5 have the property of 21-type repeater circuits that there is as much energy fed back to the talking subscriber as is sent on as main transmission to the listening subscriber. This feature of operation can be avoided by using 22-type repeater circuits which in general will require the use of more delay and amplifier equipment. A circuit of this type is shown in Fig. 6. In this circuit transmission from line section 50 passes through hybrid coil BT, delay circuit or path 70, a transmission loss equalizer 71 which compensates for non-uniformity of the frequency-response characteristic of delay path 70, an amplifier A—72, and hybrid coil BT on to line section 51. Transmission from line section 51 passes through hybrid coil BT, delay circuit or path 75, a transmission loss equalizer 76 which functions correspondingly to equalizer 71, an amplifier A—77, and hybrid coil BT on to line section 50. The delay means 70 and 75 may be of any desired type, as for example electrical or mechanical or acoustic. As indicated above, any of these circuits of Figs. 4, 5 and 6 may be adjusted to function not only for zero loss but also to give a gain, thus combining the functions of a two-wire repeater together with the insertion of delay. Any of these circuits can be used as the delay paths in any of Figs. 1 to 3, although if amplifier A—45 is used in the system of Fig. 3 it is needless to have the delay path 42 lossless.

In place of simply getting two-way delay circuits of zero loss or possible gain, it is also feasible to get two-way, two-wire secrecy schemes of the general type disclosed above which will have zero loss or possible gain. Fig. 7 shows a 21-type repeater circuit as one terminal of such a system which uses the same delay paths for opposite directions of transmission over the system and gives, for the opposite directions of transmission, dis-

similar order of the application of delays to the frequency bands. Although this circuit has the property of increasing echo effects by feeding back towards the talking subscriber as much energy as is sent on to the listening subscriber, in this case the echo is different from that usual in the 21-type repeater circuit as it is not normal speech but scrambled speech energy which is sent back. In general, it is therefore less annoying, being more like noise in the side-tone on talking instead of giving the impression that the listener is replying. Fig. 7 may, for convenience, be designated the west terminal of the system. In transmission from west to east speech passes from line 1 through bridge transformer BT and conductors 80 to the junction of low pass filter 81, band pass filter 82 and high pass filter 83, where it divides into three frequency bands. The low frequency band proceeds through filter 81, transmission loss equalizer 84, low pass filter 85, conductors 86, amplifier A—87 and bridge transformer BT on to the secrecy line 3. The mid-frequency band proceeds through filter 82, transmission loss equalizer 88, band pass filter 89, delay circuit or path 90 of delay time T, high pass filter 91, conductors 86, amplifier A—87 and bridge transformer BT on to line 3. The high frequency band proceeds through filter 83, delay circuit or path 92 of delay time T, high pass filter 93, delay path 90, filter 91, conductors 86, amplifier A—87 and bridge transformer BT on to line 3. The operation of this end of the system in transmitting from line 3 to line 1 is exactly the same. The equalizers 84 and 88 cause the overall transmission equivalent to be the same for the three frequency bands between lines 1 and 3. The east terminal of the system is like the west terminal except that the order of the relative delays of the frequency band is reversed.

If desired, a one-way amplifier (not shown) can be included in circuit 80 between the bridge points of hybrid coil BT and the junction of filters 81, 82 and 83, to facilitate balancing the bridge impedance and the series impedance of the hybrid coil so as to render negligibly small the leading or inverted echo current caused by lack of such balance, just as explained above in connection with the inclusion of amplifier A—59 in the circuit of Fig. 5.

What is claimed is:

1. A message path comprising delay means for altering the intelligibility of waves transmitted through said path, and means for transmitting message waves in opposite directions through said path to increase the intelligibility of the messages in one direction and decrease the intelligibility of the messages in the other direction, the portions of said path in which said increase and said decrease are effected being wholly common,

and said path comprising channels having their transmission frequency ranges mutually exclusive.

2. Means for altering the time relation of waves transmitted therethrough, comprising paths in opposite directions through said means, said paths in opposite directions having portions at least common, transmission delay means included in said common portions, and means for transmitting waves of given frequencies in one direction through a portion of said delay means and also transmitting waves of those frequencies in the other direction through said portion of said delay means, said paths comprising channels having their transmission frequency ranges mutually exclusive.

3. Means for altering the time relation of waves transmitted therethrough, comprising paths in opposite directions through said means, said paths in opposite directions having portions at least common, transmission delay means included in said common portions, and means for transmitting waves of given frequencies in each direction through one portion of said delay means and transmitting in each direction through said one portion of said delay means all frequencies transmitted therethrough in the opposite direction, said paths comprising channels having their transmission frequency ranges mutually exclusive.

4. Means for altering the time relation of waves transmitted therethrough, comprising paths in opposite directions through said means, said paths in opposite directions having portions at least common, transmission delay means included in said common portions, and means for transmitting waves of given frequencies in each direction through two portions of said delay means in tandem relation and transmitting waves of other frequencies through one only of said portions of said delay means.

5. A two-way signaling system comprising means for rendering signals transmitted in one direction unintelligible by altering in a given manner the time relation of waves representing those signals, and means for rendering signals transmitted in the opposite direction unintelligible by altering in another manner the time relation of waves representing those signals, each of said means comprising delay means and means for transmitting waves of given frequency through all portions of the delay means in said first mentioned means and transmitting waves of other given frequency through all portions of said second mentioned means.

6. A two-way signaling system comprising means at one end of said system for rendering said signals transmitted in one direction unintelligible by altering in a given manner the time relation of waves representing those signals, and means at the other end of said

system for rendering signals transmitted in the opposite direction unintelligible by altering in another manner the time relation of waves representing those signals, each of said means comprising paths in opposite directions through that means, said paths in opposite directions having delay means, and having means for transmitting waves of given frequency through all portions of the delay means at one end of said system and waves of other given frequency through all portions of the delay means at the other end of said system, and having portions at least of the delay means common to the paths in opposite directions.

7. In a wave transmission system which requires for its proper functioning a delay, in the transmission of waves at a point in the system, large compared with the period of the waves, two-way delay means comprising two means, each for reversibly converting energy from one form to another, one of said forms being mechanical, and a mechanical line, the mass and elastic properties of which, together with the length of the line, are proportioned to give a substantial delay, said line comprising a homogeneous medium having its mass and elastic properties continuously distributed along a substantial portion of its length.

8. In a wave transmission system which requires for its proper functioning a delay in the transmission of waves at a point in the system, large compared with the period of the waves, two-way delay means comprising two means, each for reversibly converting energy from one form to another, one of said forms being mechanical, and a mechanical line, the mass and elastic properties of which, together with the length of the line, are proportioned to give a substantial delay, said line comprising a homogeneous gaseous medium, enclosed in a sound conduit, having its mass and elastic properties continuously distributed along a substantial portion of its length.

9. In a two-way electric wave transmission system which requires for its proper functioning a time delay in the wave transmission in both directions at a point in the system, said required delay being large compared with the period of the transmitted waves, delay means comprising an enclosed air column, the mass and elastic properties of which, together with the length, are proportioned to give a substantial delay, and electro-mechanical coupling means for connecting said air column between two portions of the electrical system, said coupling means comprising a reversibly transmitting telephone receiver and transmitter at each end of said column.

10. In combination, a hybrid coil with output terminals unaffected directly by electric currents introduced at the input terminals and a network, comprising an acoustic energy

transmission path, to receive electric current from the input terminals, convert it to acoustic energy, transmit the acoustic energy through said path and back, reconvert it to electric current and make the latter current effective on the output terminals.

11. In combination a hybrid coil with a pair of input terminals and a pair of output terminals and with an absorbing acoustic network and a reflecting acoustic network balanced against each other with respect to one said pair of terminals.

12. In combination, a hybrid coil, input and output terminals and two wave propagation networks to which the input current divides, one network comprising acoustic means for substantially completely absorbing the energy transmitted thereto and the other comprising an acoustic transmission path, and means for transmitting back the waves transmitted through it whereby these waves, after twice traversing the last mentioned path, become effective on the output terminals.

13. In combination, an acoustic delay path having at one end thereof means for reversibly converting electric current to acoustic energy, two conjugate pairs of terminals, and means to establish the conjugate relation between them, and having at the other end thereof means for reversibly converting mechanical to electrical energy and a 21-type repeater for amplifying the latter energy.

14. In combination, two wave transmission paths and means always conditioned to transmit waves from each path to the other, said means comprising transmission delay means and means for preventing transmission from the output side of said delay means to its input side.

15. A signaling system comprising two circuits and means always conditioned to transmit waves from each circuit to the other, said means comprising transmission delay means operative to transmit waves in but one direction in the delay means, and means for preventing transmission from the output side of said delay means to its input side.

16. A two-way repeater circuit of the type having a single repeating element, said circuit comprising a one-way wave transmitting and amplifying path and transmission delay means in said one-way path.

In witness whereof, I hereunto subscribe my name this 29th day of March 1929.

ROBERT C. MATHES.