

May 8, 1945.

W. W. HANSEN ET AL

2,375,223

DIELECTRIC GUIDE SIGNALING

Filed Aug. 24, 1939

4 Sheets-Sheet 1

FIG. 1

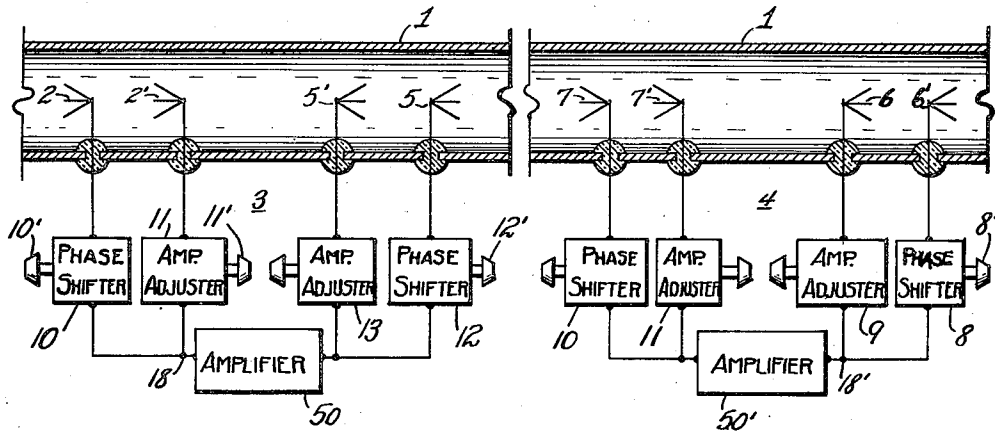
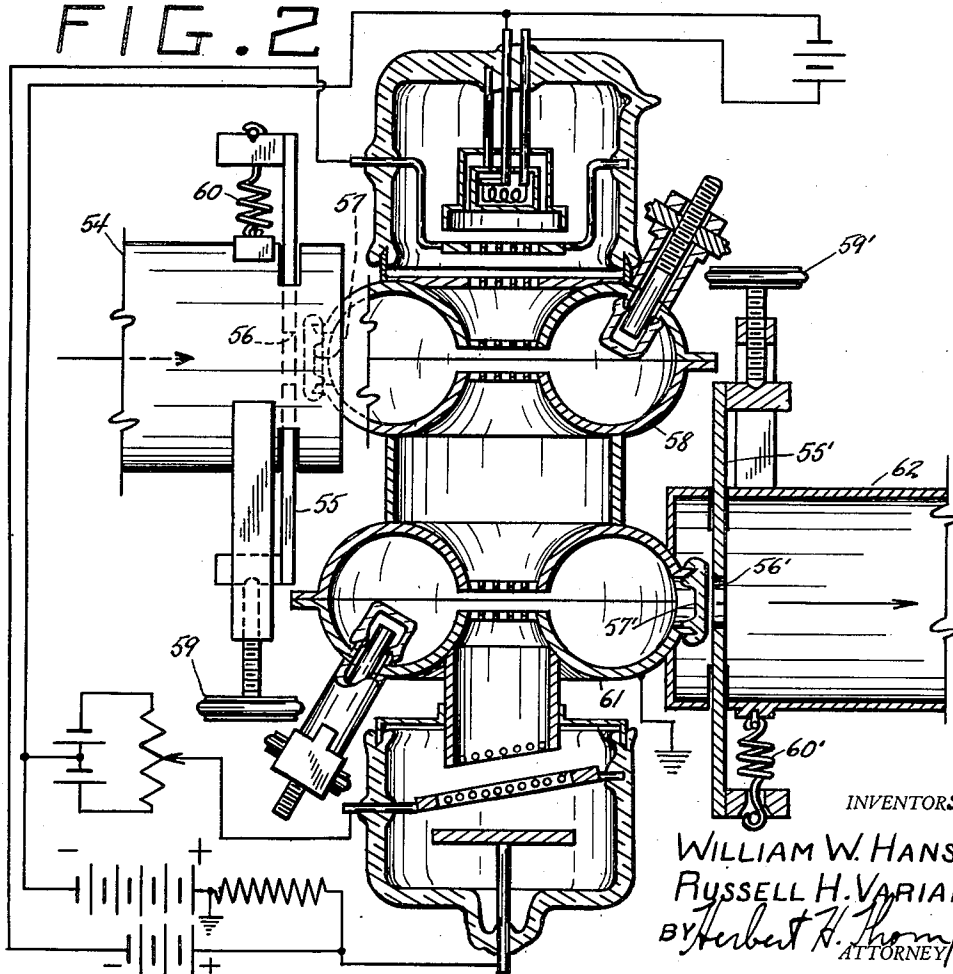


FIG. 2



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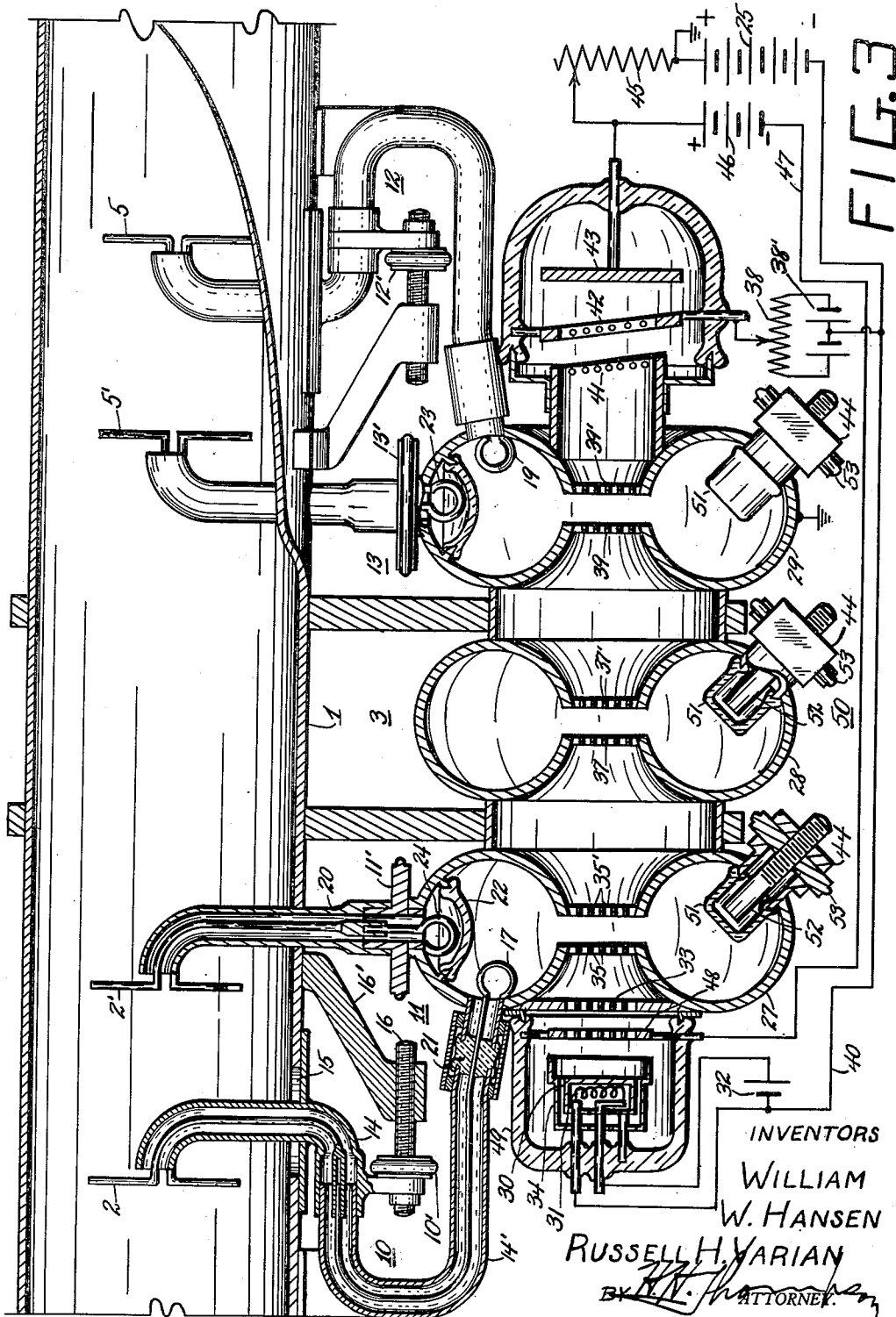
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4 Sheets-Sheet 2



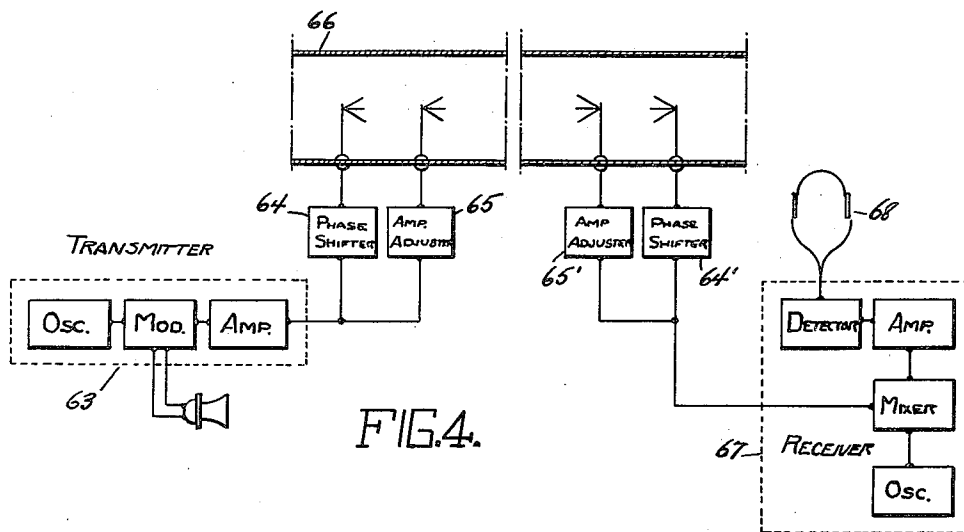
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4 Sheets-Sheet 3



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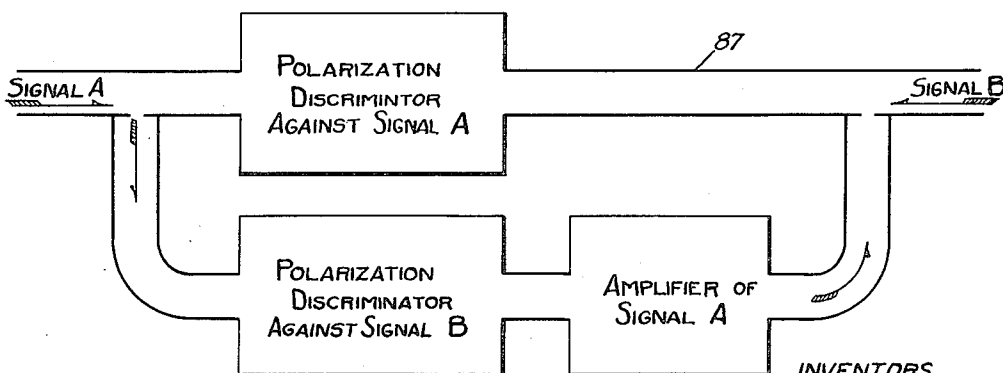
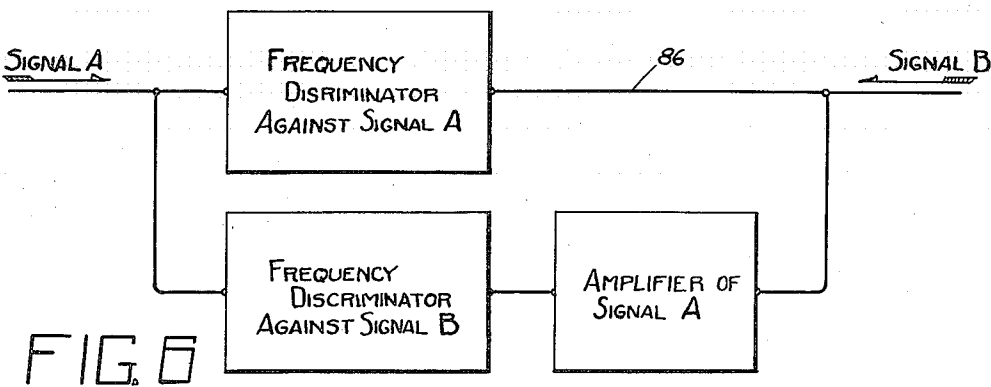
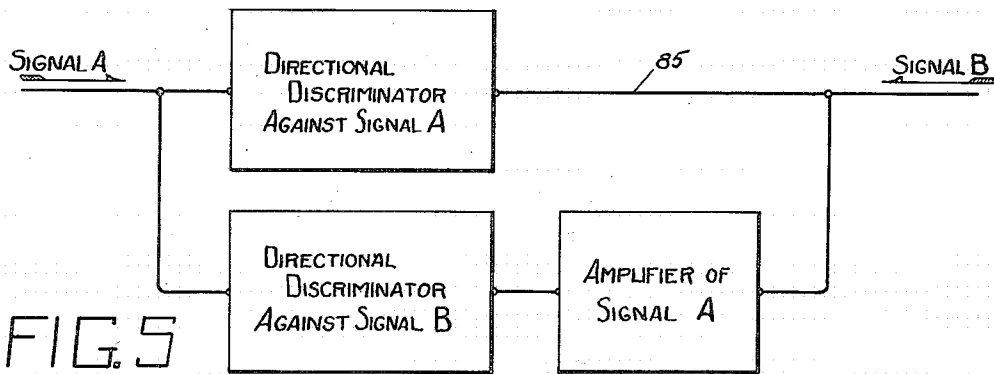
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DIELECTRIC GUIDE SIGNALING

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4 Sheets-Sheet 4



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2,375,223

DIELECTRIC GUIDE SIGNALING

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Application August 24, 1939, Serial No. 291,652

30 Claims. (Cl. 178—44)

This invention relates, generally, to ultra high frequency signaling employing the propagation of electromagnetic waves through dielectric guides, and the invention has reference, more particularly, to novel means for and methods of launching, receiving and amplifying electromagnetic energy in dielectric guides.

Apparatus heretofore used for launching and relaying electromagnetic energy in dielectric guides is incapable of transmitting signals simultaneously in both directions in the guide unless the signals are of different frequencies or are polarized differently. Inasmuch as the use of different frequencies for transmission in opposite directions doubles the width of the wave band required over that necessitated by the use of but a single frequency, and as transmission of polarized waves involves practical difficulties, these systems are not entirely satisfactory in use. Also, considerable difficulty is involved when using these prior systems in endeavoring to reduce feed-back so as to prevent self-oscillation of the relaying amplifiers.

The principal object of the present invention is to provide novel apparatus and method for simultaneously transmitting ultra high frequency signals of the same wave band in both directions in a dielectric guide without interference between such signals thereby substantially doubling the channel capacity of the guide, the apparatus also being suitable for the use of differing frequencies for transmission in opposite directions in the guide, if desired.

Another object of the present invention is to provide, in combination with a dielectric guide, a relay amplifier means for amplifying signals traversing the dielectric guide, the said amplifier means having novel receiving means designed to greatly reduce feed-back, the attenuation of the guide also serving for greatly reducing objectionable feed-back and hence self-oscillations in the guide, thereby enabling greater amplification of the signal at each relay amplifier means and greatly reducing the number of such amplifier means.

A further object of the present invention lies in the provision of novel equipment for launching electromagnetic waves in a dielectric guide for traversing the guide in one direction only from any desired point along the guide, whether near or remote from the ends thereof, the said system of this invention operating independently of the mode of motion of the waves in the guide.

Another object of the present invention lies in the provision of novel equipment for relaying waves along transmission lines and utilizing the inherent attenuation of such lines between successive relay points for preventing undesired feed-back and improving stabilization of the system.

Other objects and advantages will become ap-

parent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

5 Fig. 1 is a schematic sectional view of a dielectric guide equipped with the novel apparatus of the present invention, adapted for receiving a signal traversing the guide in one direction, amplifying the signal and reradiating the same for continuance along the guide in the same direction. The apparatus also shows means for receiving, amplifying and reradiating signals for transmission through the guide in the opposite direction.

15 Fig. 2 is a vertical part sectional view of an arrangement adapted for amplifying signals propagated in a dielectric guide in order to compensate for energy losses occurring in the guide, the said arrangement including means for matching the impedance of the amplifier means to that of the guide and for automatically maintaining control of the signal intensity in the guide.

20 Fig. 3 is an enlarged vertical sectional view of a portion of the apparatus of Fig. 1 and illustrates the amplifier for relaying a signal in a dielectric guide, together with directional discriminating means for receiving the signal to be relayed.

30 Fig. 4 shows transmitting and receiving means adapted for use with the equipment of the preceding figures.

Figs. 5 to 7 are explanatory diagrams.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

35 As used in the present specification, the term "dielectric guide" means a system of material boundaries capable of guiding waves. Such systems are also known as "wave guides." By the term "transmission line" is meant any high frequency energy conductive system including wave guides, coaxial transmission lines, or other transmission circuits.

40 Referring now to Fig. 1, the reference numeral 1 designates a dielectric guide of the type already known in the art, the same being suitable for transmission of electromagnetic energy of ultra high frequencies. In this figure, a block diagram, designated as a whole by reference numeral 3, is shown of the equipment employed for picking up a signal traversing the guide in a given direction, amplifying the signal and then reradiating the same for continued transmission along the guide. This relaying apparatus must embody directional 45 discriminating means for receiving the signal to be relayed and for reradiating the signal after it has been amplified. Such relaying devices must not be responsive to signals coming from a direction opposite to its direction of sensitivity and hence will not cause interference with signals 50 55 60

traversing the guide in the reverse direction. A similar relaying device 4 with opposite directional characteristics may be employed in the guide as shown for relaying signals in the opposite direction. Preferably a series of the relaying devices, such as 3 and 4, are equally spaced from one another along the guide 1 throughout the length of the same, alternate relaying devices amplifying signals traveling in the same direction.

In this figure, the reference numerals 2 and 2' designate receiving means, which may be of any suitable type such as dipole antennae, loops, or apertures in the guide wall. A phase shifter, designated 10, is supplied from the antenna 2, while an amplitude adjuster 11 is supplied from the antenna 2'. The outputs of the phase shifter and amplitude adjuster are combined at 18 and fed to a radio ultra high frequency amplifier 50, the output of which is supplied through a second phase shifter 12 and amplitude adjuster 13 to re-radiating antennae 5 and 5'.

The receiving means, i. e., antennae 2 and 2', are preferably located about one-quarter wave length apart within the guide 1, that is, are spaced a distance apart such that the waves received by antenna 2 and 2' are substantially 90° apart in phase due to the time consumed by the wave in travelling this distance. The phase shifter 10 is adjusted by turning its control knob 10' so that the electromagnetic waves delivered therefrom to the junction point 18 are in phase at 18 with the waves delivered to this point 18 from the amplitude adjuster 11 when the received electromagnetic waves are traveling from left to right in guide 1. Thus, though the antenna 2' is displaced one-quarter wave length from 2, the output of the amplitude adjuster at junction point 18 is in phase with the signal received from the phase shifter 10. Thus, the outputs of 10 and 11 combine additively at 18 for supplying the ultra high frequency amplifier 50. However, should a signal be received by antenna means 2' and 2 coming from the reverse direction, that is, moving from right to left in Fig. 1, then in that case the electromagnetic waves received at 2 will be 90° displaced later than those received at 2', and since the phase shifter 10 and the connections shown act to retard the phase of the output of 2 90° more, the output of the phase shifter 10 at junction point 18 will be directly out of phase with that supplied from the amplitude adjuster 11 at point 18. Thus, the signals at 18 will tend to cancel each other. If the amplitude of these signals is made identical by adjusting the knob 11' of the amplitude adjuster, the effect of the signal coming from the right at the junction point 18 will be zero due to the cancelling of the opposite signals from 10 and 11. Thus, if the receiving means 2 and 2' are approximately one-quarter wave length apart in the guide, their combined sensitivity in one direction, i. e., for signals moving from the left toward the right, will be substantially a maximum, whereas for signals moving in the opposite direction the combined signal will be zero. It is not essential that these receiver means be exactly one-quarter wave length apart, as some departure from this value will not appreciably affect the sensitivity of the system. Since it is necessary that the sensitivity of the apparatus to signals traversing the guide in the reverse direction should be as near zero as possible, the receiving means are set up, in practice, as near one-quarter wave length apart as convenient, or some odd multiple thereof. The final elimination

of the sensitivity in the wrong direction is obtained by fine adjustment of the phase shifter knob 10' and the amplitude adjuster knob 11'.

Phase shifter 12 acts to retard the phase of the waves emitted from antenna 5 90° in phase position relative to the waves emitted from antenna 5' so that by the time the waves from 5' have reached the transmitting means 5, the combined waves are in phase for transmission along the tube toward the right. The antenna means 5 and 5', on the other hand, are subtractive in their action so far as transmission to the left is concerned. Thus, radiation from antenna 5, upon reaching antenna 5', will be displaced 90° counter-clockwise from that which would be received at 5' were the phase shifter not used, but since the phase shifter retards the phase by 90°, the net result is to establish an 180° out of phase condition between the signal emitted at 5 and that received at 5' from 5, so that these two signals cancel out and hence do not traverse the tube toward the left, i. e., in the wrong direction.

The relaying apparatus 4 serves for receiving signals traveling from right toward the left in guide 1, which signals may have the same carrier frequency as those relayed by apparatus 3 and moving in the reverse direction or, if desired, these oppositely traveling signals may have different carrier frequencies. In the operation of apparatus 4, the phase shifter 8 is adjusted to retard the signal from 6 approximately 90° so that the signal delivered therefrom at point 18' is in phase with the signal supplied from the amplitude adjuster 9 provided the signal carrying waves are moving from right to left in guide 1. Signals moving in the reverse direction cancel at 18' in the manner previously described. Output phase shifter 10 retards the amplified signal so that the waves emitted from antenna 7 are 90° lagging those emitted from 7', whereby these waves are additive at 7 while waves moving from 7 to 7' are subtractive and cancel at 7'.

Actually the discriminating sensitivity of receiving means 2, 2' or 6, 6' against signals going in the wrong direction need not be very great where using the apparatus of this invention, assuming that the consecutive pieces of relaying apparatus 3, 4, etc. are mutually spaced a suitable distance apart, inasmuch as the attenuation of the line acts to greatly reduce feed-back. Thus, assuming that receiving means 2, 2' or 6, 6' possess amplitude sensitivity in the wrong direction of one thousandth of that which they possess in the right direction, then in that case the relatively minute wrong signal picked up by 2, 2' or 6, 6', as the case may be, will be amplified and sent along the guide in the opposite direction to its original direction of motion. However, even as amplified the wrong signal is relatively weak in comparison with the amplified normal signal moving in that direction, so that this incorrect signal is substantially entirely attenuated by the time the same reaches the next relaying equipment, so that in use relatively high amplification may be employed by this relay equipment without interference.

Thus, for example, the small feed-back from 2, 2' is attenuated by the line between 3 and 4, and since 6, 6' receive this feed-back in the wrong direction, only an extremely small portion of this attenuated feed-back signal is amplified by 50' and the same is sent out by 7, 7' and further attenuated by the line and must be received by 2, 2' in the wrong direction, so that in effect relatively large amplification may be used at 50, 50' without appreciable feed-back taking place. Of

course, this is not true of relay devices of the prior art wherein the line is terminated at each relay means so that relays acting in both directions must be located at each relay station, thereby losing the benefit of line attenuation of the feed-back.

If we assume that the feed-back from 7, 7' is but one-thousandth of the output of 7, 7' and that 6', 6 picks up but one-thousandth of this feed-back, then the attenuation between the output and input of a relay is one-millionth, so that it is possible to amplify the signal in 50' and 50 up to one million without self-oscillation taking place. Also, assuming that the signal from 7, 7' is attenuated in the line between 4 and 3 to one-thousandth of its value at 7, 7', then since 2, 2' receive this signal in the wrong direction, the attenuation is increased to one-millionth of the signal emitted at 7, 7', then amplified by 50, further attenuated by the line between 5', 5 and 6', 6 to one-thousandth of the amplified version, and since 6', 6 receive this signal in the wrong direction, the attenuation is also increased to one-millionth of that emitted at 5', 5, thereby also permitting amplification in 50' and 50 of up to a million. Hence, it will be seen that large amplifications can be used without serious feedback taking place so that the equipment 3, 4, etc. may be spaced relatively great distances apart in use, thereby greatly reducing the cost of the present equipment as compared with equipment heretofore used.

Fig. 3 illustrates in detail a typical relay apparatus such as the relay apparatus 3 shown in block diagram in Fig. 1. It will be noted that in Fig. 3 the receiving and radiating means are shown as dipoles, although other types of receiving and radiating elements may be used, such as loops. The phase shifter 10, connected to the receiving element 2, is illustrated as a concentric line which is adjustable as to length. One concentric line portion 14 extends through an opening 15 provided in the guide 1 and has the dipole 2 connected with its upper end, whereas the lower part of this concentric line portion 14 is provided with a female socket for receiving one end of the remaining concentric line portion 14', which latter is adapted to be adjustably telescoped into the socket of portion 14 by means of the knob 10' fixed upon a screw 16 that is threaded into a bracket 16' fixed on the guide 1. Thus, by turning knob 10' so as to lessen the distance between dipole 2 and dipole 2', thereby reducing the phase difference between these dipoles within the guide 1, the concentric line connecting dipole 2 to loop 17 within hollow resonator 27 is lengthened so that rapid change in phase of the outputs of the two dipoles as supplied to the resonator 27 is effected by adjusting the knob 10' of the phase shifter. The phase shifter 12 associated with transmitter dipole 5 is similarly constructed and connects 5 with the loop 19 contained within the resonator 29.

The amplitude adjuster 11 comprises a loop 24 that is contained within the resonator 27 and is adjustable by turning the knob 11', thereby turning the amplitude adjuster loop 24 and altering the number of magnetic lines of alternating current flux resonant in the hollow resonator 27 that are enclosed by the loop, thereby varying the intensity of the signal that is set up in 27 by a given signal passing along guide 1 from left to right. Loops 17 and 24 within resonator 27 correspond to the point 18 of Fig. 1. It will be noted that the knob 11' is attached to a portion

of a concentric line, which portion is socketed in an upper portion 20 that extends through the guide 1 and carries the dipole 2' at its upper end. Suitable seals 21 and 22, as of vitreous material, are provided for sealing the resonator 27 off from the concentric lines leading to dipoles 2 and 2'.

The amplitude adjuster 13 is similar to 11 and would appear to require no further description. The loop 23, associated with amplitude adjuster 13, is contained within hollow resonator 29 so that by turning knob 13', suitable adjustment is provided of the intensity of the waves emitted from dipole 5' relative to those emitted from dipole 5.

The amplifier 50 shown in Fig. 3 is of the type disclosed in application Serial No. 201,898, filed April 14, 1938, now Patent No. 2,280,824, issued April 28, 1942, of which the present applicants are the inventors. This amplifier comprises a plurality of aligned interconnected dielectric resonators 27, 28 and 29 that are evacuated. Within a vitreous insulating cup 49 at one end of the amplifier is provided a cathode 30 that is surrounded by the focusing shield 34, said cathode being indirectly heated by a heater coil 31 that is supplied from the battery 32. The electrons released by the cathode 30 are drawn in a columnar stream by the strongly positive grid 33, which grid is held positive with respect to the cathode by the battery 25. Note that the positive side of the battery 25 is grounded, which is also true of the casing of amplifier 50, to which casing the grid 33 is connected. Thus, the electron stream is drawn through grid 33 and then passes through subsequent pairs of grids 35, 35', 37, 37', and 39, 39', constituting grids of the hollow resonators 27, 28 and 29, respectively. After leaving grid 39', the electron stream passes through additional grids 41 and 42 to the plate 43.

The waves traveling along guide 1 from left to right are picked up by receiving means 2 and 2' and are delivered into the resonator 27 in in-phase relation. This received energy serves to excite this resonator in such mode that an alternating electric field is established between grids 35 and 35', the said electric field serving to alternately impart positive and negative accelerations to successive electrons of the stream passing therebetween, thereby causing the electrons of the stream to traverse the space between resonator 27 and the next resonator 28 with cyclically varying velocities. The faster electrons which passed through the electric field later than the preceding electrons, will tend to overtake the latter in the interspace between resonator 27 and resonator 28, so that by the time the electron stream has arrived at grid 37, the stream will have a slight periodic variation in electron density at the frequency of the field between grids 35 and 35'.

If the resonator 28 is properly tuned, which is accomplished by the tuning means 44 of the type disclosed in application Serial No. 268,898, filed April 20, 1939, now Patent No. 2,259,690, issued October 21, 1941, of which the present applicants and J. R. Woodyard are the inventors, an alternating electric field will be established between grids 37 and 37', which is much stronger than that existing between grids 35 and 35', with the result that the successive electrons will receive much larger variations in velocity than that previously possessed, thereby effecting still greater bunching and corresponding increase in variation in electron density during passage through the space between resonators 28 and 29. Similarly,

the entrance of the stream of variable electron density into resonator 29 establishes a strong alternating electric field between grids 38 and 39 which acts to retard the electrons so that they do work upon this field and thereby maintain the alternating electromagnetic field within resonator 29, the energy of which is picked up by loops 19 and 23 and reradiated along the guide 1 by transmitting means 5' and 5.

The grid 41, being at the potential of the positive side of battery 25, aids in maintaining the stream in columnar form, whereas the inclined grid 42 is preferably maintained at a potential near that of the cathode. This is accomplished by use of potentiometer 38 and battery 38' connected to the cathode lead 40. With the grid 42 at this potential, most of the electrons are reflected back and to one side and only the speeded up electrons will pass through this grid. Thus as the change in velocity increases, more and more of the faster electrons will reach the plate 43 beyond grid 42, while fewer of the slower electrons will reach this plate. The current therefore reaching the plate 43 increases as the amplitude of oscillations in the device increases, so that the device as a whole serves as a cascade amplifier and detector.

The detected signal on the plate 43 is more negative the stronger the oscillations become. Looked at in another way, as the current through the plate circuit increases, the drop across a resistor 45 in the plate circuit increases, thereby lowering the potential at the plate, which is shown connected through a biasing battery 46 and lead 47 to a grid 48 positioned in front of emitter 30. Thus the potential of grid 48 is correspondingly lowered, effecting a decrease in the current passing through the device due to the repellent action of the grid 48 on the electron stream. Thus, since the plate 43 becomes more negative as the signal intensity increases, the grid 48 acts as an automatic volume control serving to cut down the current in the device and thereby the gain when the amplitude of oscillation increases.

As disclosed in Patent No. 2,259,690, the tuning devices 44 supplied to each resonator consists of vitreous envelopes 51 that extend into the resonators and prevent the admission of air therinto. Metal plugs 52 are longitudinally adjustable in the envelopes 51 by means of nuts 53 shown, thereby operating to adjust the frequency of the resonators as desired. The position in which the envelopes 51 and metal plugs project into the resonators has an important bearing on the tuning. If the plug 52 is positioned in a part of the resonant cavity containing essentially electric field, the same by its presence serves to increase the capacity of the circuit so that the resonant frequency will be decreased, whereas if this plug 52 is inserted in a region containing mostly magnetic field, the same reduces the total volume of magnetic field since the plug contains no field, whereby the inductance will be decreased and the frequency will be increased. It is therefore possible to find an intermediate point where the mere presence of the plug will not affect the frequency. As illustrated in Fig. 3, the plugs are located where the magnetic field is strong. As the plugs are moved in and out, controlled changes in the resonant frequency of the resonators is obtained, thereby allowing the various resonant chambers 27 to 29 to be tuned to the incoming signal.

The relay device illustrated in Fig. 2 is adapted

for highly efficient performance through the matching of the guide impedance to that of the amplifier. In this figure the guide 54 carrying waves in the direction shown by the arrow, is provided with a gate structure consisting of an apertured plate 55, the aperture 56 thereof being adapted to register with an inlet opening 57 provided in the resonator 58. A thumb screw 59 opposing a spring 60 is adapted to adjust the plate 55 vertically, as shown in Fig. 2, to thereby vary the portion of the area of aperture 56 that registers with opening 57. Thus, by adjusting 59, the impedance of the guide 54 may be matched to the input impedance of the resonator 58 to obtain the best operating conditions. Similarly, the output resonator 61 is provided with an opening 57', the effective area of which is varied by adjusting the valve plate 55' through turning of the knob 59', whereby the impedance of the exit guide 62 is matched with that of the internal impedance of the amplifier. The remaining connections of the structure shown in Fig. 2 are similar to those shown in Fig. 3 and would appear to require no further description.

The specific structures of Figs. 2 and 3 are shown and claimed in copending divisional application Serial No. 513,002.

Fig. 4 illustrates a typical manner of supplying the guides of Figs. 1 to 3 with the signals traversing the same. Thus, in Fig. 4, a suitable transmitter 63 is provided, shown as including an oscillator, a modulator and an amplifier, the output of the amplifier being supplied through the phase shifter 64 and amplitude adjuster 65, as in Fig. 1, to the transmitting antenna means provided in the guide 66. The transmitter, of course, may be located at any point along the guide or at an end thereof. The receiver, which may also be located at any desired point along the guide or at the end thereof, has the amplitude adjuster 65' and the phase shifter 64' together with suitable receiving antenna means, as in Fig. 1, the output of which is fed to the receiver 67 proper. The input to the receiver is shown as passing into a mixer supplied with heterodyning frequency from an oscillator, the output being fed to an amplifier and thence to a detector which connects with suitable ear phones 68 or other audible or indicating device. Of course it will be understood that the functions of the mixer, amplifier and detector may be performed by a single tube or by a plurality of tubes. At regular intervals between the transmitter and receiver there will be provided, of course, the relay devices shown in Figs. 1 to 3.

The diagrams of Figs. 5 to 7 show various ways in which the apparatus of the present invention may be used in relaying signals along a wave guide. These diagrams illustrate the broad method by which signals may be transmitted in both directions in the line and amplified along the way without causing interference between the signals transmitted. The important feature of this method is the adaptability of the same to use the attenuation of the transmission line as an important part of the attenuation required to prevent self-oscillation in the line through feedback.

Thus, in Fig. 5 the guide 85, shown schematically as a line, is provided with direction discriminating apparatus such as that shown in Fig. 1, which discriminates against, i. e., does not pass any feedback of signal A moving toward the left, and passes signal B. In a branch parallel circuit there is provided direction sensi-

tive apparatus such as shown in Fig. 1, which discriminates against i. e., does not pass signal B but passes signal A, and associated with this apparatus is an amplifier of signal A. This amplifier does not amplify signal B since the latter is blocked by the directional discriminator in the branch current.

In Fig. 6, frequency discriminating means is provided in the guide 86 which discriminates, for example, against A but passes B. This frequency discriminating means may be of known prior types, such as an ordinary telephone line filter, or may be of the type shown in Southworth Patent #2,106,768. In this figure a parallel branch circuit is shown, including frequency discriminating means blocking signal B and passing signal A, and an amplifier is included for amplifying the signal A that passes the discriminating means.

It is to be understood that the structures of Figs. 5 and 6 need not be confined to dielectric guides, inasmuch as systems using wires or concentric lines could also employ this apparatus.

In Fig. 7 the guide 87 is shown provided with a polarization discriminating means in the guide, which discriminates against signal A, for example, but passes B. This structure may be of the type such as that shown in the Southworth Patent #2,153,728. Here also a branch circuit is provided, having a polarization discriminating means that serves to block B but passes A to the amplifier shown, which of course acts to amplify the signal A for retransmission along guide 87. At the next relay station similar apparatus is used for amplifying the signal of B.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In signaling apparatus, a dielectric wave guide for conveying electromagnetic wave signals, a relay apparatus for amplifying the wave signals, and energy interchanging means linking the wave signals in the guide and connected with said relay apparatus, said energy interchanging means being responsive to the direction of travel of the wave signals along the guide for coupling said relay apparatus to said wave guide, said energy interchanging means comprising a plurality of separate interconnected spaced means for receiving energy from the guide and interconnected spaced means for retransferring energy to the guide after amplification by said relay apparatus.

2. A signaling system comprising a wave guide for conveying electromagnetic wave signals in opposite directions therealong, a relay apparatus for amplifying said wave signals travelling in one direction along said guide while passing said wave signals travelling in the other direction along said guide, means responsive to the direction of travel of said wave signals in said one direction along said guide for coupling said relay apparatus to said wave guide, and means responsive to the output of said relay means for propagating wave signals along said wave guide in said one direction.

3. A signaling system as in claim 2 wherein said direction responsive means comprises a plu-

ality of inter-connected energy receiving means spaced along said circuit.

4. A signaling system as in claim 2 wherein said direction responsive means comprises a plurality of inter-connected energy receiving means spaced along said circuit, one of said receiving means including phase shifting means.

5. A signaling system as in claim 2 wherein said direction responsive means comprises a pair of energy receiving means spaced along said circuit and a phase shifting device connected to one of said receiving means for making the phase of the output thereof equivalent to the phase of the other of said receiving means.

6. A signaling system as in claim 2 wherein said propagating means comprises a plurality of interconnected energy coupling means spaced along said circuit.

7. Relay apparatus for dielectric guides, comprising discriminating receiving means connected with a dielectric guide, said discriminating receiving means acting to selectively receive a signal traversing the same in accordance with the direction of travel of the signal therein, an amplifier fed from said receiving means for amplifying said signal, and directional radiating means connected with said guide and said amplifier for radiating the amplified signal for continued passage along the guide in its initial direction.

8. Relay apparatus for signal transmitting dielectric guides, comprising a dielectric guide, discriminating receiving means connected with said dielectric guide for extracting signal energy from said guide, said discriminating receiving means acting to selectively receive a signal traversing said guide in accordance with the direction of travel of the signal therein, and directional radiating means connected with said guide at a point longitudinally spaced from said connection to said receiving means for radiating said received signal for continued passage along said guide in its initial direction.

9. In a transmission circuit having signals traversing the same in both directions, means responsive to the direction of travel of signals along the circuit for selectively receiving one of said signals moving along the circuit in one direction, an amplifier connected to said receiving means for amplifying said signal to the exclusion of the other signal traversing the circuit in the reverse direction, and directional transmitting means for transmitting the amplified signal back to said transmission circuit for further transmission therealong in said one direction only and with but little feed-back therefrom to said receiving means, said receiving and transmitting means operating without interfering with the passage of said other signal along said transmission circuit.

10. In a transmission circuit having signals traversing said circuit in both directions, the combination including means responsive to the direction of travel of signals along said circuit for selectively receiving one of said signals moving along said circuit in one direction to the exclusion of other signals traversing said circuit in the reverse direction, and separate directional transmitting means connected with said receiving means and spaced along said circuit from said receiving means for transmitting said received signal back to said transmission circuit for further transmission therealong in said one direction only, and with but little feedback therefrom to said receiving means, said receiving and transmitting means operating without inter-

ferring with the passage of said other signals along said transmission circuit in said reverse direction.

11. In combination, a dielectric guide having two differently polarized electromagnetic wave signals moving in opposite directions therein, repeater means connected with said guide, said repeater means comprising polarization sensitive means interposed in said guide acting to block the first of said signals traveling in one direction while passing the second signal traveling in the reverse direction and a section of dielectric guide connected in shunt with a portion of said guide and bridging said blocking means, said shunt guide section having polarization sensitive means acting to block the second of said signals so that the latter passes through said repeater means without amplification, said bridging section polarization sensitive means serving to pass the first signal, and an amplifier in said shunt guide section for amplifying said first signal for further transmission along said guide.

12. In combination, a transmission line having two differently polarized electromagnetic wave signals moving in opposite directions therein, repeater means connected with said line, said repeater means comprising polarization-sensitive means interposed in said line acting to block one of said signals traveling in one direction while passing the other of said signals travelling in the reverse direction, and a circuit connected in shunt with a portion of said line and bridging said blocking means, said shunt circuit having polarization-sensitive means acting to block the other of said signals and serving to pass said one signal for further transmission along said line.

13. In a signaling system, a transmitting circuit for transmitting signals in opposite directions, repeaters disposed at intervals along said circuit, said repeaters comprising discriminating signal selective means and amplifier means, said discriminating signal selective means comprising energy interchanging means responsive to the direction of travel of the signals along the circuit, the discriminating signal selective means of the repeaters being so designed that only alternate repeaters amplify signals traversing said circuit in one direction, while the remaining repeaters amplify signals traversing said circuit in the opposite direction, whereby feed-back is reduced by the attenuation of the circuit between repeaters, thereby enabling amplifier means of relatively large gain to be used.

14. In a signaling system, the combination including a transmission circuit for simultaneously transmitting signals in opposite directions, repeaters disposed at intervals along said circuit, said repeaters comprising discriminating signal-selective means and amplifier means, said discriminating signal-selective means comprising energy interchanging means responsive substantially only to signals traveling in one direction along said circuit, the discriminating signal selective means of said repeaters being so designed that only alternate repeaters amplify signals traversing said circuit in one direction while the remaining repeaters amplify only signals traversing said circuit in the opposite direction, said repeaters being spaced by distances offering appreciable attenuation, whereby feedback is reduced by the attenuation of said circuit between consecutive repeaters.

15. In a signaling system, a dielectric guide, means for producing high frequency oscillations,

means for modulating said oscillations with intelligence to be transmitted along said guide, and directional transmission means connected with said first and second named means and with said guide at a point remote from the ends thereof for radiating the modulated high frequency oscillations in one direction only along said guide, said directional transmitting means comprising emitters so spaced along said guide that their outputs are additive going in said one direction along the guide while their outputs are subtractive and cancel in the reverse direction.

16. A signaling system as defined in claim 15, comprising directionally responsive receiving means located in said guide at a point remote from the ends thereof for receiving signals traversing said guide in said one direction only, and amplifying and detecting means connected to said receiving means for amplifying and detecting received oscillations traversing said guide in said one direction.

17. In a signaling system, a dielectric guide, a source of high frequency oscillations, and directional transmitting means for radiating said oscillations in one direction only along said guide, said directional transmitting means comprising a pair of emitters longitudinally spaced along said guide, and means for supplying electromagnetic energy from said source to the respective emitters in predetermined relative phase displacement, said phase displacement being so correlated with said emitter spacing that the outputs of said emitters are additive in said one direction along said guide and subtractive in the reverse direction.

18. A signaling system as in claim 17, further comprising a pair of similarly spaced directionally responsive receiving means located in said guide for receiving signals traversing said guide in said one direction only, and utilization means connected to said receiving means for utilizing said received oscillations traversing said guide in said one direction.

19. In a signaling system, a dielectric guide, means for generating high frequency oscillations, two radiating means mutually spaced from one another within said guide, means electrically connecting said generating means to both of said radiating means, said connecting means including means for maintaining a definite phase difference between the respective oscillations of the individual radiating means, said connecting means also including means for maintaining the radiation field output of one radiating means substantially equal to that of the other.

20. A signaling system comprising a hollow guided electromagnetic wave transmission circuit, a source of high frequency oscillations, a pair of coupling means within said circuit for coupling high frequency energy to said circuit and mutually spaced from one another along said circuit, and means connecting said source to both of said coupling means, said connecting means including means for maintaining a definite phase difference and a definite amplitude relation between the respective oscillations of the individual coupling means.

21. A signaling system comprising a hollow guided electromagnetic energy transmission circuit, a source of high frequency oscillations, a pair of coupling means within said circuit for coupling high frequency energy to said circuit and mutually spaced from one another along said circuit, means connecting said source to both of said coupling means, said connecting

means including means for maintaining a predetermined phase difference between the respective oscillations of said individual coupling means, said phase difference being so related to the spacing of said coupling means that waves projected along said circuit in one direction by said two coupling means are in phase coincidence at each point of said circuit, whereas waves projected along said circuit in the opposite direction by said two coupling means are in phase opposition.

22. In a signaling system employing a dielectric guide, two electromagnetic energy extracting means spaced apart in said guide, a high frequency amplifier, means connecting said two energy extracting means to said amplifier, said connecting means cooperating with said two energy extracting means to deliver the signals received thereby to said amplifier in phase opposition when the electromagnetic waves producing the signals received by said two energy extracting means are traversing the guide in one direction, said signals being delivered to said amplifier in substantially the same phase when the electromagnetic waves producing the signals received by the two energy extracting means are traversing the guide in the reverse direction.

23. A signaling system as defined in claim 22, wherein amplitude adjusting means is provided for making the signal outputs of said two energy extracting means equal at the input to said amplifier.

24. A signaling system comprising a hollow guided electromagnetic energy circuit, two electromagnetic energy extracting means spaced apart along and within said circuit, an electromagnetic energy utilization device, and means connecting said two energy extracting means to said utilization device, said connecting means cooperating with said two energy extracting means to deliver the signals received thereby to said utilization device in phase opposition when the electromagnetic waves producing said signals are traversing said circuit in one direction, said signals being delivered to said utilization device in substantially the same phase when the electromagnetic waves producing said signals are traversing said circuit in the opposite direction.

25. A signaling system as defined in claim 24, further comprising amplitude adjusting means for making equal the amplitudes of the signals delivered to said utilization device by said two energy extracting means.

26. The method of relaying signals in opposite directions along a dielectric guide, comprising amplifying the signal traversing the guide in one direction substantially without feedback at a point along the guide while passing the signal moving in the opposite direction without appreciable amplification at that particular point, amplifying the signal moving in the opposite direction along the guide at a second point remote from the first point substantially without feedback at such second point while passing the signal moving in said one direction without appreciable amplification at the second point, and utilizing the spacing of the points of amplification to attenuate feedback signals amplified at both points of amplification, thereby increasing stability.

27. A system for relaying signals moving in

opposite directions along a dielectric guide, comprising means for amplifying the signal traversing said guide in one direction substantially without feedback at predetermined point along said guide, while passing the signal traversing said guide in the opposite direction without appreciable amplification at said point, and means for amplifying the signal moving in said opposite direction at a second point of said guide spaced from said first point and substantially without feedback, while passing the signal moving in said one direction without appreciable amplification at said second point, whereby the portion of said guide between said two points serves to attenuate undesired feedback signals amplified at each of said points, whereby the stability of the system may be increased.

28. The method of relaying high frequency electromagnetic signals in opposite directions along a transmission circuit, comprising the steps of amplifying a signal traversing said circuit in one direction at a predetermined point along said circuit while passing the signal traversing said circuit in the opposite direction without appreciable amplification at said point, amplifying the signal moving in said opposite direction along said circuit at a second point of said circuit remote from said first point while passing the signal moving in said one direction without appreciable amplification at said second point, and utilizing the spacing of said points to attenuate feedback signals amplified at both said points, whereby the stability of said system may be increased.

29. The method of relaying high frequency electromagnetic signals in opposite directions along a transmission circuit, comprising the steps of amplifying a signal traversing said circuit in one direction at a predetermined point along said circuit while passing the signal traversing said circuit in the opposite direction without appreciable amplification at said point, and amplifying the signal moving in the opposite direction along said circuit at a second point of said circuit separated from said first point by a distance providing appreciable attenuation while passing the signal moving in said one direction without appreciable amplification at said second point, whereby the spacing of said two points attenuates feedback signals amplified at both said points, and the stability of said system is thereby increased.

30. A system for relaying high frequency electromagnetic signals in opposite directions along a transmission circuit, comprising means for amplifying the signal traversing said circuit in one direction at a predetermined point along said circuit while passing the signal moving in the opposite direction at said point without appreciable amplification, means located at a second point spaced along said circuit from said first point for amplifying the signal moving in said opposite direction and for passing the signal moving in said one direction without appreciable amplification at said second point, whereby the portion of said circuit between said two points serves to attenuate undesired feedback signals amplified at each of said points, whereby the stability of said system may be increased.

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CERTIFICATE OF CORRECTION.

Patent No. 2,375,223.

May 8, 1945.

WILLIAM W. HANSEN, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, second column, line 13, for "if" after "impedance" read --of--; page 7, first column, line 34, claim 24, after "energy" insert --transmission--; and second column, line 4, claim 27, after "at" insert --a--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of August, A. D. 1945.

Leslie Frazer

(Seal)

Acting Commissioner of Patents.