Feb. 2, 1943. J. E. MAYNARD 2,310,198

SIGNAL TRANSMISSION SYSTEMS

Filed Jan. 17, 1941

Fig. 1.

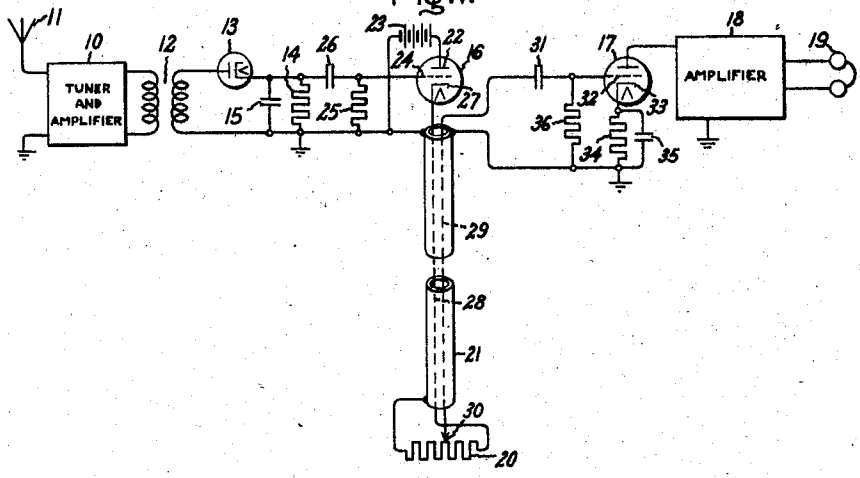


Fig. 2.

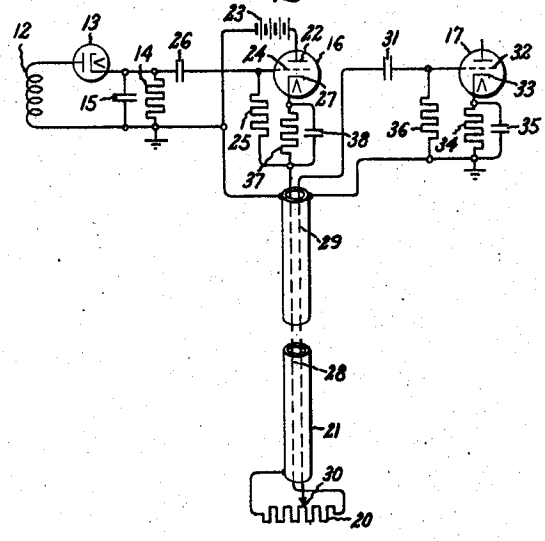


Fig. 3.

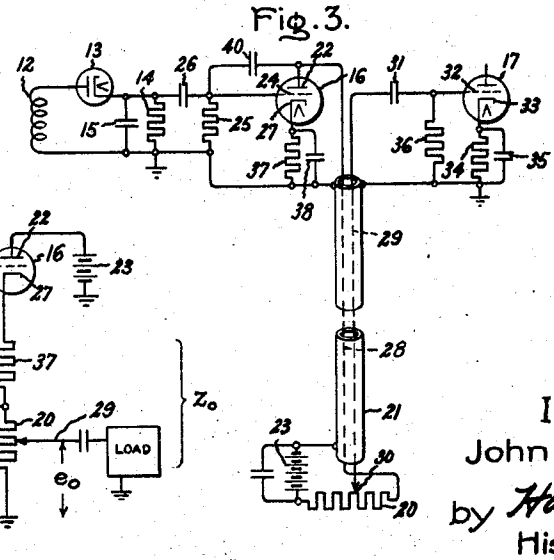
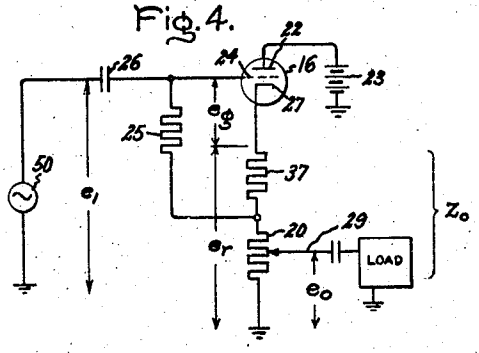


Fig. 4.



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UNITED STATES PATENT OFFICE

2,310,198

SIGNAL TRANSMISSION SYSTEM

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Application January 17, 1941, Serial No. 374,905

6 Claims. (Cl. 179—171)

My invention relates to signal transmission systems, and more particularly to improved means for automatically compensating for the effects of varying attenuation produced by such systems at different frequencies to be transmitted.

It frequently occurs, for example, that it is desired to transmit signals, represented by currents having frequencies extending over a broad range, from an amplifier through an impedance network, such as a transmission line, to a load device located at a distant point and where the impedance network, or transmission line, has different attenuation at the different frequencies to be transmitted and thus undesirably affects the output signals.

An object of my invention is to provide improved compensating means to compensate for such varying attenuation at the different frequencies thereby to permit faithful reproduction at the output device of the desired signals.

A further object of my invention is to utilize the impedance of such a transmission line to control the amplification of the amplifier from which signals are supplied to the line in such a way that the amplification of the amplifier is greater at the frequencies at which the transmission line has most attenuation, thereby to compensate for the effect of such attenuation.

A further object of my invention is to utilize such impedance to control the degeneration of the amplifier to effect such compensation.

One application in which my invention finds particular utility is in connection with aircraft radio receivers, for example, in which it is desired manually to control the output volume of the receiver from a point remote from the receiver in which detection and amplification of the signals occurs. In accordance with my invention, such signals may be transmitted through a transmission line from an amplifier in the receiver to a load resistance located at the point where manual volume control is to be effected. Signals may then be supplied from a variable portion of this resistance to the loud-speaker, or other signal reproducer, either through the transmission line or otherwise, as desired.

An object of my invention is to utilize the impedance of such a transmission line to control the degeneration of the amplifier, thereby to vary the amplification of the amplifier properly to compensate for the effects of the varying attenuation of the line with respect to frequency upon the fidelity of the reproduced signal.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 illustrates an embodiment of my invention; and Figs. 2 and 3 illustrate different modifications thereof.

In Fig. 1 of the drawing, I have illustrated a radio receiver which may comprise an amplifier 10 tuned to a carrier wave of frequency to be received, which amplifier bears the legend "Tuner and amplifier." This amplifier receives a radio wave from an antenna 11 and transmits the wave through a transformer 12 to a diode rectifier 13. A load resistance 14 and a condenser 15 in shunt thereto are connected in series with the rectifier 13 and the transformer 12. One end of the resistance 14 is grounded, and signal voltages appear thereacross due to the action of the rectifier 13. The signal voltages appearing across the resistance 14 may be audio voltages, video voltages, or the like. These signal voltages across the resistance 14 are transmitted through an electron discharge device 16 in a way to be explained hereinafter to an electron discharge amplifier device 17, which further transmits the signals through an amplifier 18 to a load device, such, for example, as headphones 19.

It is frequently desirable to control the transmission of signal voltages between the rectifier 13 and the device 17 from a remote position, perhaps 50 to 100 feet away. In many situations wide range of signal strength encountered by the antenna 11 makes it impractical to control the grid bias potential of an amplifier discharge device in the receiver, since this potential would have to be varied over such wide limits as to introduce serious distortion under certain conditions of adjustment. To avoid such distortion it is preferable to control directly through the use of a voltage dividing resistance or the like the amount of alternating signal voltage transmitted.

To accomplish this end a remote volume control resistance, or voltage divider, 20 is connected through a shielded two-conductor cable 21 at the receiver as follows: The shield covering of the cable 21 is connected to ground near the device 16, whose anode 22 is connected through a source 23 of potential to ground. The control electrode 24 is connected through a resistance 25 to ground, and is coupled through coupling condenser 26 to

the resistance 14. The cathode 27 of the device 16 is connected through a conductor 28 of the cable 21 to one end of the voltage divider 20, the other end of which is connected to the shield of the cable 21. The other conductor 29 of the cable 21 is connected to an adjustable tap 30 of the remote volume control resistance 20, and at the other end of the cable, it is connected through a coupling condenser 31 to the control electrode 32 of the device 17. The cathode 33 of the device 17 is connected through a bias resistance 34 to ground, the resistance 34 being by-passed by a condenser 35 which presents low impedance to signal current. The control electrode 32 is connected through a resistance 36 to ground.

In operation signal voltage across the resistance 14 produces corresponding voltage variation on the control electrode 24. The space current of the device 16 flows through the resistance 20 so that signal voltage appears across the remote volume control 20. A certain portion, as desired, of this signal voltage on the resistance 20 is taken off by the tap 30 and applied across the resistance 36 through the coupling condenser 31. The voltage across the resistance 36 is repeated through the amplifier device 17 and through the amplifier 18 to the headphones 19.

The device illustrated in this figure is capable of controlling signal voltage on the resistance 14 over a considerable range of intensities. In a typical example the bias voltage developed by the voltage drop through the resistance 20 was about 6 volts, and the device 16 is, therefore, capable of transmitting any signal whose peak voltage developed across the resistor 25 does not exceed 6 volts.

In Fig. 2 there is illustrated a circuit which is adapted to the control of a larger range of input voltages. In this circuit many of the elements are similar to those illustrated in Fig. 1 and are given like reference characters. The cathode 27 of the device 16 is connected through a bias resistance 37 to the conductor 28. A condenser 38 may be connected in shunt to resistance 37 for by-passing signal current therearound. The use of condenser 38 results in a slight increase of voltage transfer through the device 16, as will be explained hereinafter. The resistance 25 is connected to a point between the resistance 37 and the conductor 28. With this connection the resistance 37 is made of suitable value to provide the proper bias potential for the control electrode 24. The resistance 20 is made sufficiently large so that the potential drop across it plus the potential drop across the resistance 37 is at least as large as the maximum voltage which must be transmitted through the network. The resistance 20 may, for example, be five times as large as the resistance 37. If the bias potential developed across the resistance 37 is 6 volts, and the potential across he resistance 20 is 30 volts, an input signal which produces 36 volts at the peak across resistances 37 and 20 may be transmitted satisfactorily. The voltage of the source 23 is of sufficient magnitude to produce a voltage drop of 36 volts across resistances 37 and 20 in the absence of a signal.

Since this circuit illustrated in Fig. 2 is capable of handling large voltages, whose magnitude is not limited by consideration of the magnitude of bias voltage, it is the preferred circuit, especially since a carefully built receiver should develop voltages at the output of the detector 13 much higher than the bias voltage which is suitable for a discharge device.

It is also to be preferred in most situations that the by-pass condenser 38 be omitted. The reason for this preference is that if the by-pass condenser 38 be used, a fixed negative bias is maintained between the control electrode 24 and cathode 27, and with increasing input voltage plate current cut off is reached at a smaller input voltage than if the condenser is omitted. However, a greater proportion of the output voltage is available across the potentiometer 20 if the condenser 38 is used. The necessities of the particular situation should dictate whether the condenser 38 should be used or not.

Although there is substantial capacity between the shield of the cable 21 and the conductors 28 and 29, which may be in some cases as high as 2500 micromicrofarads for 100 foot cable, it has been found that such capacity does not substantially affect the transmission of high frequency components of signals from the resistance 14 to the device 17. The reason that the apparatus transmits signals from the resistance 14 to the device 17 with substantially equal attenuation at all frequencies in spite of the substantial capacity in the cable 21 rises from the fact that the discharge device 16 is connected to act as a degenerative amplifier.

The device 16 acts as a degenerative amplifier because the resistance 20 having one terminal connected to the cathode 27, is in a common portion of both the input and the output circuits of the device 16. The input circuit of the device 16 may be traced from the control electrode 24 through the resistance 25, the shield of the cable 21, resistance 20, conductor 28, and to the cathode 27. The output circuit of the device 16 may be traced from the anode 22 through the source of operating potential 23, the shield of the cable 21, resistance 20, conductor 28, and to the cathode 27. Upon an increase in voltage across the resistance 14, the control electrode 24 tends to become more positive with respect to the cathode 27, so that the device 16 transmits more current from the source 23 through the anode 22 and cathode 27 and through the resistance 20. The anode 22 is at a fixed positive potential with respect to ground, and upon increased current flow through the resistance 20, the cathode 27 rises to a more positive voltage with respect to ground. When the cathode 27 becomes more positive with respect to ground, the rise in voltage of the control electrode 24 is in part offset, so that only a portion of the voltage across the resistance 25 appears between the control electrode 24 and the cathode 27. A wave impressed across the resistance 25 is thus partially opposed by a wave consequently appearing across the resistance 20 in opposing phase in the input circuit of the device 16.

An amplifier so connected with a resistance common to its input and output circuits operates in a well known manner, and is termed a degenerative amplifier. The operation of this amplifier including the discharge device 16 may be more fully explained with reference to Fig. 4.

In Fig. 4, a signal source 50 is illustrated as coupled through a coupling condenser 26 to the control electrode 24 of the device 16. Other elements of the circuit are identical with those illustrated in Fig. 2, the condenser 38 being omitted. The instantaneous voltage of the source 50 is designated as e_i in the figure, while the instantaneous voltage between the conductor 29 and ground is designated as e_o. The instantaneous voltage between the control electrode 24 and

the cathode 27 is designated as e_g, and the instantaneous voltage across the resistances 20 and 37 is designated as e_r. The amplification factor of the device 16 is termed μ, and its "plate resistance" is hereinafter called R_p. The impedance of the circuit into which the device 16 delivers energy, which circuit includes the resistances 20 and 37, the load connected between the conductor 29 and ground, and all capacities thereacross, is termed Z_o.

The relation between e_g and e_r may now be expressed as follows:

$$e_r=\frac{\mu Z_o}{Z_o+R_p}e_g \qquad (1)$$

Considering the instantaneous voltages e_g, e_i, and e_r as vectorial quantities, the following relation exists therebetween:

$$e_g=e_i-e_r \qquad (2)$$

Eliminating e_g from these two equations, the following equation results:

$$e_r=\frac{\left(\frac{\mu}{1+\mu}\right)Z_o}{Z_o+\frac{R_p}{1+\mu}}e_i \qquad (3)$$

This equation may be restated in terms of e_o, because:

$$e_r=Ke_o \qquad (4)$$

where K is a factor depending only on the position of the tap 30.

$$e_o=\frac{\left(\frac{\mu}{1+\mu}\right)Z_o}{Z_o+\frac{R_p}{1+\mu}}\frac{e_i}{K} \qquad (5)$$

The form of this Equation 5, upon comparison with the form of Equation 1, shows that the same result might be secured if the device 16 were not connected degeneratively, but instead were constructed to have an amplification factor

$$\mu_1=\frac{\mu}{1+\mu}$$

and whose plate resistance

$$R_{p1}=\frac{R_p}{1+\mu}$$

The equation for the newly constructed device 16 would appear:

$$e_o=\frac{\mu_1 Z_o}{Z_o+R_{p1}}\frac{e_i}{K} \qquad (6)$$

If the amplification factor μ of the device 16 be large, for example, of the order of 10 or 15 or more, the apparent plate resistance R_{p1} will be a small fraction of the actual plate resistance R_p of the device 16.

The impedance Z_o, which is constituted by the entire load on the device 16 including resistance 37, resistance 20 and the load connected across the resistance 20, as well as all capacities effectively in shunt to the load and to the resistances, can easily be made very large with respect to this apparent resistance R_{p1} of the device 16. When the device 16 operates as a degenerative amplifier, has an apparent plate resistance R_{p1} which is a small fraction of its actual plate resistance R_p, and the impedance Z_o is made large with respect to the apparent plate resistance R_{p1}, the device 16 tends to produce a constant voltage across the impedance Z_o when a predetermined voltage of any frequency is impressed on the input circuit of the device 16 from the source 50. Stated in other words, the load impedance may vary (as, for example, upon a change in frequency), but the voltage developed across the load impedance tends always to remain constant for a given input voltage of any frequency.

Viewed in still another way, a voltage e_i impressed on the device 16 produces a voltage e_o at the output. The voltage e_o is made considerably smaller than the voltage e_i by the use of a very large amount of degeneration. Now, if the frequency of the voltage e_i impressed on the input of the device 16 be increased, the voltage across the impedance Z_o is smaller because of the capacity component of Z_o which makes the impedance Z_o smaller at the higher frequency. However, with a smaller voltage across the impedance Z_o, there is less degeneration and consequently more amplification through the device 16, so that the voltage e_o is maintained substantially constant.

In a particular example the device 16 is a 12SR7 tube whose amplification factor is 16 and whose plate resistance is 8500 ohms. The resistance 20 is 20,000 ohms and the resistance 37 is 2000 ohms. The source 23 supplies 140 volts between the anode 22 and ground and 35 volts appear across the resistance 20, while 3½ volts appear across the resistance 37. This circuit can handle an input signal whose peak voltage across the resistances 20 and 37 reaches 38½ volts, and whose peak voltage between the control electrode 24 and ground reaches 41 volts. Very little change in output is detectable even when a capacity of 3000 micromicrofarads is present between the conductor 29 and ground, at normal audio frequencies.

In Fig. 3 there is illustrated a different modification in which degeneration is produced in a somewhat different way. Many of the circuit elements are similar to those illustrated in Figs. 1 and 2 and are given like reference characters. In this circuit the signal voltage across the resistance 14 is coupled through coupling condenser 26 directly across the resistance 25. The resistance 25 is connected between the control electrode 24 and ground, and the cathode 27 is connected to ground through the resistance 37, bypassed by the condenser 38 for signal currents. The anode 22 is coupled through a condenser 40 to the control electrode 24 to provide sufficient degeneration to reduce the amplification of the device 16 to an amount less than unity. The anode 22 is further connected through the conductor 28 and the volume control resistor 20 to the positive terminal of the source 23, whose negative terminal is connected to the shield of the cable 21. Other connections are as illustrated in Figs. 1 and 2.

In operation this circuit behaves similarly to the circuit illustrated in Fig. 2 and is capable of handling about the same amount of input signal. Its theory of operation is much the same. In this circuit as in the circuits of Figs. 1 and 2 the volume control resistor 20 should be large with respect to the apparent plate resistance of the device 16. The shunting effect of capacity on high frequency portions of the signal is a minimum.

My invention is not limited in usefulness to a radio receiver but it may be utilized to provide remote control of any signal, such, for example, as from a public address system, broadcast studio audio channel, or a television transmitter. Furthermore, the attenuated signal across the voltage divider 20 may be transmitted elsewhere than

through the conductor 29 back to a point near the signal source. It may, for example, be utilized at a point near the divider 20. In any case the device 16 operates to transmit signals at any frequency in proper intensity, regardless of large amounts of capacity.

The device may be utilized to good advantage wherever a load device has an impedance characteristic such that signals transmitted to it are attenuated differently at different frequencies. The conductors 28, 29, for example, might be replaced by a device having inductance so that the wave transmitted from the device 16 to the resistance 20 would be attenuated less at high frequencies than at low frequencies. In such cases, less degenerative voltage is impressed in the input circuit of the device 16 at low frequencies by reason of the inductance in series with the resistance 20. Consequently, there is less degeneration at low frequencies and transmission of higher low frequency voltages through device 16. In any case, the device is useful for equalizing the attenuation of a signal having frequencies extending over a band, where the signal must be impressed on a load device having substantial reactance.

While I have shown a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto, since different modifications may be made both in the circuit arrangement and the instrumentalities employed, and I aim by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In combination, a source of signals having frequencies extending over a band of frequencies, a network through which the signals from said source are to be transmitted, said network having reactance varying with frequency whereby signals transmitted through said network are attenuated differently at different frequencies, an electron discharge device having a cathode, an anode, and a control electrode, an output circuit connected between said anode and cathode and including said network, an input circuit connected between said control electrode and cathode and including said source of signals, and means comprising a capacity between said anode and control electrode for producing in said input circuit a degenerative voltage derived from the signal voltage across said input reactance, said capacity having such value as to cooperate with said reactance in producing sufficient degeneration at any particular frequency in said band to reduce the amplification through said discharge device to a value less than unity and to compensate the variation in attenuation of said signals over said band of frequencies caused by said reactance.

2. An electron discharge amplifier having an anode, a cathode, and a control electrode, a load device remote from said amplifier, a transmission line extending from said amplifier to said load device, a source of signals to be transmitted through said line to said load device, an input circuit connected between said control electrode and cathode through said source, an output circuit including said load device and connected between said anode and cathode through said transmission line, the impedance of said transmission line being variable with frequency whereby said signals are distorted during transmission through said line, and means comprising the impedance of said line and a capacity between said anode and control electrode for producing in said input circuit a degenerative voltage derived from the signal voltage across the impedance of said line, said capacity being of sufficient magnitude to produce said degenerative voltage in an amount sufficient to reduce the amplification of said amplifier to value less than unity thereby reducing distortion of said signals at said load device caused by the varying impedance characteristics of said line.

3. A source of signals extending over band of frequencies, a voltage divider distant from said source, an electron discharge device having an anode, a cathode, and a control electrode, a circuit including said divider and connected between the anode and cathode of said device, said circuit comprising conductors having substantial capacity therebetween, a circuit including said source and connected between said control electrode and cathode, and means including a condenser connected between said anode and control electrode for impressing on said control electrode a degenerative voltage derived from the voltage across said conductors and voltage divider, said condenser being sufficiently large to produce degeneration through said device to reduce the amplification therethrough to an amount less than unity, whereby the effect of capacity between said conductors is reduced and the various frequency components of said signals at said divider tend to be equalized in intensity.

4. A source of signals extending over a band of frequencies, a voltage divider distant from said source, connections from said source to said divider comprising a plurality of conductors in close proximity having appreciable capacity therebetween, and means for transmitting a large proportion of the higher frequency components of said signals with respect to the lower frequency components, said means comprising said conductors and said divider, an electron discharge device having a cathode, an anode, and a control electrode included in said connections near said source, and a condenser connected between said anode and control electrode, said condenser being of sufficient capacity to produce degenerative feedback reducing the amplification through said device to an amount less than unity, whereby the various frequency components of said signals at said load device tend to be equalized.

5. In combination, an electron discharge device having an anode, a cathode, and a control electrode, an output circuit connected between said anode and cathode, an input circuit connected between said control electrode and cathode, said input circuit including a source of signals having frequencies extending over a wide range to be transmitted by said device to said output circuit, a resistance and a source of discharge current for said device connected in said output circuit and located at a considerable distance from said device, the conductors of said output circuit extending from said resistance and current source to said device having substantial capacitance therebetween, a condenser connected between said anode and control electrode, and a load device connected across at least a part of said resistance, the voltage across said conductors and said resistance being impressed on said control electrode through said condenser in a degenerative sense, said condenser having such a value that the variation in attenuation of said signals over said band of frequencies is compensated by variation of degeneration of said de-

vice caused by the reactance of said capacitance.

6. In combination, signal apparatus comprising a source of signals and means for utilizing signals from said source, means located at a point remote from said signal apparatus for attenuating said signals in transmission from said source to said utilizing means, said attenuating means being connected to said source and said utilizing means through conductors having sufficient capacity therebetween to cause said signals in transmission to be undesirably attenuated differently at different frequencies, and means for substantially eliminating said undesirably different attenuation comprising an electron discharge amplifier device having an anode, a cathode, and a control electrode included in said conductors near said source, and a condenser connected between said anode and said control electrode, said condenser being of sufficient capacity to produce degenerative feedback reducing the amplification from said source through said device and conductors to said utilizing means to an amount less than unity, whereby the various frequency components of said signals at said utilizing means are substantially equalized.

JOHN E. MAYNARD.