June 27, 1933. S. READ, JR 1,916,187

ELECTRICAL ATTENUATING SYSTEM

Filed May 20, 1931

Fig. 2.

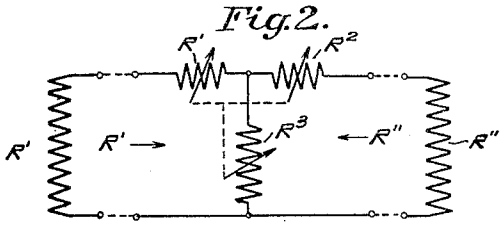


Fig. 1.

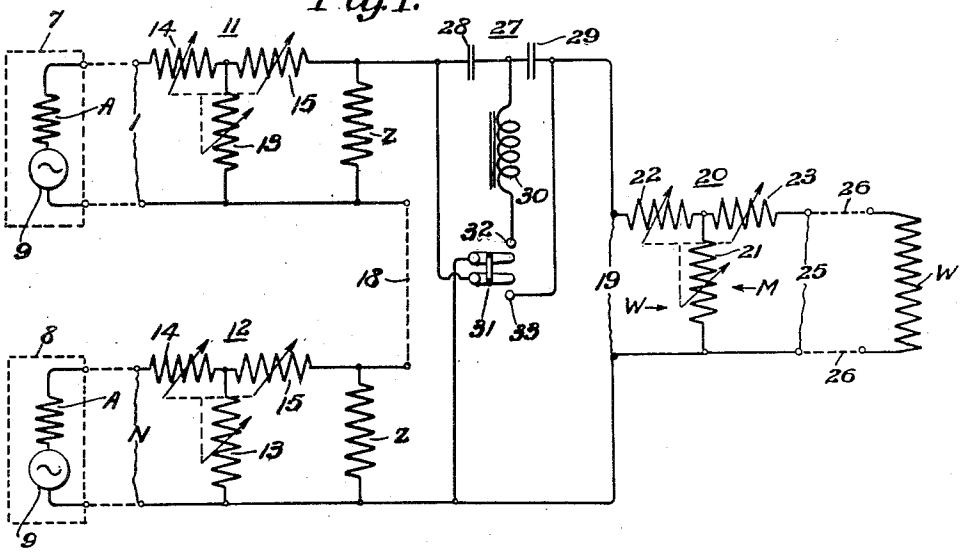


Fig. 3.

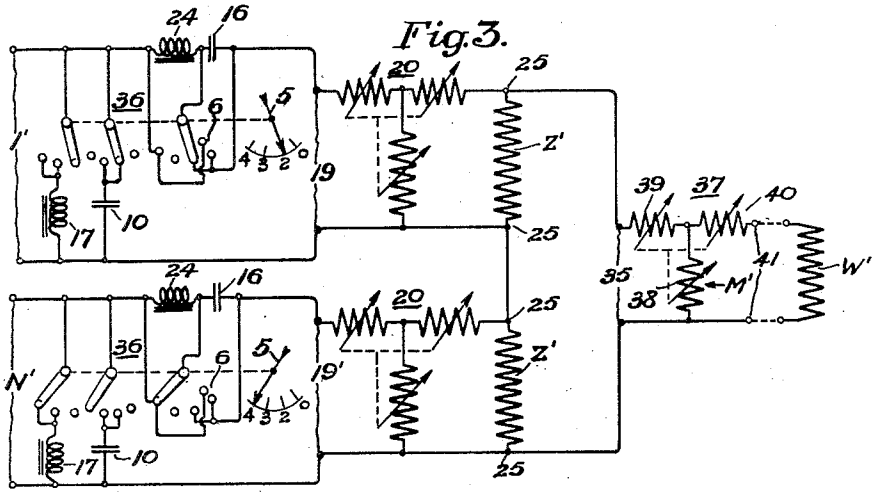
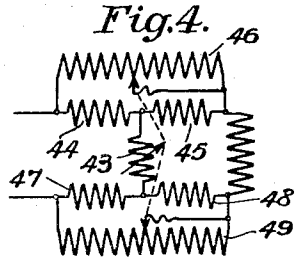


Fig. 4.



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Patented June 27, 1933 1,916,187

UNITED STATES PATENT OFFICE

SIDNEY READ, JR., OF HADDONFIELD, NEW JERSEY, ASSIGNOR, BY MESNE ASSIGNMENTS, TO RADIO CORPORATION OF AMERICA, OF NEW YORK, N. Y., A CORPORATION OF DELAWARE

ELECTRICAL ATTENUATING SYSTEM

Application filed May 20, 1931. Serial No. 538,705.

My invention relates to wave transmission systems and more particularly to variable attenuation networks useful in the combination or distribution of electric signal waves representing speech, music, or other subject matter.

In systems of the above character a plurality of electrical signal channels are employed which are capable of handling waves of a relatively wide frequency range and which are operated simultaneously in connection with a common circuit, device or channel. Such a system, when used for combining signal waves, may include a plurality of audio frequency signal channels, each of which is connected with a source of signals, such as a microphone, pickup, amplifier, or the like, with means for combining the outputs of the several channels into a common channel. Such a system for distribution of signal waves may include a common source of audio frequency signals, for example the output of an amplifier, with means for distributing said output into a plurality of channels, as in chain broadcasting where a program originates from a central studio and is transmitted by wires to a number of stations. Heretofore, in systems with which I am familiar, the output of such an amplifier has been fed into a single resistor from which several channels have been supplied, each channel employing a separate amplifier.

In recording or broadcasting, using pickups or microphones, it has often been necessary to use a plurality of microphones located, respectively, at the different points from which sound is to be picked up. This arrangement is used to increase the ratio of desired signals to interference or background noise and to obtain certain acoustic effects. It is sometimes desirable to utilize filters in the several channels, respectively, to obtain different ratios of low and high audio frequencies.

Heretofore, multiple channel systems of the types above described and with which I am familiar, have not been designed, among other things, to maintain constant loads upon the incoming channel or channels, giving a resultant non-uniform fidelity of transmission or frequency characteristic distortion for the different signal level adjustments of the adjustable controls. Certain circuit apparatus previously used included coupling tubes and transformers with the necessary added bulk of equipment, such as power supply apparatus, and with the added disadvantage of grid circuit pickup, of interference and stray coupling, as well as the difficulty of obtaining signals of extremely low amplitude adjustments.

Accordingly, an object of my invention is to provide an improved, simplified and effective system for combining the outputs of a plurality of branch or incoming signal channels into a common circuit or outgoing channel.

Another object is to provide in the system described immediately above, individual means for effectively controlling the output signal amplitude from each incoming channel without affecting the impedance of any of the other channels, or without affecting the respective signal intensities from any of said other incoming channels.

Another object of my invention is to provide a system of the above character which is adapted to distribute signals from a source or incoming channel into a plurality of outgoing branch channels.

Another object is to provide in the system described immediately above, including an individual attenuator in each branch channel, so arranged or designed as to have, when varied, substantially no effect on the amplitude level or frequency characteristics of any of the other channels.

Another object of my invention is to provide in the common channel in the above systems, a variable attenuator for adjusting the signal amplitude in said common channel without changing the fidelity of the system or the ratio of the signal intensities from or in the branch channels.

Another object of my invention is to provide an attenuator for amplitude adjustment in connection with the transmission of signals in each of several associated signal channels, adapted to variably control the attenuation of each channel and to maintain substantially a constant load on the channel so con-

trolled, and thereby to prevent change in the frequency characteristics or fidelity of the channel.

A further object of my invention is to provide, in systems of the above character, means for the purpose of obtaining certain desired frequency characteristics in or among said channels or circuits.

In accordance with my invention, I provide an attenuator for amplitude adjustment in connection with transmission of signals in each of a plurality of associated channels, with a suitable resistance or impedance element connected in shunt with each of said attenuators and at one end of the channel. The channels are then connected together in combination with a common channel, said resistance elements being connected in series relation across said common channel. Each of said elements, in addition to being in shunt with its particular channel, is effectively in parallel with the rest of the system external of said channel and connected therewith, and is of such a value that the combined impedance of said element and the rest of the system properly loads its associated variable attenuator.

The invention will, however, be better understood, and other objects of my invention will become evident from the following description when taken in conjunction with the accompanying drawing, to which attention is now directed.

In the drawing,

Fig. 1 is a circuit diagram of a signal attenuator or attenuation network, for a multiple channel signal transmission system, embodying my invention;

Fig. 2 is a detail of the circuit shown in Fig. 1 for the purpose of illustrating certain principles of operation;

Fig. 3 is a circuit diagram illustrating a modification of the control network of Fig. 1; and

Fig. 4 is a similar circuit diagram illustrating a further modification.

The signal amplitude, in a combining system, from each branch channel may be adjusted by an attenuation network in its output, without affecting the impedance of or signal amplitude from any other branch channel, provided the output impedance of each signal source on the input of each network and channel is of proper value with respect to the design of the network and channel that the impedance, looking into the network from the output end, remains substantially constant for all adjustments.

Referring to Fig. 1, a plurality of incoming signal channels or circuits are represented at 1 and N, each having its input connected with a signal current source of varying frequency indicated at 7 and 8, respectively. The usual system which I ordinarily employ includes four channels, of which two are shown in the present example by way of simplifying the drawing. The signal sources may each include a microphone, a pickup, or other signal generating device indicated at 9, together with a suitable amplifier, not shown. The respective generating devices may be different in kind or design in some cases. The output impedance or resistance of each source is represented by a series impedance A therein. This impedance comprises the internal impedance of each signal source, and in the present case, of the system which I have designed and built, it includes auxiliary series resistance added to adjust the output impedance of each of said sources to a value which provides a proper load upon the input of each of the attenuating networks 11 and 12 and respective channels.

Although I have in the present case disclosed the use of auxiliary resistance in series at the source of signals to bring up the impedance thereof to the proper desired value, any other means, such as a transformer, may be used. It is possible to design the attenuator to conform with the actual impedance of the source of signals. However, in such a case the impedance load on one end of the attenuator would then in many instances be different from that on the other end, necessitating designing the series arms of the attenuator with different resistance values or characteristics and with the introduction of certain objectionable features, particularly in connection with the maximum amplitude adjustment of the attenuator.

The output of a frequency source may be controlled, without affecting the frequency characteristics or fidelity, by means of a variable attenuation network, provided the load impedance or resistance on the source is maintained constant. For this purpose, in the output of the branch channels 1 and N are provided, respectively, attenuators of the constant impedance type, properly designed with respect to the output impedance of said source, together with means for properly loading each attenuator on the output end thereof.

To insure that the input impedance of each attenuator 11 and 12 may remain constant when a plurality of these channels and their attenuators are connected as shown, I have provided on the output side of each T network in each channel to be so combined with the other channels, a shunt resistance or impedance element Z, designed to provide, with the external circuit impedance, an impedance of a value to properly load the output of the attenuator. These shunt elements Z, with their associated channels, are connected in series relation, as indicated by the connection 18, which is shown as a dotted line to indicate that any number of channels may be added in series with channels 1 and N. Each of the

elements Z is in shunt not only with its associated attenuator and channel but also with the external circuits, namely the output channel 19 and the other input channel or channels, in combined series relation. This factor is taken in consideration in the calculation of the size of the element Z.

The attenuators, namely 11 and 12, may each comprise three continuously adjustable resistance arms 13, 14 and 15 arranged to form a T type network, although any suitable adjustable network, for example the H type, may be used. Only the main resistance arm 13, connected in shunt in the channel, is in the present case electrically tapered, and series resistors 14 and 15 may also be tapered if desired, although for simplicity of design I have not done so in this case. As indicated by the dotted lines, the resistance arms are arranged to be varied simultaneously by a common means in such manner that as the resistance arm 13 decreases in value, the series arms 14 and 15, increase in magnitude. In the particular apparatus that I have designed and built the series arms 14 and 15 are preferably equal in value during all settings for reasons which follow. The theory and operation of a T network will be more fully described later, particularly in connection with Fig. 2.

For a more detailed explanation of the operation and design of an attenuation network of the T type, used in the above system, reference is had to Fig. 2. Generally, the arms of an attenuation network of the constant impedance type can be so designed that the resistance looking into one end of the attenuator is R′, indicated by the arrow, when the other end is loaded with a resistance R″, and the resistance looking into said other end is R″ when the first mentioned end is loaded with a resistance R′. In the present case, however, the resistance R′ and R″ are made equal, as above mentioned, and they may be represented by R in the following discussion.

The resistance R, therefore, of such a network is the resistance looking into either end when the other end is loaded with a resistance R. If the desired ratio of input to output voltage is K and the load resistance on each end of a T type network equals R, the values of the arms R1, R2 and R3 of the section are:

$$R1 = R2 = R\frac{K-1}{K+1} \quad (1)$$

$$R3 = R\frac{2K}{K^2-1} \quad (2)$$

An advantage of designing a system having the loads on both sides of the attenuator equal is that the variable resistors R1 and R2 are similar, and equal in resistance throughout the adjustment of amplitude, as above mentioned. This permits a maximum amplitude adjustment because of the fact that both series arms R1 and R2 can be adjusted to a zero value simultaneously. Otherwise, one arm would be zero while the other is a finite value, in series in the line.

For the purpose of simplifying the operation and control of my improved system, an overall control network or attenuator 20 is preferably used in the common outgoing channel or circuit 19 and comprises a variable control resistor 21 across the channel, and series variable resistors 22 and 23 on the input and output sides, respectively, of the control resistor 21. The total output load is represented by an impedance or resistor W, usually in the form of a recording system physically separated and distant from the mixing system, and connected with the output terminals 25 of the outgoing channel 19 by leads of desired length indicated at 26. The requirements and reasons for the design of the attenuator 20 are similar to those in connection with the attenuators 11 and 12, and a more detailed disclosure will appear further on.

A frequency filter 27 is ordinarily employed in association with the mixing system, preferably connected in the common outgoing channel, although in some cases it is desirable to insert a filter in any or all of the other channels. The filter shown is of the high-pass type, e. g. with a cut-off at about 100 cycles, particularly adapted in the case of motion picture sound recording to reduce interfering noises. In some cases it is desirable to employ a filter of the low-pass, or one of the band-pass type, or preferably, to provide several types, using a switching arrangement, such as that disclosed by Fetter 1,735,742, for selection of the desired filter circuit. Such an arrangement is shown in Fig. 3. The filter shown in Fig. 1 comprises a series impedance element, e. g. one or more series condensers 28 and 29, with a shunt impedance element or choke coil 30 connected to one side of the channel at a point between the condensers 28 and 29 and adapted to be connected across the channel. A simplified switch 31 is provided for readily cutting the filter into or out of circuit. From an inspection of the circuit diagram, it will be seen that when one blade of the switch makes contact with the lower end of the choke 27 at a point 32 of the switch, the filter is in the operating condition. When the switch is thrown so that the other blade contacts with a point 33 of the switch, the condensers 28 and 29 are short-circuited and the choke coil 30 is open-circuited, and therefore, the filter is effectively out of the circuit.

Referring to Fig. 3, a plurality of unitary or group systems, each similar to that described in connection with Fig. 1, are arranged to be combined into a single outgoing channel 35. Across each unitary outgoing channel 19, preferably containing the atten-

uation network 20, is connected an impedance of substantially fixed magnitude Z' whose value is determined in a manner similar to that in the design of impedance Z in Fig. 1. An overall variable attenuation control device 37, composed of resistance arms 38, 39 and 40, is connected in said common output for convenience of operation. In this manner the output of the two unitary systems shown may be combined and controlled, the final outgoing circuit or channel having output terminals 41 connected with any suitable device or load W' for receiving the output.

It is frequently desirable to place a pickup device in or near the orchestra in an auditorium and to place another pickup device near a performer or the stage. In such a case it may be desirable to obtain a different filtering effect in each of the associated branch circuits. When operating a mixing system using a simple filter and switching means like that shown in Fig. 1, each branch channel, it is possible if desirable, to throw out of circuit the filter in one branch while leaving the filter in the other branch, thereby obtaining a different frequency response in the two branches shown and a resultant modified frequency characteristic in the common outgoing channel.

In some cases a greater flexibility of frequency characteristic adjustment would be desired than could be obtained with the above simple filter arrangement, for the purpose of obtaining certain desired acoustic effects. I therefore have modified the circuit of Fig. 1, shown as a part of the combined system of Fig. 3, by the inclusion of a section of the more elaborate filtering arrangement of a type disclosed by the above mentioned Fetter patent, but slightly modified. In each of the branches 19 and 19' is included in series in the line, an inductance element 24 and condenser 16, and in shunt relation with each branch is an inductance element 17 and condenser 10. Although for purposes of simplification I have shown merely a half section filter comprising but two arms of the filter disclosed in the Fetter patent, above mentioned, any number of filter arms may be employed.

The switching device 36 is adapted to throw these elements into various combinations giving low-pass, band-pass, and high-pass filtering depending upon the position of the switch, as indicated by the location of the pointer 5 in relation to points 2, 3, 4 on the scale, respectively. Additional contacts 6, corresponding with point 0, have been provided for removing the filter from either or both channels if desired. It is obvious, for example, that the operator may adjust the filter in branch 19 to give a low-pass action, as indicated by the pointer 5 on point 2 while adjusting the filter in branch 19' to give a high-pass effect, as indicated by the pointer on point 4.

I have illustrated in Fig. 4 a slightly modified and simplified construction of a control network or attenuation device which may be used to advantage in combination with the above system. A shunt resistor 43 is variable as in the above cases, but series resistors indicated at 44 and 45 are fixed. Across the latter two is bridged a single variable resistor 46 which serves to effectively vary the series line resistance, the fixed resistors 44 and 45 serving merely as a potential divider in the channel or line with respect to series resistor 46. Since it is frequently desirable to employ H pads as the attenuation devices, the foregoing arrangement has particular utility in that only three variable elements are necessary instead of the usual five. In such a case resistors 47, 48 and 49, corresponding to resistors 44, 45 and 46, respectively, are placed in like positions in the other side of the channel or line. The same arrangemen could be used to advantage in any or all of the individual channels. This effects a considerable reduction, for purposes of manufacture, of the number of variable elements, having a common actuating means, resulting in but two variable controls for a variable T pad and but three for a variable H pad.

For a fuller understanding of my improved system, referring to the symbols in the drawing, let:

N=number of channels whose outputs are to be combined.

A=Resistance or impedance of the generator or source of potential feeding into the T network or variable attenuator of each branch channel; also the resistance R of the T network in each channel looking into this network from either end.

Z=Shunting resistance or impedance across the output of the T network in each channel.

Y=Resistance or impedance of A and Z above in parallel.

W=Resistance of the T network or variable attenuator used for overall volume control, looking into one end of the network in the direction of the load W, as indicated by the arrow from W.

M=Resistance of the T network or device used for overall volume control, as viewed from load W or output terminals of channel, indicated by the arrow at M.

The resistance Y will remain constant for all attenuations of the incoming channel, and therefore varying the attenuation of one of the incoming channels will not affect the attenuation of any of the other incoming channels.

The load on each input circuit or signal source will not change if its associated variable attenuation constant impedance network is properly loaded by impedance comprising

the resistance Z in parallel with the external circuit impedance represented by

$$Y(N-1)+W.$$

$$A=\frac{[Z[Y(N-1)+W]}{Y(N-1)+W+Z} \quad (3)$$

$$Y=\frac{AZ}{A+Z} \quad (4)$$

Combining (3) and (4)

$$Z=[NA+\sqrt{(NA+2W)^2-8AW}]\frac{A}{2[A(N-2)+W]} \quad (5)$$

If the resistance M, looking from the load W on the outgoing channel 19, does not have to be designed to equal the load W, the values of N, A and W can be substituted into equation (5) and the value of the loading resistor Z determined. This is satisfactory for any condition where it is permissible to supply power to a load without the effective resistance in series with the load remaining constant.

If several of the above combined outputs are to be further combined into one overall common channel and the load is of such a nature as to require a constant effective series resistance, it is obvious that M must equal W and remain constant. This imposes the condition that:

$$W=NY \quad (6)$$

Solving (3), (4) and (5)

$$A=\frac{W(2N-1)}{N^2} \quad (7)$$

W and N known.

$$Z=\frac{W(2N-1)}{N(N-1)} \quad (8)$$

$$W=\frac{AN^2}{2N-1} \quad (9)$$

A and N known.

$$Z=\frac{AN}{N-1} \quad (10)$$

It should be noted that the last imposed condition makes it possible to choose only two of the variables in the system. If three variables must be chosen and the last imposed condition exists, it will be necessary to use a transformer device in the outgoing channel, either before or after the overall control attenuator.

Although Fig. 1 shows but two channels, in actual practice I have employed four channels, each having a capacity microphone and an amplifier. It was desirable to have the input to the recording amplifier at W, not shown, equal 500 ohms, so that for four channels W equals 500 ohms and N equals 4. From Equations (7) and (8) A equals 219 ohms and Z equals 292 ohms.

The effective output impedance of the signal generating device 9 employed at the signal source is 125 ohms. Therefore a series resistance of 219 minus 125 ohms, or 94 ohms, must be added, to make the output of said source or the input resistance to each attenuator equal to A. This means that the pickup amplifier circuit has a constant load of 219 plus 94 or 313 ohms.

Referring to Fig. 3 where two of the above systems are to be combined, and in the particular case where M′ does not have to equal W′, Equation (5) can be used to solve for Z′, in which case

$$N'=2$$
$$A=W'=500 \text{ ohms}$$
then $Z'=1212$ ohms

Although the above described embodiments of my invention have been shown in an arrangement for combining or mixing electric signal waves from several different channels or sources, substantially the same system may be reversed and used as a distribution system from a single input channel; for example in Fig. 1, W may represent the impedance of a source of signal waves and the blocks 7 and 8 may represent suitable output devices having each a load resistance A. A similar reversal of parts may be made in the combined system shown in Fig. 3.

In the case of distribution of waves, the impedance elements Z, in Fig. 1, are of such value together with the effective impedance of the other channels in circuit therewith as to maintain constant the effective series resistance in each outgoing channel. This will maintain the fidelity of the system independent of the settings of the variable attenuators.

To insure independent operation of the several attenuators in the system when adapted to distribution of signals, it is desirable that resistance A, now the load on the output end of the attenuator and channel, be of proper value with respect to the design of the attenuating networks 11 and 12 and the channels respectively, that the resistance looking into the attenuator from the other end of the attenuator, remain constant. To preserve fidelity of transmission in the system when used for distribution it is desirable that the load on W, now the source of signals, be maintained constant. Substantially the same novel features of design embodies in the combining system apply in the case of the system used for distribution of signals. The changes in the system and elements therein will be readily obvious to those skilled in the art.

While I have disclosed my invention in connection with embodiments in combining and distribution systems, it has utility in correcting systems of the type disclosed for example by Mathes 1,311,283 where the incoming electrical waves, as in a channel, are

separated into a plurality of bands of different frequency ranges or components in a plurality of channels for selective treatment, and are then recombined into a common output circuit or channel.

With the above described system embodying my invention, it is possible, in a channel-combining system, to adjust the current corresponding to the intensity of sound at any of the pick-up points without varying the currents from any of the other points and without changing the frequency characteristics of the channels carrying said currents. Furthermore, the same general result is obtained in a distribution system, e. g. a chain boardcast system of the type above mentioned, or the like, that is, the signals set out to any one of the chain stations may be varied in intensity or character without affecting the amplitude level or frequency characteristics of signals sent out to any of the other stations.

I claim as my invention:

1. In a wave transmission system, the combination with a plurality of branch channels and a common channel therefor, of a variable attenuator in the output of each branch channel, and an impedance element in shunt across the output of each attenuator, said impedance elements being connected in series relation to each other and across the input of said common channel, the combined impedance of each of said elements and that of the total exterior circuit in shunt therewith being such as to properly load its associated attenuator, whereby the fidelity of transmission of said channels remains constant.

2. In a wave transmission system, the combination with a plurality of branch channels and a common channel therefor, of an adjustable attenuator connected in each of said channels and arranged for controlling the amplitude of waves therein while maintaining the fidelity of transmission in said system constant, an impedance element connected across one end of each branch channel and in shunt relation with the attenuator therein, the combined impedance of said element and that of the external circuit connected in shunt with each branch channel being such that the load upon the other end of each of said branch channels remains substantially constant for all adjustments of said attenuators.

3. In a multiple channel signal transmission system for combining the signal outputs of a plurality of audio frequency sources into a common output circuit, the combination of a signal attenuator of the constant impedance type connected in the output of each of said sources, the output impedance of each of said sources being so related to the impedance of its associated attenuator that individual adjustments in the amplitude of signals from any one of said sources has substantially no effect upon the amplitude of signals from any of the other sources, and means associated with each of said attenuators for maintaining constant load on each of said sources, respectively.

4. In a multiple channel signal transmission system for combining the signal outputs of a plurality of audio frequency sources into a common output circuit, the combination of a signal attenuator of the constant impedance type connected in the output of each of said sources, the output impedance of each of said sources being so related to the impedance of its associated attenuator that individual adjustments in the amplitude of signals from any one of said sources has substantially no effect upon the amplitude of signals from any of the other sources, and means for preserving fidelity of transmission constant comprising an impedance element of fixed value connected in shunt across the output of each of said attenuators, said fixed impedance elements being connected in series relation to each other and across the input of said common output circuit, whereby a substantially constant load is maintained upon each of said sources for all adjustments of said attenuators.

5. The combination as set forth in claim 4 further characterized by a variable attenuation network of the constant impedance type in said common output circuit for overall attenuation control.

6. In a signal distribution system, the combination with a plurality of signal outgoing channels and of a common incoming channel, of a variable attenuator of the constant impedance type in each of said outgoing channels, and impedance element in shunt across the input of each of said channels and said attenuator, said elements being connected in series relation to each other across the output of said common incoming channel, each of said elements being of such impedance value together with the effective impedance of the other channels in circuits therewith as to maintain substantially constant the effective series resistance in each of said outgoing channels.

7. In a signal distribution system, the combination with an incoming channel and a plurality of outgoing channels, of a variable attenuator within said incoming channel for varying the signal level from the output of said channel, a variable attenuator in each of said outgoing channels for individually varying the signal level in each channel, an impedance element in shunt across the input of each of said outgoing channels and in series relation with each other across the output of said incoming channel, and an adjustable filter associated with said channels.

8. In a signal transmission system, the combination with a plurality of incoming channels and a common outgoing channel, of

a variable T attenuator in the output of each incoming channel, a fixed resistor in shunt across the output of each of said attenuators, said resistors being connected in series relation to each other and across the input of said outgoing channel, and a variable T attenuator in said outgoing channel.

9. In a signal transmission system, the combination with a plurality of incoming channels and a common outgoing channel, a microphone in the input of each of said incoming channels, a variable T attenuator in the output of each of said input channels for varying the level of signals from said microphone to be impressed upon said output channel, means for matching the impedance of said microphone to that of said attenuator, and an impedance element connected in shunt across the output of each input channel, said impedance elements being connected in series relation across the input of said outgoing channel.

10. In a signal transmission system, the combination with a plurality of incoming channels and associated signal sources therefor, and a common outgoing channel, of an adjustable attenuator in the output of each incoming channel, an impedance element of fixed magnitude in shunt across the output of each of said attenuators and connected in series relation to each other across said outgoing channel, each of said elements being of such value with respect to its associated attenuator and the external circuit in shunt therewith as to cause a constant load to be maintained on said frequency source for all adjustments of said attenuators.

11. In a signal transmission system, the combination with a plurality of channels and a common channel associated therewith, of a variable attenuator in each of said channels, an impedance in shunt relation with each of said attenuators, said impedance being of such value with respect to the total exterior circuit in shunt therewith as to properly load its associated variable attenuator, and an adjustable filter section in each of a plurality of said channels for varying the relative frequency characteristics among the several channels.

12. In a signal transmission system, the combination with a plurality of channels and a common circuit associated therewith, of a variable attenuator in the output of each of said channels, said attenuator comprising a variable resistance in shunt with said channel and variable resistances in series in said channel on each side of said variable shunt resistance, and means for loading said attenuator comprising a resistor of fixed magnitude connected in shunt relation with said attenuator, said fixed resistor and said variable resistances being relatively so proportioned that for all variations of said attenuator, the load on the input of each of said channels remains substantially constant.

13. In a channel of a multiple channel transmission system, a source of waves at one end of said channel, and a fixed shunt resistor at the other end of said channel, a variable attenuator in said channel between said source and fixed resistor comprising a variable shunt resistance and a variable series resistance on each side of said variable shunt resistance, said variable resistances being relatively so proportioned that for all variations of said attenuator the resistance R of said attenuator is the resistance looking into either end when the other end is loaded with a resistance R, said resistance R on the output end of said attenuator comprising said fixed resistor in parallel with the rest of the multiple channel system and connected to the output of said channel.

14. In a channel of a multiple channel transmission system, a source of waves at one end of said channel, and a fixed shunt resistor at the other end of said channel, a variable attenuator in said channel between said source and fixed resistor comprising a variable shunt resistance and a variable series resistance on each side of said variable shunt resistance, said variable resistances being relatively so proportioned that for all variations of said attenuator the resistance R of said attenuator is the resistance looking into either end when the other end is loaded with a resistance R, said resistance R at the input end of said attenuator comprising the internal resistance of said source and an auxiliary series resistor, and said resistance R on the output end of said attenuator comprising said fixed resistor in parallel with the rest of the multiple channel system and connected to the output of said channel.

15. In a wave transmission system, the combination with a plurality of branch channels and a common channel therefor, of a variable attenuator in the output of each branch channel, and an impedance element in the output of each attenuator, said impedance elements being connected with each other and the input of said common channel, the combined impedance of each of said elements and that of the total exterior circuit in combination therewith being such as to properly load its associated attenuator, whereby the fidelity of transmission of said channels remains constant.

16. In a wave transmission system, the combination with a plurality of branch channels and a common channel therefor, of an adjustable attenuator connected in each of said channels and arranged for controlling the amplitude of waves therein while maintaining the fidelity of transmission in said system constant, an impedance element in circuit at one end of each branch channel and in operative relation with the attenuator

therein, the combined impedance of said element and that of the external circuit being such that the load upon the other end of each of said branch channels remains substantially constant for all adjustments of said attenuators.

17. In a multiple channel signal transmission system, the combination with a plurality of branch channels and a common channel therefor, of an adjustable attenuator of the constant impedance type connected in each of said branch channels and arranged for controlling the amplitude of signals therein while maintaining the fidelity of transmission in said system substantially constant, said attenuator in each channel, consisting of a variable shunt resistor and a fixed resistor on each side of said shunt resistor in series in the channel, and means including a second variable resistor in shunt with both of said fixed resistors for varying the series resistance of said attenuator, said variable resistors being simultaneously adjustable, and means associated with each of said attenuators for maintaining constant load on each of said channels, respectively.

18. In a signal transmission system, the combination with a plurality of channels and a common circuit associated therewith, of a variable attenuator in the output of each of said channels, said attenuator in each channel comprising a variable resistor in shunt in said channel and a pair of fixed resistors in series in said channel on either side of said variable shunt resistor, a single adjustable means comprising a variable resistor shunting both of said fixed resistors for varying the series resistance of said attenuator, means for loading said attenuator comprising a resistor of fixed magnitude operatively associated with said attenuator, said last named fixed resistor and said attenuator resistors being relatively so proportioned that for all variations of said attenuator the load upon the input of each of said channels remains substantially constant.

In testimony whereof, I have hereunto subscribed my name this thirteenth day of May 1931.

SIDNEY READ, JR.