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DEVICE FOR STEREOPHONIC REPRODUCTION OF SIGNALS

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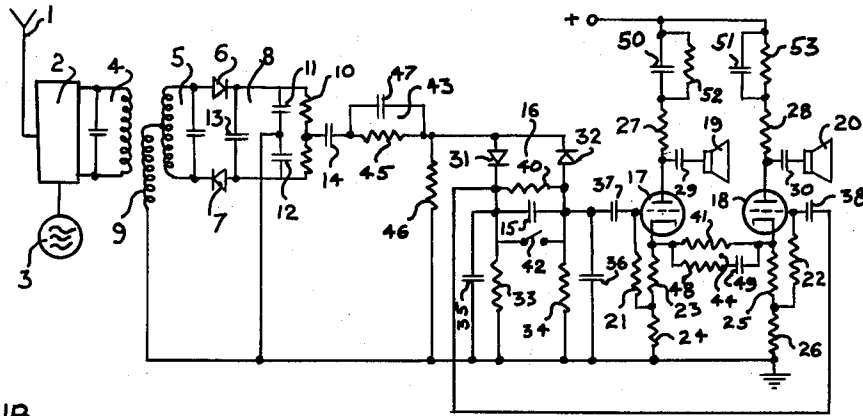


FIG. 1

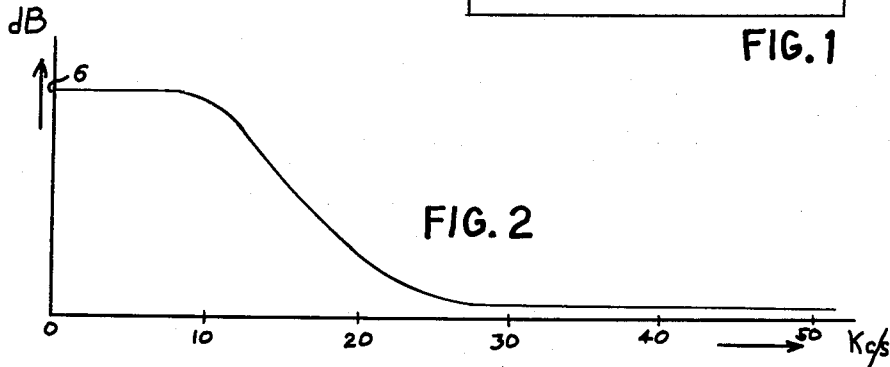


FIG. 2

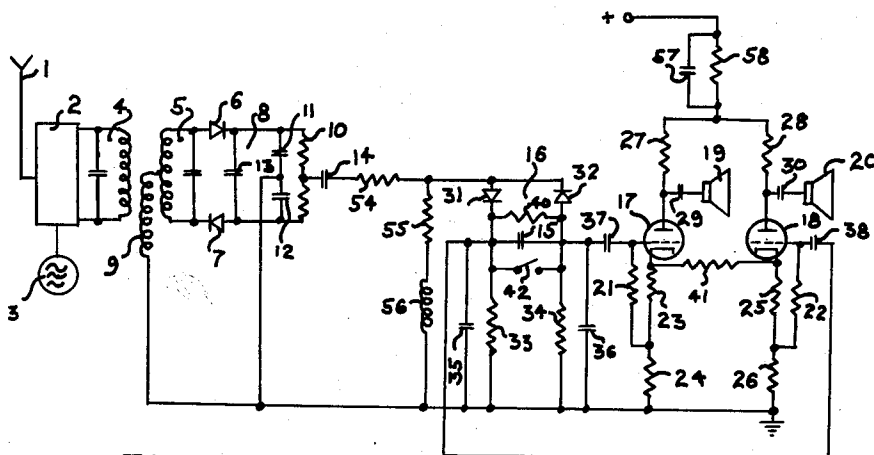


FIG. 3

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## DEVICE FOR STEREOPHONIC REPRODUCTION OF SIGNALS

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9 Claims. (Cl. 179-15)

Copending United States application Serial No. 16,214, filed March 21, 1960, now Patent No. 3,087,994, relates to a device for the stereophonic reproduction of signals, which are supplied to the input circuit of this device in the form of a sum signal  $A+B$  of the coherent stereophonic signals  $A$  and  $B$  and of a difference signal  $A-B$  of these coherent signals  $A$  and  $B$ , modulated in amplitude on a subcarrier, the said stereophonic reproducing device being furthermore provided with reproducing members arranged in separate channels, which are fed by the coherent stereophonic signals  $A$  and  $B$ , whilst the signals occurring at the input circuit of the stereophonic reproducing device and consisting of the audio-frequency sum signal  $A+B$  and the difference signal  $A-B$ , modulated in amplitude on a subcarrier, are fed, in common, to two amplitude-detection devices, which are of opposite polarity with respect to the audio-frequency sum signal  $A+B$ , whilst each of the output circuits of these amplitude detection devices is connected to an input of one of the separate channels. As described in detail in the said copending application, particular advantages are obtained with the described device for the stereophonic reproduction of signals; the device described is distinguished inter alia by a simple structure, a satisfactory reproduction quality and advantageous cross-talk properties, which permit of minimizing cross-talk between the channels by simple means, for example to less than 30-40 db.

The invention has for its object to provide a further improvement in a device of the kind set forth, in which the reproduction quality can be further enhanced by simple means, which device is particularly suitable for the stereophonic reproduction of signals, of which the audio-frequency sum signal  $A+B$  has a higher level than the difference signal  $A-B$ , modulated on the subcarrier.

The device according to the invention is characterized in that between the input of the stereophonic reproducing device and the two amplitude detection devices provision is made of a frequency-dependent attenuator having substantially uniform damping factors in the frequency bands of the audio-frequency sum signal  $A+B$  and the difference signal  $A-B$ , modulated on the subcarrier, which factor for the sum signal  $A+B$  in the audio-frequency band exceeds that of the difference signal  $A-B$ , modulated on the subcarrier.

In order to utilize completely the improvement realized in the transmission quality, the separate channels of the stereophonic reproducing device are coupled to each other, in accordance with a further aspect of the invention, by a frequency-dependent compensation network to compensate the frequency-dependent cross-talk produced by the frequency-dependent attenuator in the separate channels.

The invention and its advantages will now be described more fully with reference to the figures.

FIGURE 1 shows a stereophonic broadcast receiver having a device according to the invention.

FIGURE 2 shows a frequency-damping characteristic curve to explain the device according to the invention, and

FIGURE 3 shows a variant of the stereophonic receiver shown in FIGURE 1.

The stereophonic receiver shown in FIGURE 1 is

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adapted to receive stereophonic signals transmitted by frequency modulation on the same carrier frequency, which signals consist of the sum signal  $A+B$  of the coherent stereophonic signals  $A$  and  $B$ , lying, for example, in the band from 30 to 15,000 c./s., and of a subcarrier of 35 kc./s., amplitude-modulated by the difference signal  $A-B$ , the modulation signal thus formed and lying in the band from 30 to 50,000 c./s. modulating in frequency the carrier of a frequency of about 100 mc./s. with a sweep of 75 kc./s. in frequency. The audio-frequency sum signal  $A+B$  is transmitted at a higher level, for example, 6 db in excess of the difference signal  $A-B$  modulated on the subcarrier.

The stereophonic receiver comprises an aerial 1 and an intermediate-frequency stage 2 having a mixing stage and an oscillator 3 connected thereto, of which the intermediate-frequency signals obtained by mixing and lying in the band of 10,700 kc./s. being supplied, subsequent to amplification and, if necessary, subsequent to limitation in the intermediate-frequency stage 2, to an output band-pass filter, which is formed by two coupled circuits 4 and 5.

The bandpass filter 4, 5 forms part of a type of frequency-detector known per se for the detection of conventional frequency-modulation transmission and comprises two rectifiers 6, 7, connected to the ends of the circuit 5 and passing current in opposite directions and connected to an output impedance 8, whilst a central tapping of the circuit 5 is connected to the end of a coupling coil 9, coupled with the circuit coil 4. The output impedance 8 of the frequency detector consists of a resistor 10, which is shunted by the series combination of two capacitors 11, 12 with an earth-connection junction and a smoothing capacitor 13, the output voltage of the frequency detector being obtained from a central tapping of the output resistor 10.

Thus at the output of the frequency detector is produced an output voltage, which is formed by the sum signal  $A+B$  in the band from 30 to 15,000 c./s. and the difference signal  $A-B$  amplitude-modulated on the subcarrier and lying in the frequency band from 20 to 50 kc./s., this output voltage being fed via a separation capacitor 14 to a device 16, to be described hereinafter, in order to regain the coherent stereophonic signals  $A$  and  $B$ , which are fed to the reproducing devices 19, 20, subsequent to low-frequency amplification in separate low-frequency amplifiers 17, 18.

The low-frequency amplifiers 17, 18, which are of identical construction, are formed by triodes comprising grid-leakage resistors 21, 22 and non-shunted cathode resistors 23, 24, and 25, 26, which bring about a negative feed-back of the triodes 17, 18. The amplified, coherent stereophonic signals  $A$  and  $B$  are obtained from the output resistors 27, 28 included in the anode circuits of the triodes 17, 18 and connected to the reproducing devices 19, 20 via separation capacitors 29, 30, as is indicated diagrammatically in the figure.

In order to regain in a simple manner the coherent stereophonic signals  $A$  and  $B$  from the output voltage of the frequency detector 6, 7, this output voltage consisting of the sum signal  $A+B$  and the difference signal  $A-B$ , amplitude-modulated on the subcarrier is fed to the device 16, which is provided with two amplitude detection devices of opposite polarity, of which the input circuits are connected in parallel with the output circuit of the frequency detector 6, 7. Each of these amplitude detection devices is provided with a rectifying cell 31, 32 and an output impedance, connected thereto and formed by the parallel combination of a resistor 33, 34 and a capacitor 35, 36 respectively, the output voltages of the amplitude detection devices 31, 32 being fed via separation capacitors 37, 38 respectively to the control-grids of the tri-

odes 17 and 18 respectively, connected as low-frequency amplifiers. Apart from the opposite pass directions for the current in the rectifying cells 31, 32, the amplitude detection devices are identical.

If at the input of the described detection devices 31, 32 occurs the output voltage of the frequency detector 6, 7 consisting of the audio-frequency sum signal  $A+B$  and the difference signal  $A-B$  amplitude-modulated on the subcarrier, each of the amplitude detection devices 31, 32 produces amplitude detection of the difference signal  $A-B$ , modulated on the subcarrier, whilst the audio-frequency sum signal  $A+B$  operates as a threshold voltage for the two rectifying cells 31, 32 of opposite polarities, so that in opposite directions a working-point displacement of the two rectifying cells 31, 32 is produced in the rhythm of the sum signal  $A+B$ . In addition to amplitude detection of the harmonic signal formed by the difference signal  $A-B$  sum and difference production of the audio-frequency difference and sum signals  $A-B$  and  $A+B$  occurs, whilst the coherent stereophonic signals A and B are obtained from the output circuits 33, 35 and 34, 36 respectively of the amplitude detection devices 31 and 32 respectively, which signals are fed via the two low-frequency amplifiers 17 and 18 to the two reproducing devices 19 and 20 respectively.

Apart from a satisfactory reproduction quality and a fixed phase relationship the cross-talk between the two channels of the stereophonic receiver shown, due, for example, to intercoupling or to a relatively different level of the  $A+B$ -signal and the  $A-B$ -signal can be reduced throughout the audio-frequency band of 15 kc./s. to less than 30-40 db; it was found that a frequency-independent cross-talk occurs, of which the cross-talk voltages exhibit a fixed phase relationship with respect to the stereophonic signals A and B; particularly these cross-talk voltages are in co-phase or in opposite phase with respect to the stereophonic signals A and B. It appears, particularly, that the voltages of the two channels can be represented approximately by:

$$\begin{aligned} A + \alpha B \\ B + \alpha A \end{aligned}$$

wherein  $\alpha B$  and  $\alpha A$  designate the cross-talk voltages and  $\alpha$  the cross-talk factors, of which the value and the phase are the same and which may have a positive or a negative value.

As is described in detail in the aforesaid application Serial No. 16,214, cross-talk compensation between the channels is obtained with a positive value of the frequency-independent cross-talk factors  $\alpha$ , the signals in the two channels being then represented by  $A + \alpha B$  and  $B + \alpha A$ , by connecting a resistor 41 between the cathode resistors 23, 24 and 25, 26. If the frequency-dependent cross-talk factors  $\alpha$  have negative polarity, so that the signals in the two channels are represented by  $A - \alpha B$  and  $B - \alpha A$ , the cross-talk is compensated by including, between the two output impedances 33, 35 and 34, 36 of the amplitude detection devices, the parallel combination of a resistor 40 and a capacitor 15, which parallel combination 40, 15 is proportioned so that the time constant of the network 40, 15 is equal to the time constant of the output impedances 33, 35 and 34, 36 of the amplitude detection devices 31 and 32 respectively. As described more fully in the aforesaid application, the network 40, 15 provides, moreover, an improvement in the reproduction quality.

In this manner, apart from a very satisfactory reproduction quality and a fixed phase variation, the cross-talk between the two channels throughout the audio-frequency band of 30 to 15,000 c./s. in this device is reduced to below 30-40 db. Moreover, the receiver shown may be rendered suitable in a simple manner for the conventional frequency-modulation reception by interconnecting the output circuits of the amplitude-detection devices 31, 32 by means of a switch 42.

The present patent application provides an improvement in the transmission quality in that between the separation

capacitor 14 and the two amplitude detection devices 31, 32 a frequency-dependent attenuator 43 is connected which has substantially uniform damping factors in the frequency bands of the audio-frequency sum signal  $A+B$  (30-15,000 c./s.) and the difference signal  $A-B$  (20,000-50,000 c./s.) modulated on the subcarrier, which factors are higher for the sum signal  $A+B$  in the audio-frequency band than those for the difference signal  $A-B$ , modulated on the subcarrier, this frequency-dependent attenuator 43 being formed in the embodiment shown by a voltage divider provided with a series resistor 45 and a transverse resistor 46, of which the series resistor 45 is shunted by a capacitor 47 to form a high bandpass filter, which allows the difference signal  $A-B$ , modulated on the subcarrier to pass; the limit frequency of the high bandpass filter may, for example, be 10,000 c./s. FIGURE 2 shows the damping characteristic curve of the frequency-dependent attenuator 43, in which the damping of the attenuator 43 is indicated in db in accordance with the frequency.

If the output signal of the frequency detector 6, 7, consisting of the sum signal  $A+B$  in the band from 30 to 15,000 c./s. and the difference signal  $A-B$  modulated on the subcarrier of 35 kc./s. in the band from 20 to 50 kc./s. is fed via the frequency-dependent attenuator 43, to the amplitude detection devices 31, 32, the audio-frequency sum signal  $A+B$  is subjected in the frequency-dependent attenuator 43, to a greater attenuation than the difference signal  $A-B$  modulated on the subcarrier. In the embodiment shown the greater attenuation of the audio-frequency sum signal is, for example, 6 db. By this measure a further improvement in the transmission quality is obtained; particularly residual, non-linear distortions produced in the two amplitude detection devices 31, 32 during the amplitude detection and the sum and difference formation, are materially reduced, but this improvement does not yet become completely manifest in the transmission quality since in the relatively separated channels simultaneously a frequency-dependent cross-talk appears to be introduced, which cross-talk can be compensated, however, in a simple manner by intercoupling the separate channels of the stereophonic reproducing device by means of a frequency-dependent compensation network.

A frequency-dependent cross-talk in the higher frequencies of the coherent stereophonic signals A and B is concerned here; it appears from the damping characteristic curve of FIGURE 2 that the signal frequencies of the audio-frequency sum signal  $A+B$  of about 10 kc./s. and the signal frequencies of the difference signal modulated on the subcarrier in the proximity of 20 kc./s. which consequently correspond with the higher frequencies of the stereophonic signals A and B are exposed to a frequency-dependent damping, whilst the frequency-dependent phase shift in the network 43 involved contributes to the frequency-dependent cross-talk.

The cross-talk in the two stereophonic channels, is of such a character, as can be proved mathematically and empirically that the signals in these channels may be represented by the formula:

$$\begin{aligned} A + \gamma B \\ B + \gamma A \end{aligned}$$

wherein the frequency-dependent cross-talk factors  $\gamma$  in the two channels are identical, whilst these cross-talk factors  $\gamma$  exhibits, moreover, a simple frequency-dependent variation. The two properties of the frequency-dependent cross-talk produced by the frequency-dependent attenuator permit or compensate accurately this cross-talk in a surprisingly simple manner, which is realized by shunting the resistor 41, included between the cathode circuits of the low-frequency amplifiers 17, 18 by a network 44 consisting of the series combination of a resistor 48 and a capacitor 49, which are proportioned so that the time constant of the network 41, 48, 49 with the cathode resistors 23, 24, 25, 26, which together constitute the frequency-dependent compensation network is substantially

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equal to the time constant of the frequency-dependent attenuator 43. In practice, very satisfactory results appear to be obtained by omitting the resistor 48 in the network 44.

By surprisingly simple means a considerably better reproduction quality is obtained, whilst an advantageous cross-talk factor is maintained—for example the cross-talk between the two stereophonic channels throughout the frequency band is less than 30 to 40 db—which improvement is particularly important for stereophonic reproduction of signals, in which the audio-frequency signal  $A+B$  has a higher level, for example as in the embodiment shown, of 6 db than the difference signal  $A-B$  modulated on the subcarrier.

If in the stereophonic reproducing device described above an accurately smooth frequency characteristic curve is desired, the higher signal frequencies of the stereophonic signals A and B are to be attenuated slightly further; in the frequency-dependent attenuator 43 and during the compensation of the frequency-dependent cross-talk the network 44 slightly emphasizes at the same time the higher frequencies of the signals A and B. This may be obtained in a simple manner by connecting in series with each of the anode resistors 27, 28 of the low-frequency amplifiers 17, 18 a capacitor 50, 51 shunted by a resistor 52, 53 respectively; the time constants of the network 50, 52 and 51, 53 are approximately equal to those of the frequency-dependent attenuator 43.

Hereinafter the following data of a practically tested device of the kind set forth are given:

|                          |                          |
|--------------------------|--------------------------|
| Resistor 45—10K ohm      | Resistor 41—80K ohm      |
| Resistor 46—10K ohm      | Resistor 48—7.5K ohm     |
| Capacitor 47—1500 pf.    | Capacitor 49—270 pf.     |
| Capacitor 50, 51—390 pf. | Resistor 52, 53—100K ohm |

Without the need for further means these measures may be carried out with transistorized stereophonic receivers. The low-frequency amplifiers in the separate channels may be formed by amplifiers in common emitter connection with non-shunted emitter resistors; in this case the cross-talk produced by the frequency-dependent network 43 may be compensated in a simple manner by means of a network included between the emitter electrodes of the amplifiers in common emitter connection, which network consists of the series combination shunted by a resistor and consisting of a resistor and a capacitor of suitable values, which network constitutes, together with the non-shunted emitter resistors, the frequency-dependent network.

Both the frequency-dependent attenuator 43 and the compensation network to compensate the frequency-dependent cross-talk may be constructed in a different manner. It is advantageous that the frequency-dependent attenuator 43 is of simple structure, since this permits not only of obtaining a simple construction but also of obtaining a substantially complete compensation of the frequency-dependent cross-talk between the channels throughout the frequency band to be reproduced.

FIGURE 3 shows a variant of the receiver shown in FIGURE 1, which is also provided with a simple frequency-dependent attenuator. Corresponding elements are designated by the same reference numerals.

In this embodiment the frequency-dependent attenuator is formed by a series resistor 54 and a transverse resistor 55 and in series with the transverse resistor 55 is connected an inductor 56, which, together with the resistors 54, 55, constitutes a high band-pass filter for the difference signal modulated on the subcarrier. In the damping characteristic curve the frequency-dependent attenuator 54, 55, 56 shown exhibits the same variation as shown in the diagram of FIGURE 2 and the cross-talk between the channels has the same frequency-dependent variation as in the device shown in FIGURE 1.

In this embodiment a material simplification is obtained by using the same network for producing the frequency-dependent cross-talk and of a smooth frequency char-

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acteristic curve, which network, as is shown in the figure, is included as a common output impedance, in the output circuit of the low-frequency amplifiers 17, 18. The network consists of the parallel combination of a capacitor 57 and a resistor 58, of which the time constant is approximately equal to that of the frequency-dependent attenuator 54, 55, 56. In completely the same manner as described with reference to FIGURE 1 the reproducing quality is materially improved whilst an advantageous cross-talk factor between the channels is maintained.

Hereinafter follow data of a practically tested device of the kind set forth:

|                     |                      |
|---------------------|----------------------|
| Resistor 54—10K ohm | Resistor 58—200K ohm |
| Resistor 55—10K ohm | Capacitor 57—68 pf.  |
| Inductor 56—150 mh. | Resistor 41—8K ohm   |

As in the device shown in FIGURE 1, the device described with reference to FIGURE 3 is suitable for transistor equipment; in this case the compensation network formed by the parallel combination of the capacitor 57 and the resistor 58 is connected as a common output impedance in the collector circuit of the low-frequency amplifiers in common emitter connection.

For the sake of completeness it should be noted that the frequency-dependent attenuator 45, 46, 47 of FIGURE 1 may be used in conjunction with the correction network 57, 58 of FIGURE 3 and, conversely the frequency-dependent attenuator 54, 55, 56 of FIGURE 3 may be used in conjunction with the correction network 41, 48, 49 of FIGURE 1.

What is claimed is:

1. A circuit for the stereophonic reproduction of signals of the type having a sum signal of first and second coherent stereophonic signals, and a difference signal of said first and second signals, said difference signal being in the form of amplitude modulation of a subcarrier, said circuit comprising a source of said sum and difference signals, first and second amplitude detector circuits comprising first and second unidirectional current devices respectively, frequency dependent attenuator means connected to apply said sum and difference signals in common to said first and second amplitude detector circuits, said first and second unidirectional current devices being connected with opposite polarities with respect to said sum signal, and means connected to said first and second detector circuits to derive first and second stereophonic output signals respectively, said attenuator means having substantially uniform damping factors in the frequency ranges of each of said sum and difference signals, the damping factor for the frequency band of said sum signal being greater than the damping factor for the frequency band of said difference signal.

2. The circuit of claim 1, in which said attenuator means comprises a series resistor connected between said source and said amplitude detector circuits, a parallel resistor connected in shunt with the input to said amplitude detector circuits, and a capacitor connected in parallel with said series resistor, said series and parallel resistors and capacitor comprising a high bandpass filter.

3. The circuit of claim 1, in which said attenuator means comprises a series resistor connected between said source and said amplitude detector circuits, and the series combination of a shunt resistor and inductor connected in shunt with the input to said amplitude detector circuit, said series and shunt resistors and inductor comprising a high bandpass filter.

4. A circuit for the stereophonic reproduction of signals of the type having a sum signal of first and second coherent stereophonic signals, and a difference signal of said first and second signals, said difference signal being in the form of amplitude modulation of a subcarrier, said circuit comprising a source of said sum and difference signals, first and second amplitude detector circuits comprising first and second unidirectional current devices respectively, frequency dependent attenuator means con-

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connected to apply said sum and difference signals in common to said first and second amplitude detector circuits, said first and second unidirectional current devices being connected with opposite polarities with respect to said sum signal, means connected to said first and second amplitude detector circuits to derive first and second stereophonic output signals respectively, a frequency dependent compensation network, and means combining said output signals in said compensation network to compensate for frequency dependent cross-talk produced by said attenuator means, said attenuator means having substantially uniform damping factors in the frequency ranges of each of said sum and difference signals, the damping factor for the frequency band of said sum signal being greater than the damping factor for the frequency band of said difference signal.

5. A circuit for the stereophonic reproduction of signals of the type having a sum signal of first and second coherent stereophonic signals, and a difference signal of said first and second signals, said difference signal being in the form of amplitude modulation of a subcarrier, said circuit comprising a source of said sum and difference signals, first and second amplitude detector circuits comprising first and second unidirectional current devices respectively, frequency dependent attenuator means connected to apply said sum and difference signals in common to said first and second amplitude detector circuits, said first and second unidirectional current devices being connected with opposite polarities with respect to said sum signal, means connected to said first and second amplitude detector circuits to derive first and second stereophonic output signals respectively, first and second amplifier devices having input, output and common electrodes, means applying said first and second output signals to the input electrodes of said first and second amplifier devices respectively, a point of reference potential, separate resistor means connecting each of said common electrodes to said point, and a parallel circuit of a resistor and capacitor connected between said common electrodes, said attenuator means having substantially uniform damping factors in the frequency ranges of each of said sum and difference signals, the damping factor for the frequency band of said sum signal being greater than the damping factor for the frequency band of said difference signal.

6. The circuit of claim 5 comprising a resistor connected in series with said capacitor.

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7. A circuit for the stereophonic reproduction of signals of the type having a sum signal of first and second coherent stereophonic signals, and a difference signal of said first and second signals, said difference signal being in the form of amplitude modulation of a subcarrier, said circuit comprising a source of said sum and difference signals, first and second amplitude detector circuits comprising first and second unidirectional current devices respectively, frequency dependent attenuator means connected to apply said sum and difference signals in common to said first and second amplitude detector circuits, said first and second unidirectional current devices being connected with opposite polarities with respect to said sum signal, means connected to said first and second amplitude detector circuits to derive first and second stereophonic signals respectively, first and second amplifier devices having input, output and common electrodes, means applying said first and second output signals to the input electrodes of said first and second amplifier devices respectively, means connecting said common electrodes to a point of reference potential, and parallel resistance-capacitance means connected to said output electrodes, said attenuator means having substantially uniform damping factors in the frequency ranges of each of said sum and difference signals, the damping factor for the frequency band of said sum signal being greater than the damping factor for the frequency band of said difference signal.

8. The circuit of claim 7, in which said parallel resistance-capacitance means comprises first and second parallel circuits of a parallel-connected resistor and capacitor, and means connecting said first and second parallel circuits to separate output electrodes.

9. The circuit of claim 7, in which said parallel resistance-capacitance means comprises a parallel circuit of a resistor and capacitor, said means connecting said parallel circuit in common to said output electrodes.

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