

[54] **CIRCUIT ARRANGEMENT FOR IMPROVING THE SIGNAL-TO-NOISE RATIO OF A STEREO DECODER**

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[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

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[57] **ABSTRACT**

A variable resistor, a photoconductor shone upon by an incandescent lamp the brightness of which is inversely proportional to the carrier strength, or a variable time constant RC-network is connected to the stereo decoder to vary the stereo separation in direct proportion to the carrier strength.

13 Claims, 4 Drawing Figures

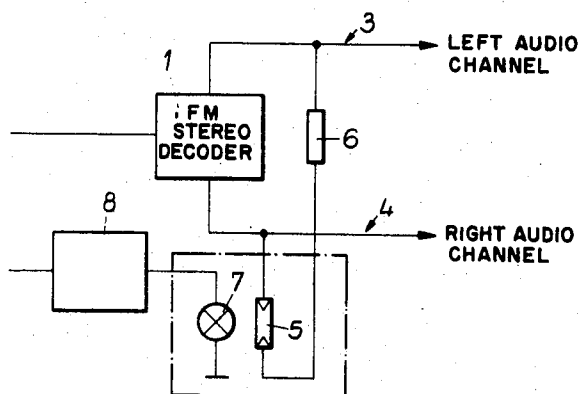


Fig. 1

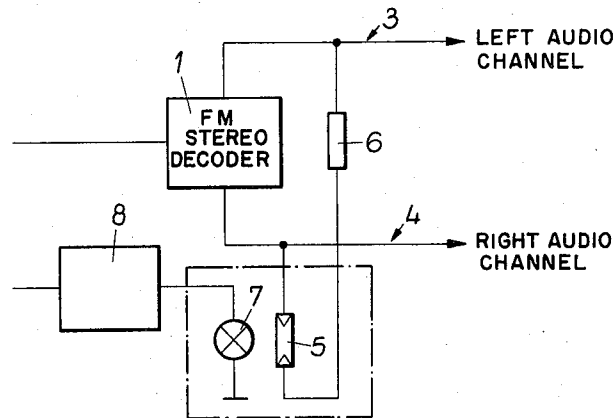


Fig. 3

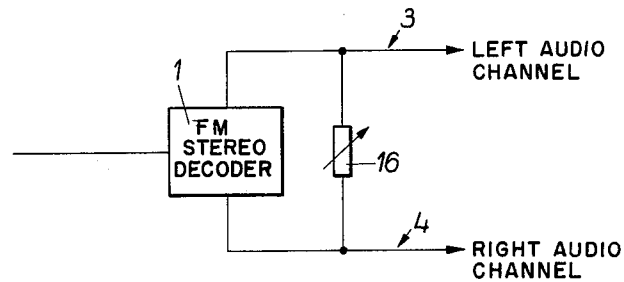
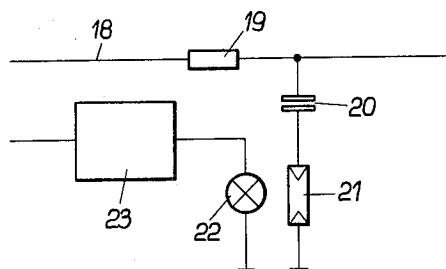


Fig. 4

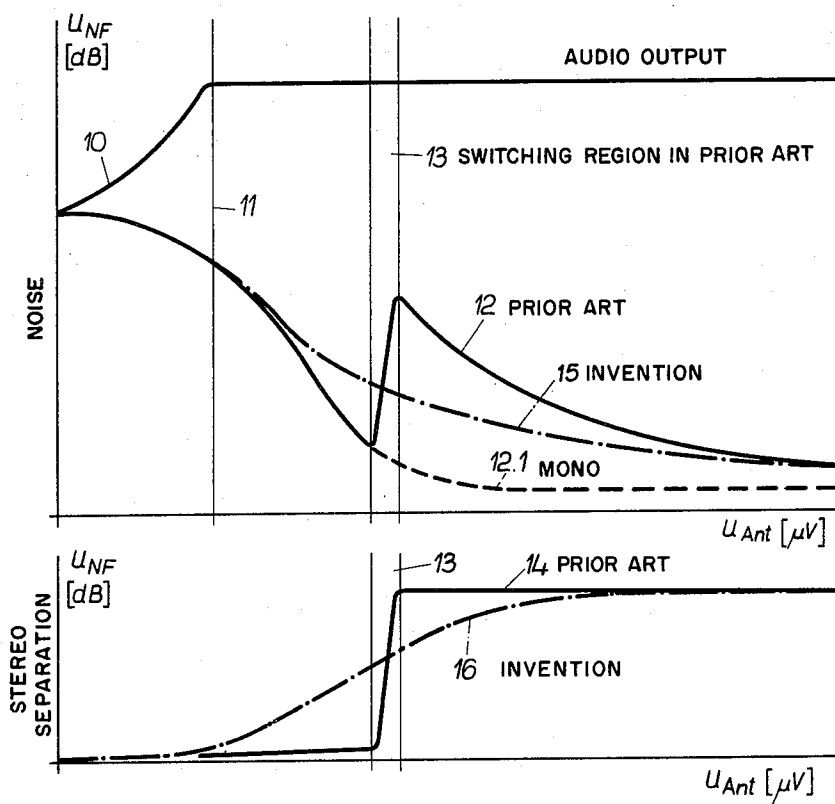


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Fig. 2



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CIRCUIT ARRANGEMENT FOR IMPROVING THE SIGNAL-TO-NOISE RATIO OF A STEREO DECODER

BACKGROUND OF THE INVENTION

The invention relates to a circuit arrangement for improving the signal-to-noise ratio of a stereo decoder for frequency-modulated multiplex signals transmitted on a carrier in accordance with the method approved by the FCC.

The multiplex signal consists of three components: the audio-frequency sum signal for the left and right channels, the subcarrier from the difference signal amplitude-modulated on a suppressed carrier, and the pilot frequency for regenerating the suppressed subcarrier. The stereo decoder recomposes the two audio signals.

Receivers for compatible stereophonic transmission are so designed that they also can receive monophonic transmissions. These receivers are provided with stereo decoders that enable switching from monophonic to stereophonic reception. At lower carrier levels it is impossible to get satisfactory stereophonic reception, because of the customary noise, side-band distortion, and general high-frequency interference. Consequently, it is necessary to switch to monophonic reception of these signals to improve the signal-to-noise ratio.

The stereo decoder usually switches automatically to stereophonic reception when the pilot frequency reaches a predetermined level. This switching can be accomplished, for example, by a relay controlled by the pilot frequency or else by a transistor that is switched by the forward bias developed by the frequency doubler stage for regenerating the subcarrier.

When the carrier level is in the switching region, a continual irregular switching back and forth between monophonic and stereophonic reception and the annoying switching noise in the loudspeaker are avoided by providing a sharp switching action. This action can be obtained, for example, by using a common output of two symmetrical voltage doublers for switching the current supply of the subcarrier output stage of the decoder. Also used is a kind of Schmitt trigger having two input stages, one of which is furnished with voltage from the decoder and the other with voltage the value of which is dependent on the carrier level.

All of these circuits have in common the desire to obtain the greatest possible stereo separation of the two audio channels when the decoder switches to stereophonic reception. This maximum separation is obtained at the cost of as much as 20 dB reduction in the signal-to-noise ratio. This abrupt increase in the noise level is caused not only by interference resulting from the necessarily large bandwidth, but also by supersonic interfering frequencies that are contained in the subcarrier channel and introduced into the audio-frequency range by the stereo carrier. Consequently, switching is possible only at a relatively high level of the carrier. But even if the carrier level lies above the minimum switching level, stereophonic reception may still not be satisfactory because of an inadequate signal-to-noise ratio. For this reason, high quality FM stereophonic receivers not only incorporate automatic switching between monophonic and stereophonic reception, but also a manually operated switch for switching to monophonic reception.

SUMMARY OF THE INVENTION

An object of the invention is a circuit arrangement for improving the signal-to-noise ratio of multiplex stereo decoders in the switching range.

The invention essentially consists of electric circuit means connected to the stereo decoder for varying the degree of stereo separation between the two audio channels of the decoder in dependence on the strength of the carrier received.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the

following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram of a first embodiment of the invention;

FIG. 2 graphically shows the variation in signal-to-noise ratio and stereo separation in dependence on the antenna voltage; and

FIGS. 3 and 4 are circuit diagrams of two further embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, the reference numeral 1 denotes the output of a decoder. The box represents a matrix, in the case of a matrix- or frequency-multiplex decoder, or an electronic switch operated in synchronism with the 38 kHz subcarrier or a full-wave rectifier for envelope demodulation, in the case of a switching- or time-division-multiplex decoder. Between the two audio channels 3 and 4, connected to the decoder output 1, there are connected a photoconductor 5 and in series with the latter a fixed resistor 6. The resistance of the photoconductor 5 is varied by an incandescent lamp 7, the light of which shines upon the photoconductor. The incandescent lamp is energized by an amplifier 8, which is connected to a non-limiting intermediate frequency stage of the FM receiver, such as the first stage, the output voltage of which is directly related to the voltage at the antenna. The energization of the lamp 7, therefore, is proportional to the strength of the carrier received at the antenna. The photoconductor 5 and lamp 7 are housed in a light proof box 9 so as to avoid illumination of the photoconductor by other incandescent lamps of the receiver, such as the scale lamp or the stereo-indicating lamp.

The amplifier 8 is so designed that the energization of the lamp 7 is inversely proportional to the strength of the carrier at the antenna. In other words, less and less current flows through the lamp as the carrier strength increases. If the signal-to-noise ratio is equal to 30 dB, as required by the Federal Communications Commission, the lamp 7 turns off. The resistance of the unilluminated photoconductor 5 and of the fixed resistor 6 is then so great that the stereo separation between the two audiofrequency channels 3 and 4 is not appreciably affected. The fixed resistor 6 should be sufficiently large to ensure that there is a minimum stereo separation when the photoconductor 5 receives maximum illumination.

With reference to FIG. 2, curve 10 shows the rise in the stereophonic audio output, beginning with zero volts and increasing until the transistor of the last intermediate frequency stage begins to limit at 11, at which point the voltage at the antenna terminals of the receiver is approximately 1 microvolt. To the right of point 11 the audio output remains constant for increasing voltage at the antenna terminals. What is not taken into account is the loss in level caused by demodulating the composite signal into right and left channel signals.

Curve 12 shows, for increasing antenna voltages, the change in noise and hum for stereophonic reception using a conventional circuit, and curve 12.1 shows the same for monophonic reception. If the receiver limits rather than regulates the frequency-modulated carrier, the signal-to-noise ratio can be further improved, since the noise also modulates the FM carrier, and this noise can be reduced to the level of the residual noise of the receiver by limiting in the intermediate-frequency stages of the receiver.

Dashed curve 12.1 which shows the variation of noise for monophonic reception of a stereophonic signal, demonstrates that the signal-to-noise ratio increases steadily until it asymptotically approaches its maximum value for increasing antenna voltages. If the receiver is switched from monophonic to stereophonic reception (curve 12), the signal-to-noise ratio falls abruptly in the switching region 13. This fall is caused by supersonic interference frequencies that are part of the pilot

frequency and introduced into the audio-frequency range by the stereo carrier. As curve 12 indicates, the signal-to-noise ratio increases for increasing antenna voltages until, at the highest permissible voltage at the antenna terminals, there is a 3 dB difference with respect to curve 12.1 for monophonic reception of a stereophonic signal. The fall of the curve 12, and therefore the improved signal-to-noise ratio, is caused by limiting and regulation in the receiver.

Curve 14 of FIG. 2 shows the variation in stereo separation between the two audio-frequency channels. For small antenna signals, until the switching region 13, there is only a minimum of separation; in the switching region 13 the separation increases suddenly to its maximum value at which it remains for increasing antenna voltages.

If the arrangement shown in FIG. 1 is connected between the two audio-frequency channels 3 and 4, within or after the decoder output 1, noise and hum vary as shown by curve 15 in FIG. 2. The sudden noticeable and annoying decline in the signal-to-noise ratio in the switching range 13 is avoided, since the curve 15 varies smoothly, whereby the signal-to-noise ratio is suitable for a continuous and smooth transition to stereophonic reception. The circuit arrangement of FIG. 1 ensures a direct relationship between the value of the resistance of the photoconductor 5, and therefore the stereo separation, on the one hand, and the strength of the received carrier, or the level of the carrier modulated multiplex signal, on the other.

Switching can occur at any desired level of the audio signal. It can occur at level zero, in which case the shift from monophonic to maximum stereophonic reception is continuous. Curve 16 shows the manner in which stereo separation increases with the circuit arrangement of FIG. 1. There is minimum separation for very small antenna voltages. As the voltage at the antenna terminals increases, there is a continuous increase in the stereo separation until it asymptotically approaches its maximum value. The stereo separation increases smoothly and continuously throughout the switching region 13.

In the embodiment shown in FIG. 3, the photoconductor 5 in FIG. 1 is replaced by a potentiometer 16. The incandescent lamp 7 and the amplifier 8, required for controlling resistance of the photoconductor 5, are eliminated. While receiving a stereophonic transmission the potentiometer 16 is manually adjusted until there is obtained an acceptable subjective compromise between background noise and stereo separation. For this embodiment, curve 15 of FIG. 2 would be replaced by a family of curves, since there is no longer a direct relationship between the value of the potentiometer 16 and the strength of the carrier. The value of the potentiometer should be sufficiently large so that when it is set to full resistance the separation between the two audio-frequency channels is not appreciably affected.

In a third embodiment of the invention, shown in FIG. 4, an RC-network, having a resistor 19 and a capacitor 20, is connected in a branch 18 of the decoder carrying at least the sub-carrier. The network, for example, can be connected in the decoder input. Connected in series with the capacitor 20 is a photoconductor 21, the resistance of which is controlled by an incandescent lamp 22, as in the embodiment shown in FIG. 1. The lamp is powered by an amplifier 23, which is connected to a non-limiting stage of the intermediate frequency amplifier, the output voltage of which is directly related to the carrier level. The amplifier 23 is so designed that a current supplied to the lamp 22 is inversely proportional to the carrier level. The electrical values of the components 19, 20 and 21 are such that, in dependence on the resistance of the photoconductor 21, as determined by the brightness of the lamp 22, i.e., in dependence on the strength of the received carrier the bandwidth of the difference signal modulated on the 38 kHz sub-carrier (23 to 53 kHz) is more or less reduced, thereby reducing the amplitude of the difference signal. In this way, when the carrier signal is received with sufficient strength, the bandwidth of the difference signal (and thus its amplitude) will be

very little reduced; thus complete separation will occur. On the other hand, if the carrier signal is weak, the bandwidth of the difference signal (and thus also its amplitude) will be considerably limited; thus only partial stereo separation will result when the sum and difference signals are combined. The curves 15 and 16 of FIG. 2 also apply to the embodiment of FIG. 4.

If the current in amplifier 23 is directly proportional to the carrier level, the photoconductor 21 is connected in series with the resistor 19 of the RC-network 19, 20.

In the embodiment of FIG. 4 the automatic control of stereo separation can be replaced by manual control, whereby the photoconductor 21 is replaced by a potentiometer.

The invention, for the first time, enables switching from monophonic to stereophonic reception without a sudden and annoying reduction of the signal-to-noise ratio. The switching can be continuous and smooth, beginning at a zero carrier level and progressing continuously to maximum stereo separation. The switching can also take place at any desired carrier level.

The compromise, inherent in the invention, between stereo separation and signal-to-noise ratio that favors the latter would appear at first blush to be opposed to the general tenor of development in this field. Surprisingly, it has been shown, however, that the human ear is far more sensitive to noise than it is to stereo separation. For example, the human ear listens only to the louder of two spatially separated sound sources of the same frequency but of different intensity, when the intensity difference is merely 6 dB. On the other hand, a signal-to-noise ratio of 26 dB is inadequate because it is found that the noise level is disturbingly high.

From these considerations, it is apparent that the human ear is relatively insensitive to poor stereo separation, whereas an abrupt fall in the signal-to-noise ratio is extremely annoying.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of circuits differing from the types described above.

While the invention has been illustrated and described an embodied in a circuit arrangement for improving the signal-to-noise ratio of a stereo decoder, it is not intended to be limited to the details shown, since various modifications and circuit changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will be fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended

1. In an FM stereo receiver, in combination, decoder means having at its output a first and a second audio channel, and adapted to convert a received broadcast FM stereo carrier signal into first and second signals respectively appearing at said first and second channels and constituting the left and right signals of a stereo audio output; and circuit means operatively associated with said decoder means for continuously varying the degree of separation between said left and right signals in dependence upon the strength of the carrier signal received, whereby to effect smooth transitions between mono and stereo reproduction with concomitant substantially smooth variations in output noise.

2. An arrangement as defined in claim 1, wherein said circuit means comprise variable resistance means connected between said audio channels.

3. An arrangement as defined in claim 2, wherein said variable resistance means comprise photoconductor means, and incandescent lamp means connected to be energized in dependence on the strength of the received carrier, and illuminating said photoconductor means.

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4. An arrangement as defined in claim 3, including energizing means for energizing said lamp in inverse proportion to the strength of the received carrier, and wherein said photosensitive means are photoconductive.

5. An arrangement as defined in claim 4, wherein said energizing means comprises amplifying means connected to a non-limiting stage of an FM receiver.

6. An arrangement as defined in claim 1, wherein said circuit means are frequency filter means in circuit with the decoder for reducing the bandwidth of the modulated subcarrier in dependence on the strength of the received carrier, whereby to change the stereo separation in dependence on the strength of the received carrier.

7. An arrangement as defined in claim 6, wherein said filter means comprise a variable time constant RC-network.

8. An arrangement as defined in claim 6, wherein said filter means comprises photosensitive means and incandescent lamp means connected to be energized in dependence on the

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strength of the received carrier and illuminating said photosensitive means.

9. An arrangement as defined in claim 8, wherein said photosensitive means are photoconductive, and further including energizing means for energizing said lamp in inverse proportion to the strength of the received carrier.

10. An arrangement as defined in claim 8, wherein said photosensitive means are photoconductive, and including energizing means for energizing said lamp in direct proportion to the strength of the received carrier.

11. An arrangement as defined in claim 9, wherein said energizing means are amplifying means connected to a non-limiting stage of an FM receiver.

12. An arrangement as defined in claim 7, wherein said RC-network is connected in the input of the decoder.

13. An arrangement as defined in claim 7, wherein said RC-network includes variable potentiometer means.

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