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IMPROVEMENTS RELATING TO REPRODUCTION ARRANGEMENTS FOR STEREOPHONIC SOUND SYSTEMS

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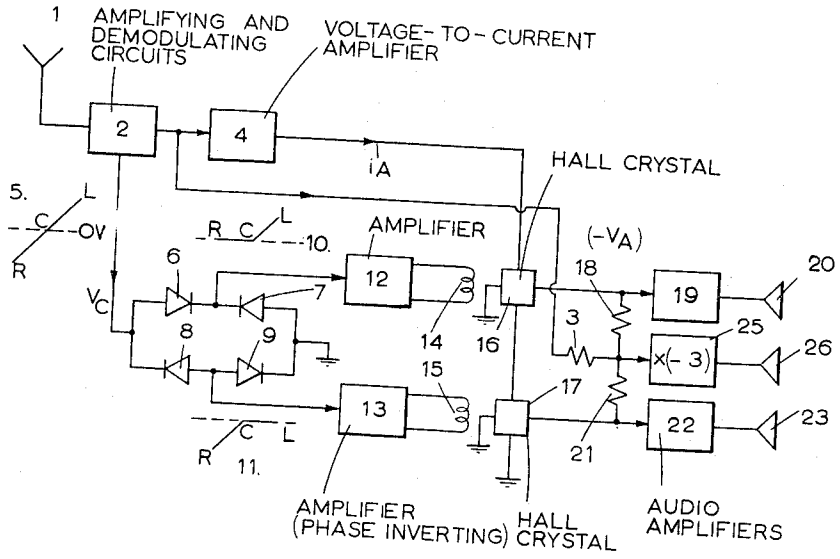


FIG. 1

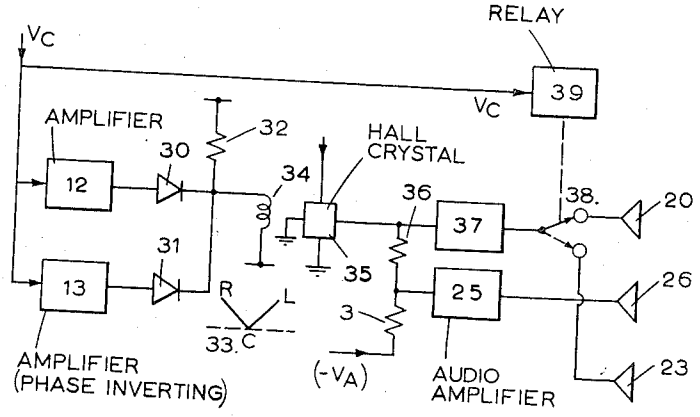


FIG. 2

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IMPROVEMENTS RELATING TO REPRODUCTION ARRANGEMENTS FOR STEREOPHONIC SOUND SYSTEMS

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3 Claims. (Cl. 179—1)

This invention relates to reproduction arrangements for stereophonic sound systems.

One defect of stereophonic reproduction in which audio signals are reproduced by two spaced loudspeakers is that as the listener moves along the line parallel to the line joining the loudspeakers, the apparent position of the source of sound tends also to move. The result is that satisfactory stereophonic reproduction is available only for listeners on or near the centre line between the loudspeakers.

The object of the present invention is to provide an improved stereophonic sound reproducer which enables stereophonic reproduction to be obtained such that the apparent direction of reproduced sound is less dependent on the position of the listener than in arrangements such as indicated in the preceding paragraphs.

According to the present invention there is provided a stereophonic sound reproducer comprising means for providing an audio signal representing the waveshape of sound, means for providing a control signal which represents the direction or position of the source or sources of said sound, and is substantially independent of the loudness of the sound, at least three loudspeaker units, and means for applying the audio signals to said loudspeaker units in relative proportions dependent upon the instantaneous value of said control signal, in such a way that the audio signal is applied to a single and different one of said loudspeaker units for different discrete values of said control signal and is proportioned between the respective two loudspeaker units for values of the control signal intermediate said discrete values.

The expression "loudspeaker unit" is used to denote either a single loudspeaker, or a group of loudspeakers, having for example different frequency responses, mounted in such relative positions that sound emanating from them would appear to the listener to come substantially from the same direction or position.

The invention may be applied to reproducers adapted to reproduce sounds from a radio broadcast comprising the audio signal and the control signal, in which case the means for providing the audio signal and the control signal may comprise amplifying and detecting circuits such as are conventional in broadcast radio receivers. The invention may nevertheless be applied to reproducers adapted to reproduce signals derived from twin track record tape or complex cut record discs. In such a case the input signal to the reproducer may comprise two audio signals; for example the sum and difference of two directional signals and the means for providing the control signal at the reproducer would need to be such as to derive the latter signals from the two audio signals.

In order that the present invention may be clearly understood and readily carried into effect the invention will now be described with reference to the accompanying drawings, in which:

FIGURE 1 illustrates diagrammatically, and mainly in block form, one example of a stereophonic sound reproducer according to the present invention, and

FIGURE 2 illustrates a modification of FIGURE 1.

It will be assumed that the sound reproducer which is illustrated in FIGURE 1 is adapted to receive a broadcast carrier wave which is modulated in any suitable manner

by an audio signal representing the waveshape of the sound to be reproduced, and a control signal which represents the direction or position of the source of the sound. The audio signal is denoted by the symbol V_A whilst the control signal is denoted by the symbol

$$\frac{V''_L - V''_R}{V''_L + V''_R}$$

The control signal, which for brevity may be denoted as V_C, is substantially independent of the loudness of the sound, it has the value of $+1$ when it represents sound coming from the extreme left of the stereophonic base, it has the value -1 when it represents sound coming from the extreme right of the stereophonic base, and it has value zero when it represents sound coming from the centre of the stereophonic base. The control signal and the audio signal may for example be obtained at the transmitter by means of apparatus such as described in United States patent application Number 742,175, filed by W. S. Percival on June 16, 1958. This application describes the derivation of a control signal having the form

$$\frac{V''_L}{V''_L + V''_R}$$

but it will be evident that the above control signal V_C can be obtained simply from the latter control signal. In fact the control signal may be transmitted in either form and then changed to the other form, if necessary, at the receiver.

The receiver shown in FIGURE 1 comprises an antenna 1 which feeds the received carrier wave to conventional amplifying and demodulating circuits 2 which are arranged to separate the audio signal from the control signal V_C. The signals V_A and V_C, as derived from the circuits 2 are voltage signals and the polarity of the audio signal is such that it can be represented as $-V_A$. The audio signal $-V_A$ is applied to one end of a resistor 3 which will be referred to subsequently and it is also applied to an amplifier 4 which is arranged to derive a current i_A proportional to the voltage V_A but is of positive polarity. The relationship between a voltage signal V_C and direction as represented by the diagram 5 which shows that V_C has a maximum positive value L to represent the extreme left direction, has zero value to represent the central direction, and has a maximum negative value R to represent the extreme right direction. The signal V_C is applied to a bridge network of four diodes 6, 7, 8 and 9, polarised as shown so that at the junction of the diodes 6 and 7 signals representing left of centre yield a positive voltage whereas central signals and those representing right of centre yield zero output voltage. On the other hand, at the junction of the diodes 8 and 9, signals representing right of centre give a negative output voltage whereas central signals and signals representing left of centre give zero output voltage. The relationships between direction and voltage of the two output signals derived from the diode bridge circuit are represented by the diagrams 10 and 11. The voltage derived from the junction of 6 and 7 is applied to a non-phase inverting amplifier 12 and that derived from the junction of the diodes 8 and 9 is applied to a phase inverting amplifier 13 and the two signals are then applied to the field windings 14 and 15 of two Hall amplitude circuits, comprising Hall crystals represented by the rectangles 16 and 17. It will be understood that the field windings 14 and 15 are arranged to set up magnetic fields normal to the planes of the respective Hall crystals. The current i_A from the aforesaid amplifier 4 is fed through the Hall crystals from one edge to another so that the current flows in a direction perpendicular to the respective magnetic fields. As a result, voltages are induced between the remaining edges of the Hall crystals, proportional to control current i_A and

the respective magnetic fields. As shown the voltage induced across the Hall crystal **16** is applied to one end of the resistor **18** and through an audio amplifier **19** to a loudspeaker **20** which is placed at the left hand side of the auditorium. Similarly the voltage induced across the Hall crystal **17** is applied to one end of the resistor **21** and through an audio amplifier **22** to a loudspeaker **23** which is placed at the right hand side of the auditorium. The other ends of the resistors **18** and **21**, of the aforesaid resistor **3** are joined together, and any voltage appearing at this junction is applied via audio amplifier **25** to a loudspeaker **26** which is placed in the centre of the auditorium. The resistors **3**, **18** and **21** have equal resistances and the constant of proportionality between the voltage V_A, applied to the resistor **3** and the current i_A is such that V_A is numerically equal to the maximum voltages obtained from the outputs of the Hall crystals **16** and **17**. The voltage V_A is however of opposite polarity to the outputs of the Hall crystals. The amplifier **25** is required to be phase inverting relative to the amplifiers **19** and **22**, and to have three times as much gain, in order to compensate for attenuation of the signal V_A at the junction of **3**, **18** and **21**.

The result of the arrangement shown is that the output of the Hall crystal **16** is a voltage proportional to both the audio signal V_A and the control voltage obtained from the amplifier **12**, and conforming to the directional relationship **10**. The output of the Hall crystal **17** is a voltage proportional to both the audio signal V_A and the control voltage obtained from the amplifier **13**, and conforming to the inverted directional relationship **11**. The voltage output from the Hall crystal **16** will equal to the voltage V_A when the direction is fully left, and in this condition because the resistors **3**, **18** and **21** have equal resistances, and because the output impedance of a Hall crystal can be assumed to be small, no voltage will appear at the input to the amplifier **25** or at the input to the amplifier **22**. Therefore sound is reproduced only by the loudspeaker **20**. Similarly when the direction is fully right, sound is reproduced only by the loudspeaker **23**. For a central direction, the output voltage of both Hall crystals is zero and sound is reproduced only from the central loudspeaker **26**. For directions between left and centre, sound is reproduced simultaneously from the loudspeakers **20** and **26**, the audio signal being in effect applied to these two loudspeakers in different ratios dependent upon the instantaneous value of the control signal. For a given sound of constant value moving from left to centre the output of the two speakers **20** and **26** is also of constant volume. No sound is reproduced from the right end loudspeaker **23**. Conversely for directions between centre and right, sound is reproduced from the loudspeakers **23** and **26** in different ratios dependent upon the values of the control signal, no sound being reproduced by the left hand loudspeaker **20**.

In the modification of the invention which is illustrated in FIGURE 2, one of the Hall crystal amplitude control circuits and one of the audio amplifiers before the loudspeakers are dispensed with. The control signal V_A is applied directly to the amplifiers **12** and **13**, the amplifier **13** being as in FIGURE 1 a phase inverting amplifier. The outputs of the amplifiers **12** and **13** are then applied to diodes **30** and **31** which have a common load resistor **32**, so that the voltage across the resistor **32** corresponds to the more positive of the voltages applied to the diodes **30** and **31**. The voltage across the resistor **32** therefore represents the modulus of the voltage V_C, the relationship between voltage and direction being as indicated by the diagram **33**. This voltage is applied to the field winding **34** of the single Hall crystal amplitude control circuit the crystal of which is denoted by the reference **35**. The current i_A is fed to this crystal in the manner described with reference to FIGURE 1 and the resultant voltage is applied to one end of the resistor **36** which corresponds either to the resistance **18** or **21** of FIGURE 1. The other end of this resistor is joined as shown to the resistor **3**. The output voltage from the Hall crystal **35** is also applied to an audio amplifier **37**. The output of the amplifier **37** is applied to a switch **38** which though represented as a mechanical switch may in fact be an electronic switch. The switch is controlled by a polarized relay **39** in such a way that the output of the amplifier **37** can be applied either to the left hand loudspeaker **20** or to the right hand loudspeaker **23**. The voltage at the junction of the resistors **3** and **36** is applied via the phase inverting amplifier **25** to the central loudspeaker **26**. The gain of the amplifier **25** is adjusted relative to that of the amplifier **37** to suit the attenuation of the network **3**, **36**.

The relay **39** is polarized in such a way that whenever the control voltage V_C has a positive value, the output of the amplifier **37** is applied to the left hand loudspeaker **20** and whenever the control voltage V_C has a negative value, the output of the amplifier **37** is applied to the right hand loudspeaker **23**. The arrangement takes advantage of the fact that at any instant one or other of the loudspeakers **20** and **23** should reproduce no sound, and the operation of the relay **39** ensures that the switching over from one loudspeaker to the other occurs when the control voltage corresponds to a centre direction, in which circumstance neither of the loudspeakers **20** and **23** should reproduce sound. Distortion of the sound output due to switching is therefore avoided. In other respects the operation of FIGURE 2 is similar to that described with reference to FIGURE 1.

In both FIGURE 1 and FIGURE 2, the proportioning of the audio signal among the loudspeakers is performed in effect by controlling the amplitude of the audio signal V_A in response to the modulus of the control signal V_L to produce an amplitude controlled signal, and by deriving a signal representing the difference of the uncontrolled audio signal V_A and the amplitude controlled signal, the differencing being effected in the network **3**, **18** and **21** of FIGURE 1 and the network **3** and **36** of FIGURE 2. The difference signal is applied to the central loudspeaker and the amplitude controlled signal applied either to the loudspeaker **20** or the loudspeaker **23** depending on whether the control signal represents a direction or position to one side or other of the central direction or position. In the arrangement shown in FIGURE 1 two amplitude controlling circuits are used to form the amplitude controlled signal, the amplitude control circuit including the crystal **16** for controlling the audio signal with the control signal when the control signal has a positive value, and the amplitude control circuit including the crystal **17** for controlling the audio signal with the negative of the control signal when the control signal has a negative value.

The control signal V_C requires to have only a limited band width relative to the audio signal V_A, although the control signal may extend in to the audio frequency band. The band width of the control signal may be for example from 0 to 100 c./s. The amplifiers **12** and **13** therefore require only a limited pass band, corresponding to that of the control signal. The loudspeakers **20**, **23** and **26** need not be single loudspeakers, but may comprise groups of loudspeakers positioned in such a way as to form single loudspeaker units. Furthermore although the arrangements described ensure that the sum of the signals applied to the three loudspeakers is always linearly proportional to the audio signal it may not always be necessary to arrange that this is so, as the acoustics, of a particular room may be such that better results are obtained with some other relationship. The amplitude controlled signals obtained from the amplitude control circuits may not be linearly related to the control signal, in order to obtain optimal conditions as judged by listening tests. The reproducer may include means for varying the relationship between the control signal V_C and direction, to provide for "spread" adjustments which can be controlled by the listener.

In a further modification, it is arranged that the very low audio frequencies are diverted entirely to the ampli-

fier **25** and the central loudspeaker **26**. In this case only the loudspeaker **26** need have a full bass response. This modification takes advantage of the fact that stereo effects for very low frequencies are not so important as for higher frequencies and allows economy to be effected at the cost of only a small loss of stereo effects since good bass reproduction involves more expensive amplifiers and speakers.

In the arrangement shown in FIGURE 2, the switch **38** may be placed before the amplifier **37**, and in this case a separate audio amplifier must be introduced for the speaker **23**. In this modification the switch is situated at a point in which the signal level is relatively low and this facilititates the employment of an electronic switch. If an electronic switch is used, that is one employing thermionic or transistor valves, the impedances of the valves when conducting are of low value so that the power consumption is considerably less than that required for an additional amplifier.

The invention can also be applied to reproducers in which more than three loudspeaker units are provided, spaced one from another along the stereophonic base. In such an application of the invention, an expedient similar to that illustrated in FIGURE 2 is preferably adopted in order to reduce the number of audio amplifiers which are required. The switch equivalent to **38** is required to operate in such a way that the two audio amplifiers are always connected to the two speakers which are required to operate at a given instant. The switching is arranged to occur at instants when all the sound output is produced by one speaker and is such as to switch the amplifier not in service at that instant from the speaker on one side of the inoperative speaker to that on the other side.

What I claim is:

1. A stereophonic sound reproducer comprising means for providing an audio signal representing the waveshape of sound, means for providing a control signal which represents the direction or position of the source or sources of said sound, at least left hand, central and right

hand loudspeakers and means responsive to the instantaneous value of said control signal comprising means for controlling the amplitude of said audio signal in response to the modulus of said control signal to produce an amplitude controlled signal, means for deriving a signal representing the difference between said audio signal and said amplitude controlled signal, means for applying said difference signal to said central loudspeaker, and means for applying said amplitude controlled signal to said left hand or said right hand loudspeaker, depending on whether the control signal represents a direction or position to the left or right of a central direction or position.

2. A sound reproducer according to claim 1 comprising a first amplitude control circuit for producing said amplitude controlled signal when the control signal represents any direction or position to the left of said center direction or position, and a second amplitude control circuit for producing said amplitude controlled signal when the control signal represents any direction or position to the right of said central direction or position, said left hand loudspeaker being connected to receive the amplitude controlled signal from said first amplitude control circuit, and said right hand loudspeaker being connected to receive the amplitude controlled signal from said second amplitude control circuit.

3. A sound reproducer according to claim 1 comprising an amplitude control circuit common to both said left hand and right hand loudspeakers for producing said amplitude controlled signal, and a switch for applying the amplitude controlled signal from said amplitude control circuit either to the left hand or right hand loudspeaker depending on whether said control signal represents a direction or position to the left or the right of said central direction or position.

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