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Sotome

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[54] **SPEAKER SYSTEM FOR MULTICHANNEL STEREOSIGNAL REPRODUCTION**

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[30] **Foreign Application Priority Data**

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Oct. 7, 1971	Japan	46-92395
Oct. 7, 1971	Japan	46-92396

[52] **U.S. Cl.** ..... **179/1 GQ**; 179/1 GA; 179/81 B

[51] **Int. Cl.** **H04r 5/00**

[58] **Field of Search** ..... 179/1 GQ, 1 GP, 1 G; 181/31 B

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Primary Examiner—Kathleen H. Claffy

Assistant Examiner—Thomas D'Amico

Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

This invention relates to a multichannel stereosignal reproduction system in which a pair of speaker devices each comprising at least two speakers in a speaker box are provided. Left and right signals are applied to the two speakers, respectively, in such manner that the left and right signals are mutually in opposite phase between the speakers in one of the speaker devices and speakers in the other of the speaker devices, and wherein sound wave outputs from these speakers are composed spatially. Further the signal from one of said two speakers which is opposite in phase to the signal from the other of said two speakers may be adjusted in terms of the level of its antiphase component.

Further, the speakers within each speaker device to be supplied with signals opposite in phase to each other may be placed opposite to each other in a spaced relationship and by providing a sound wave reflector within the space between these opposed speakers, sound wave outputs from the speakers can be composed spatially. In this case the composite output will be radiated uniformly, with directivity being thus eliminated.

6 Claims, 14 Drawing Figures

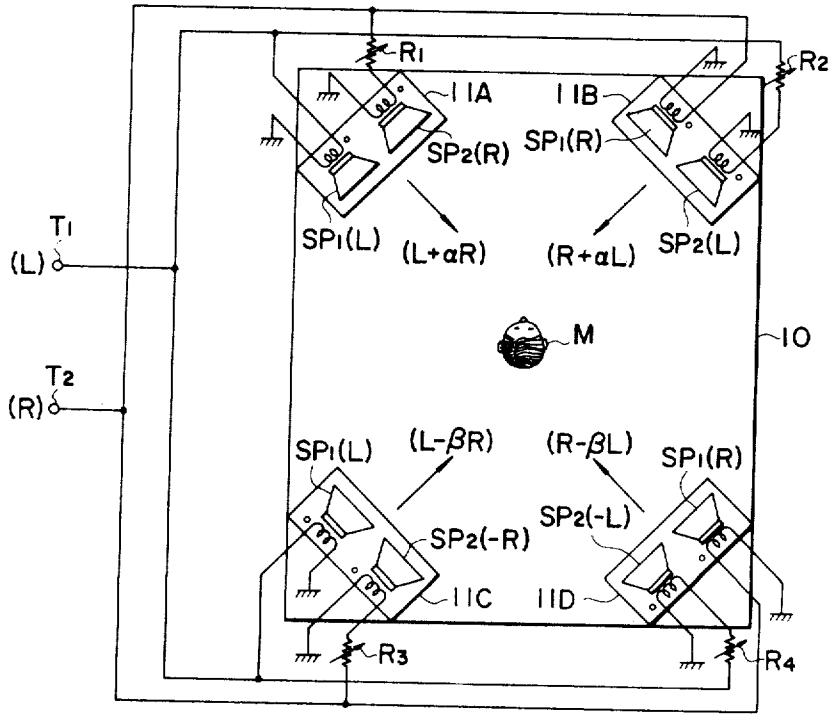


FIG. 1 PRIOR ART

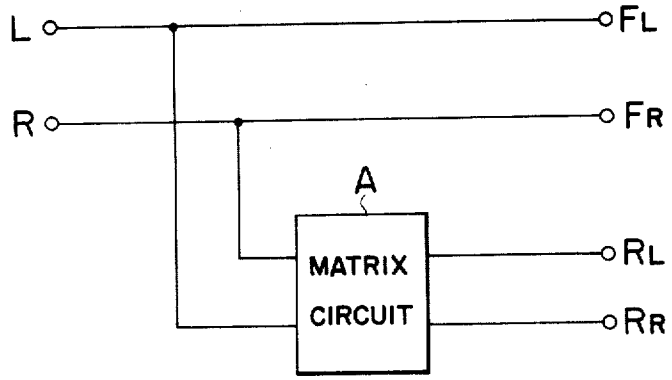


FIG. 2
PRIOR ART

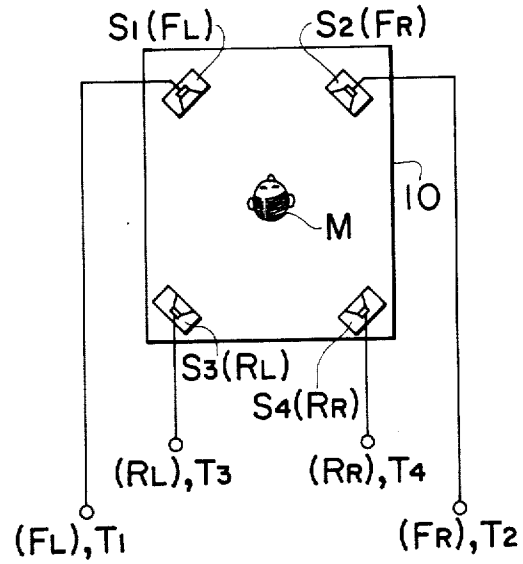


FIG. 3 PRIOR ART

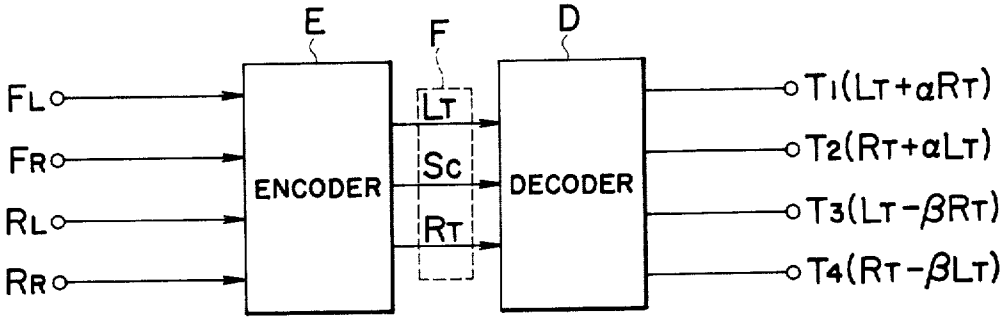


FIG. 4

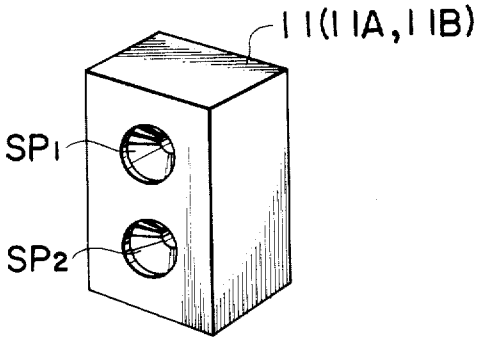
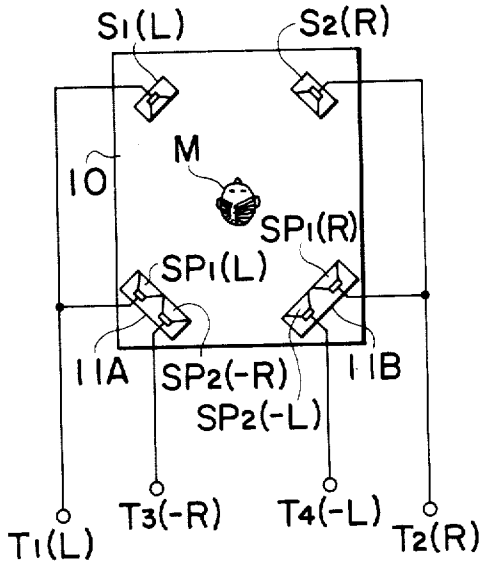


FIG. 5



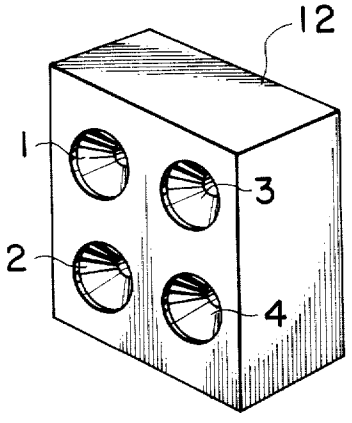


FIG. 6

FIG. 7

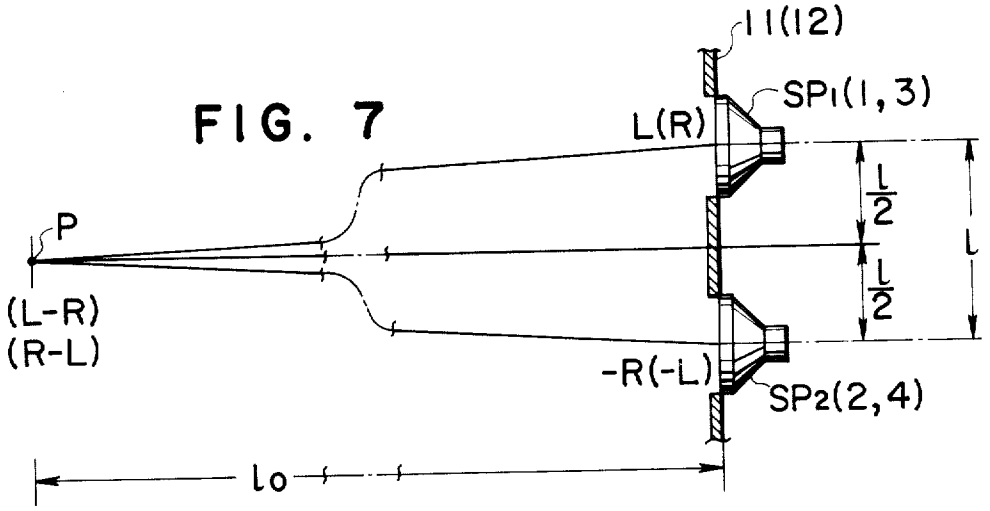


FIG. 8

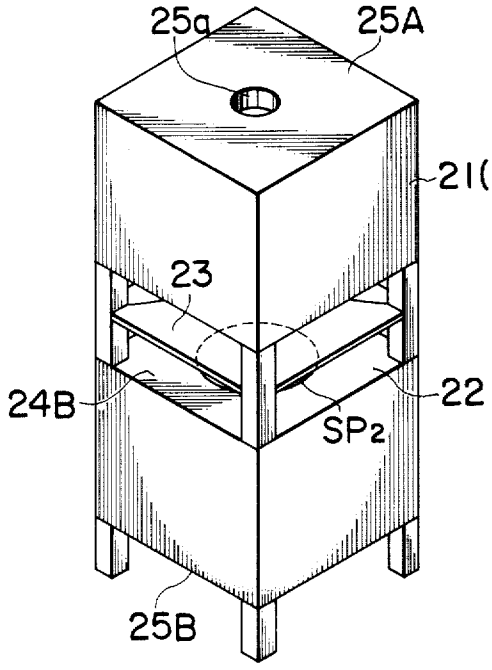


FIG. 10

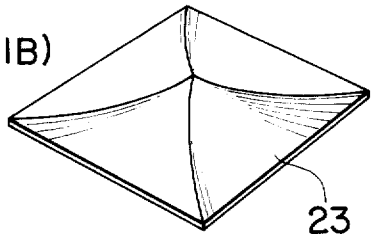


FIG. 9

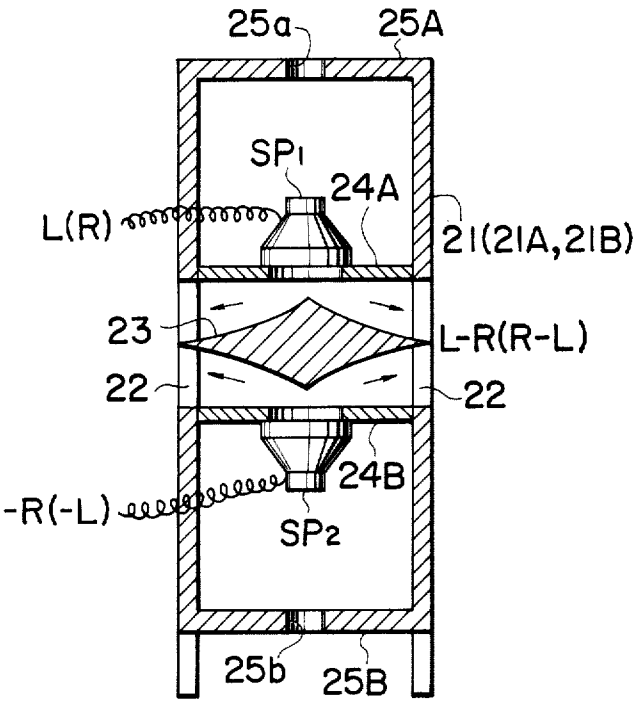


FIG. 11

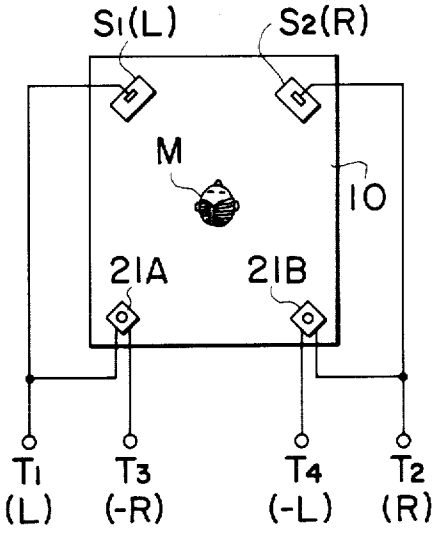


FIG. 12

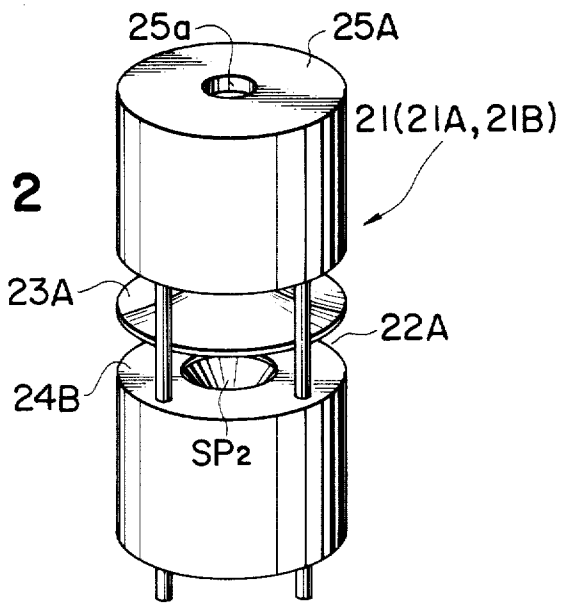


FIG. 13

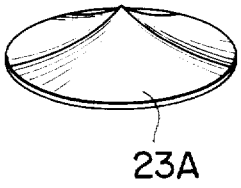
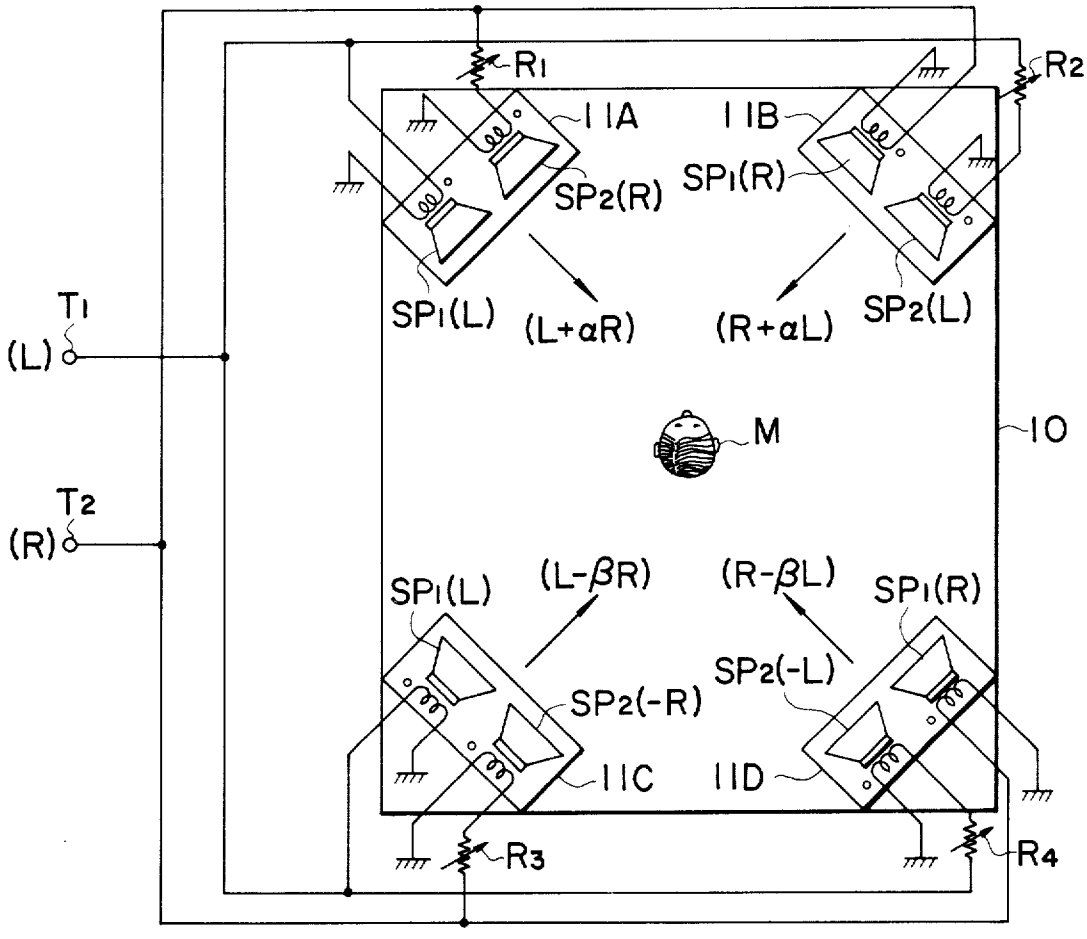


FIG. 14



SPEAKER SYSTEM FOR MULTICHANNEL STEREOSIGNAL REPRODUCTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a reproduction system of multichannel stereosignals.

2. Description to the prior art

Systems for attaining the reproduction of multichannel stereo-signal can be divided primarily into three, namely the discrete, matrix and quasi multichannel systems. The discrete system is the one under which all the processes from recording to reproduction are separated correspondingly to the channels, this system also being called "the 4—4—4 system." Concerning the matrix system, an SQ system (with logics) and a Scheiber system are available, and of which the latter is taken up presently, which is in principle similar to the speaker matrix. Regarding the quasi multichannel system, two types are available, one being an acoustic reverberation addition type and the other, a magnetic reverberation addition type. That is, the three systems mentioned above are now mainly employed for the transmission system from recording to reproduction.

As for the conventional 4-channel stereo systems, first of all a quasi four-channel system as shown in FIG. 1 is available. In this system, ordinary two-channel left and right stereosignals L, R are taken out as they are from the front output terminals F_L, F_R respectively, while differential signals L−R and R−L of the stereosignals L, R are formed by way of the matrix circuit A and are taken out from the rear output terminals R_L, R_R. These signals are supplied, as shown in FIG. 2, to the left and right front speakers S_1, S_2 as well as the left and right rear speakers S_3, S_4, provided at the corners of the listening room 10, whereby the listener M in the abovementioned listening room can hear the quasi four-channel stereo sound similar to a real four-channel stereo sound.

In addition, a matrix four-channel stereo system as shown in FIG. 3 is also available as a conventional one. In this system, left and right signals F_L, F_R for front speakers and left and right signals R_L, R_R for rear speakers are converted by means of an encoder E into binary signals $L_T=(F_L+R_L+\beta F_R-\alpha R_R)$, $R_T=(F_R+R_R+\beta F_L-\alpha R_L)$. These signals, which are then put into a decoder D along with a subcarrier signal SC by way of the signal transmission line F such as a stereorecord or FM stereobroadcasting network, etc., from whose output terminals T_1, T_2 and T_3, T_4 are taken out left and right signals $L_T+\alpha R_T$, $R_T+\alpha L_T$ for front speakers and left and right signals $L_T-\beta R_T$, $R_T-\beta L_T$ for rear speakers respectively. These signals are supplied to the left and right front speakers S_1, S_2 and left and right rear speakers S_3, S_4 shown in FIG. 2, whereby the listener M in the listening room 10 can hear a real four-channel stereo sound of full attendance at the scene.

As, however, in these systems the left and right signals R_L, R_R, $L_T+\alpha R_T$, $R_T+\alpha L_T$, $L_T-\beta B_T$, and $R_T-\beta L_T$ are composed electrically by means of the matrix circuit or the encoder and decoder, they become expensive and complicated, having the disadvantage that these conventional systems cannot be easily and inexpensively employed.

SUMMARY OF INVENTION

By use of the multichannel stereosignal reproduction system according to this invention it is possible to attain the following objects:

1. There is provided a speaker system suitable for reproduction of four-channel stereo and in particular, one in which at least two, first and second, speakers are provided in a signal rear speaker box and left and right stereosignals are applied in mutually opposite phase to the first and second speakers, respectively and sound waves of these signals are composed spatially to obtain rear sound of four-channel stereo.
2. Further, left and right stereosignals are applied in-phase to first and second speakers in the front speaker box and a level adjustment is made of those signal components in the left or right signal. Left and right stereosignals are applied in mutually opposite phase to first and second speakers in the rear speaker box and a level adjustment is made of the antiphase components in the left or right signal. By composing sound waves of these signals, front and rear sound waves of four-channel stereo are obtained.
3. Moreover, a plurality of speakers are placed oppositely in a single speaker box, interposing an acoustic reflector between them, and left and right stereosignals are applied in mutually opposite phase to the respective speakers, thus shortening the spatial mixing distance of the sound waves of these signals and eliminating directly to obtain rear sound of four-channel stereo.
4. In applying the techniques described above, a novel four-channel stereoproduction system is provided. According to an embodiment of this invention, for the purpose of achieving a four-channel stereo reproduction simply, there is provided a decoder system in which a plurality of speakers are provided in each stereo rear speaker box and left and right stereo signals are applied in mutually opposite phase to these speakers and at the same time, these antiphase components are adjusted in terms of level. The resultant sound waves are composed spatially, thus obtaining rear sound waves of the four-channel stereo. While the left and right signals are applied in-phase to a plurality of speakers within each front speaker box respectively, level adjustment is made of those signal components in the left or right signal alone, and sound waves of these signals are composed spatially to obtain front sound waves of the four-channle stereo.

In addition, according to this invention, an opening for sound emission is provided near the center of the stereo rear speaker box and a fanwise sound wave reflector is provided in the middle of the opening, with two speakers being placed oppositely with respect to the sound wave reflector in between them. Left and right signals are applied in mutually opposite phase to these speakers and sound waves of these signals from the abovementioned two speakers are composed spatially by way of the aforesaid reflector to obtain rear sound waves of the four channel stereo.

BRIEF DESCRIPTION OF THE INVENTION

FIG. 1 is a drawing explaining the principle of the transmission system in an artificial four-channel system.

FIG. 2 is a drawing of the formation of reproduction field in a listening room.

FIG. 3 is a drawing of the principle of the transmission system under a matrix four-channel system.

FIG. 4 is a perspective view of an example of the speaker device employed in this invention.

FIG. 5 is a drawing of speaker arrangement in a listening room showing an example of application of this invention.

FIG. 6 is a perspective view showing another embodiment of the speaker device employed according to this invention.

FIG. 7 is a schematic drawing illustrating the operations of the speakers.

FIG. 8 is a perspective view showing an example of the speaker device employed in this invention.

FIG. 9 is a sectional view of the speaker device shown in FIG. 8.

FIG. 10 is a perspective view showing an example of the sound wave reflector to be employed for the speaker device shown in FIG. 8.

FIG. 11 is a view of a speaker arrangement within a listening room showing an example of the application of this invention.

FIG. 12 is a perspective view showing another embodiment of the speaker employed in this invention.

FIG. 13 is a perspective view showing another embodiment of the sound wave reflector to be employed for the speaker device shown in FIG. 12.

FIG. 14 is a view of speaker arrangement in a listening room employing the speaker devices shown in FIG. 4 or 8.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 4 reference numeral 11 (11A or 11B) represents a speaker box which is provided with a first speaker SP_1 and a second speaker SP_2. These first and second speakers are the same or similar in their electroacoustic characteristics.

In the case of a practical application, as shown in FIG. 5 the aforesaid speaker boxes 11A, 11B are placed at the left and right rear positions of the listening room 10, respectively (for convenience of illustration, SP_1 and SP_2 are arranged side by side in the figure). The first speakers SP_1, SP_1 in these boxes 11A, 11B are individually connected in parallel (or in series) with the left and right front speakers S_1, S_2 provided at the left and right front positions of the listening room 10. The left and right signals L, R are supplied to their terminals T_1, T_2 respectively.

On the other hand, to the terminals T_3, T_4 connected to the second speakers SP_2, SP_2 within the speaker boxes 11A, 11B are supplied signals −R, −L which are opposite in phase to the left and right stereosignals L, R supplied to the speakers SP_1, SP_1.

When used as above, the acoustic effect is as shown in FIG. 7, that is, where the distance between the first speaker SP_1 and the second speaker SP_2 is l on the one part and the distance between each of these speakers and the listening point P is l O on the other, there is the relation $l_a >> l$, $l << \lambda$ (λ: Wavelength of sound wave heard). Then the left signal L (or the right signal R) and the antiphase signal $-R$ of the right signal (or the antiphase signal $-L$ of the left signal) are not separately audible at the listening point P, but sound waves of the spatially composed differential signal L−R (or R−L) corresponding to the difference between left and right signals L and R are audible, and accordingly, the listener M in FIG. 5 can hear a four-channel stereo sound having the same effect as under the aforesaid conventional systems.

In the meantime, the rear speaker box applicable according to this invention won't be limited to the one shown in FIG. 4, that is, as shown in FIG. 6, 4 speakers 1, 2, 3 and 4 are provided in a single speaker box 12. The stereo left signal L (or right signal R) and the antiphase signal −R of the stereo right signal (or antiphase signal −L of the left signal) can be applied to 1, 4 and 2, 3 respectively, in which case, compared with two speakers provided in one box as in FIG. 4, the sense of separation is reduced further, enabling one to enjoy a four-channel stereo reproduction sounding quite natural.

In the meantime, in each of the aforesaid embodiments, the absolute values 1L−R1 and 1R−L1 of spatially composed waves are considerably smaller than the acoustic output available when applying the same signals (in-phase signals) to two speakers and therefore it isn't necessary to comply with the established conventional theory: "When providing 2 speakers having the same or similar characteristics within a single speaker box, the speaker box should be doubled in volume," and an effective volume about 1.0 to 1.5 times that of an ordinary speaker box will suffice.

Further, in connection with the above-mentioned embodiment it has been described that the antiphase signal −R of the right signal (or the antiphase signal −L of the left signal) is supplied to the speaker SP_2, but instead of applying the antiphase signal −R (or −L), the right signal R (or the left signal L) may be supplied as it is by making the connection of the voice coil of the speaker SP_2 reverse to that of the speaker SP_1.

A means to shorten the distance l_a required for spatial mixing described above will now be explained in the following.

In FIG.'s 8 and 9 reference numeral 21 (21A or 21B) is a vertically long speaker box and an opening 22 for sound emission is provided near the middle part thereof, while a fanwise sound wave reflector 23 as shown in FIG. 10 is provided horizontally in the middle part of the opening 22 and two speakers SP_1, SP_2 are placed opposite to each other in a spaced relationship by way of baffle plates 24A, 24B with the sound wave reflector being in between them, and sound waves from each of these speakers are emitted around by the reflector 23 through the opening 22. As for the speakers SP_1, SP_2, those speakers having the asme or similar electroacoustic characteristics are employed. Further, if one provides the sound-passing holes 25*a*, 25*b* in the top and bottom plates 25A, 25B of the speaker box 21, bass tonal components will be reproduced therethrough.

The sound wave reflector 23 is shaped such that it can radiate the sound wave, emitted from the speakers SP_1 and SP_2, uniformly in all of the directions, that is, the reflector 23 is the thickest at the center thereof, becoming gradually thinner toward edges thereof.

In the case of a practical use thereof, as shown in FIG. 11 the aforesaid speaker boxes 21A, 21B are arranged at the left and right rear positions of the listening room 10 and the first speakers SP_1, SP_1 in each of these boxes are individually connected in parallel (or in series) to the left and right front speakers S_1, S_2 provided at the left and right front positions of the listening room, to the terminals T_1, T_2 of which are supplied two-channel left and right signals L, R respectively.

On the other hand, the terminals T_3, T_4 connected to the second speakers SP_2, SP_2 within the speaker boxes **11A**, **11B** are supplied antiphase signals $-R$ and $-L$ of the stereo right and left signals, respectively.

As for the acoustic effect in the case of the above-mentioned application, sound waves of signals L (or R) from the speaker SP_1 and sound waves of the antipahse signal $-R$ (or $-L$) are emitted toward the reflector **23**, by which the sound waves emitted are radiated uniformly into the middle part of the listening room **10** and, at the position of the listener M, the left signal L (or the right signal R) and the antiphase signal $-R$ of the right signal (or the antiphase signal $-L$ of the left signal) are not audible separately, but sound waves of the spatially composed non-directional stereo left-right difference signal L−R (or R−L) are audible, for which reason the listener M in FIG. **11** can hear a **4**-channel stereo sound having an efficient acoustic effect.

Further, the rear speaker box applicable according to this invention will not be limited to the ones shown in FIG.'s **8** and **9** but various other modifications are applicable. For instance, as shown in FIG. **12**, the cylindrical speaker boxes B_1, B_2 may be placed oppositely to each other and a sound wave reflector **23A**, being of a flat conical foam on both the top and bottom faces as shown in FIG. **13**, may be placed horizontally in the opening **22A**.

In connection with the above-mentioned embodiment, it has been described that the antiphase signal $-R$ of the right signal (or the antiphase signal $-L$ of the left signal) is applied to the speaker SP_2, but instead of supplying the antiphase signal $-R$ (or $-L$), the right signal R (or the left signal L) may be applied as it is by making the connection of the voice coil of the speaker SP_2 reverse with respect to that of the speaker SP_1.

An embodiment in which the speaker system as indicated in FIG.'s **4**, **6**, **8** and **12** can be used in a listening room will be described by reference to FIG. **14**.

At the left and right front corners and the left and right rear corners of the listening room **10**, there are provided speaker boxes **11A**, **11B** and **11C**, **11D** separately (for convenience of illustration, SP_1, and SP_2 are arranged laterally in this figure) and, the first speaker SP_1 (L) and SP_1 (R) in the speaker boxes **11C** and **11D** are respectively connected in-phase and in parallel (or in series) with the first speakers SP_1(L), SP_1 (R) provided in the speaker boxes **11A** and **11B**, to the terminals T_1, T_2 which are supplied **2**-channel stereo left and right signals L, R respectively.

On the other hand, stereo right and left signals R, L are applied to the second speakers SP_2 (R), SP_2(L) in the said speaker boxes **11A**, **11B** by way of the variable resistance R_1, R_2 respectively in phase with the said speakers SP_1 (L), SP_1 (R), while stereo right and left signals R, L are applied to the second speakers SP_2 (−R), SP_2 (−L) within the rear speaker boxes **11C**, **11D** respectively via the variable resistance R_3, R_4 in opposite phase. (In the said figure, connections of the voice coils of the rear second speakers SP_2 (−R) and SP_2 (−L) are made in reverse to each other.

The acoustic effect when using the rear speakers as above is as shown in FIG. **7** that is, if there is the relation $l_{\,n} >> l$, $l << r$ (r: wavelength of sound wave heard) between the distance l between the first speaker SP_1 and the second speaker SP_2 on the one part and the distance l_n from these speakers to the listening point P on the other, the left signal L (or the right signal R) and the antipahse signal $-R$ of the right signal (or the antiphase signal $-L$ of the left signal) are not audible separately at the listening point P, but sound waves of the spatially composed the difference signal L−R (or R−L) between the stereo left and right signals L, R are audible and the listener M in FIG. **14** can hear a four-channel stereo sound full of the feeling of attendance and having the acoustic effect equivalent to the conventional system illustaration in FIG. **3**.

That is, by operation of the variable resistances R_1 and R_2 for input level adjustment of the speakers SP_2 (R) and SP_2(L), it is possible to obtain from the front speaker boxes **11A**, **11B** sound waves of the four-channel stereo front left and right signals of $(L+\alpha R)$ and $(R+\alpha L)$, while it is similarly possible from the rear speaker boxes **11C**, **11D**, through input level control of the speakers SP_2 (−R) and SP_2 (−L) by way of the variable resistances R_3, R_4, to obtain sound waves of the four-channel stereo rear left and right signals of $(L-\beta R)$ and $(R-\beta L)$. Therefore it is possible to obtain a real-four-channel stereo sound full of the feeling of attendance at the scene even when completely eliminating the expensive decoder network D comprising complicated electrical circuits under the aforesaid conventional system shown in FIG. **3**.

Further, the front and rear speaker boxes **11A** through **11D** employed in this invention won't be limited to the ones shown in FIG. **4**, but it is also possible, as shown in FIG. **6** for instance, to supply to **1**, **4** and **2**, **3** of the four speakers, **1**, **2**, **3** and **4** arranged in one speaker box **12** the stereo left signal L (or the right signal R) and the stereo right signal R or its antipahse signal $-R$ (or the left signal L or its antiphase signal $-L$) respectively, in which case, in comparison with the case in which **2** speakers are accommodated in one box as in FIG. **4**, the sense of separation is reduced further, enabling one to enjoy a four-channel stereo reproduction sounding quite natural.

In the meantime, in connection with the rear second speakers SP_2(−R) and SP_2(−L) in the preceding embodiment, the connection of their voice coils was described as being opposite with respect to other speakers to obtain antiphase sound waves, but if left and right signals reversed in phase beforehand by other circuits or devices are applied to the above-mentioned speakers, the connections of the speakers SP_1, SP_2 may be made all in a forward direction.

As described, according to this invention, a plurality of speakers are provided in the stereo rear speaker box, to which speakers are applied stereo left and right signals respectively in opposite phase. A level adjustment is made of these antiphase components and, by spatially composing the same with sound waves of the left and right signals, four-channel stereo rear sound waves $(L-\beta R)$ and $(R-\beta L)$ are obtained. Stereo left and right signals are applied in phase to a plurality of speakers within the front speaker box and a level adjustment is made of those signal components in the left or right signal alone and sound waves of these signals are composed to obtain **4**-channel stereo front sound waves $(L+\alpha R)$ and $R+\alpha L)$. In comparison with the conventional systems shown in FIG.'s **1** to **3**, electric matrix elements, encoder, decoder and any other complicated and expensive networks are not required at all and amplifiers for two channels are fully sufficient for practical application, thus permitting a simple embodiment of this invention at a remarkably low cost.

Further, as this invention utilizes acoustic spatial mixing and sound interference, there is little distortion and inasmuch as the effective volume of the rear speaker box can be made small as described hereinbefore, one can enjoy stereo reproduction with excellent sound quality in a small-sized system and in addition, can set the values of α and β, etc. as one desires, with this invention having many advantages as above, providing a really great acoustic effect. Moreover, according to this invention, a plurality of speakers having the identical or similar characteristics are placed oppositely to each other in a single speaker box and a stereo left and right signals are applied in mutually opposite phase to these speakers respectively, with sound waves of these signals from the speakers being composed spatially via a reflector and emitted through the box opening to obtain reproduced sound for a four-channel stereo and thus, in comparison with the conventional systems, electric matrix elements, decoder encoder and any other complicated and expensive networks are not required at all and amplifiers for two channels are fully sufficient for practical application, thus permitting a simple embodiment of this invention at a remarkably low cost.

Further, as this invention utilizes acoustic spatial mixing and sound interference, it has the advantage that one can enjoy stereo reproduction with excellent sound quality and little distortion, and many other advantages, providing a really great acoustic effect.

I claim:

1. A stereophonic speaker system for converting monophonic input signals to composite stereophonic output sound waves comprising in combination:

at least two front speakers;

means for energizing at least one of said front speakers with a monophonic L signal from a first channel;

means for energizing at least another of said speakers with a monophonic R signal from a second channel;

at least two rear speaker devices, each of said speaker devices including at least two speakers, said two speakers in each speaker device facing oppositely and in close proximity to one another, and a sound wave reflector positioned intermediate said speakers;

means for energizing one of said speakers in each of said speaker devices with a monophonic L signal from said first channel; and

means for energizing the other speaker in each of said speaker devices with a monophonic R signal from said second channel, said channel signals being in reverse phase relationship to one another and wherein the sound waves from each speaker are combined spatially to form a composite stereophonic signal.

2. The stereophonic speaker system of claim 1 further comprising means for adjusting the level of one of said channel signals applied to one of the speakers in each of said speaker devices with respect to the level of the signal coupled to the other of said speakers.

3. The stereophonic speaker system of claim 2 wherein said adjusting means is a variable resistor.

4. A stereophonic speaker system for converting monophonic input signals to composite stereophonic output sound waves comprising in combination:

at least a pair of front speaker devices, each of said speaker devices including at least two speakers, said two speakers in each speaker device facing oppositely and in close proximity to one another, and a sound wave reflector positioned intermediate said speakers;

at least two rear speaker devices, each of said speaker devices including at least two speakers, said two speakers in each speaker device facing oppositely and in close proximity to one another, and a sound wave reflector positioned intermediate said speakers;

means for energizing one of said speakers in each of said speaker devices with a monophonic L signal from a first channel, and means for energizing the other speaker in each of said speaker devices with a monophonic R signal from a second channel, said channel signals being in phase between said speakers in the front channel speaker devices and being in reverse phase relationship to one another in said rear speaker devices and wherein the sound waves from each speaker are combined spatially to form a composite stereophonic signal.

5. The stereophonic speaker system of claim 4 further comprising means for adjusting the level of one of said channel signals applied to one of the speakers in each of said speaker devices with respect to the level of the signal coupled to the other of said speakers.

6. The stereophonic speaker system of claim 5 wherein said level adjusting means comprises a resistor.

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