June 14, 1955

M. CAMRAS

SOUND PROJECTION SYSTEM

2,710,662

4 Sheets-Sheet 1

Filed Dec. 23, 1948

Fig. 1

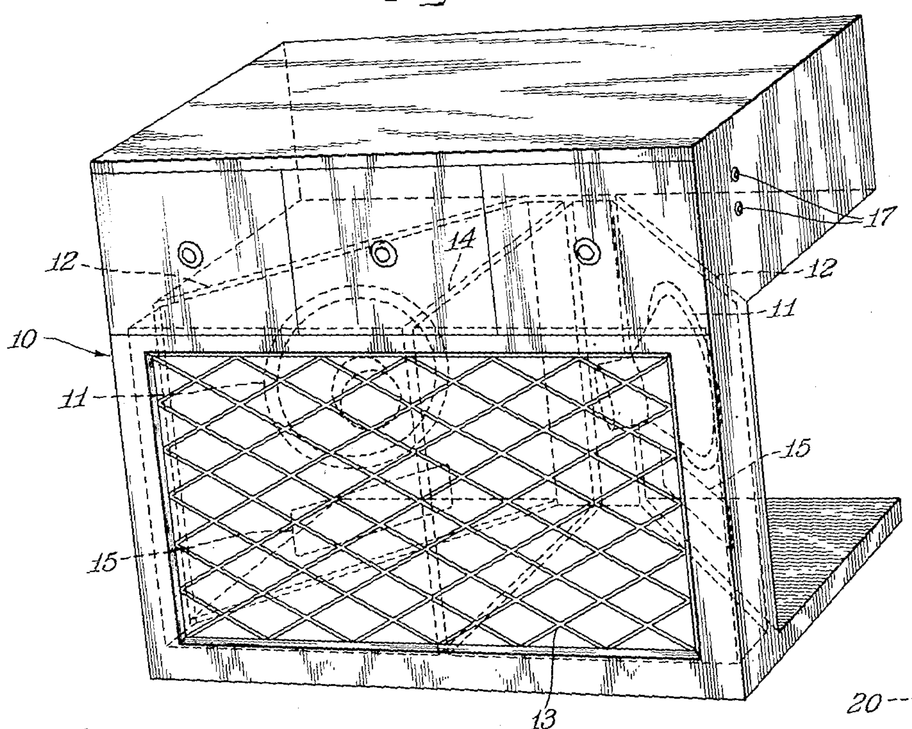

Fig. 2

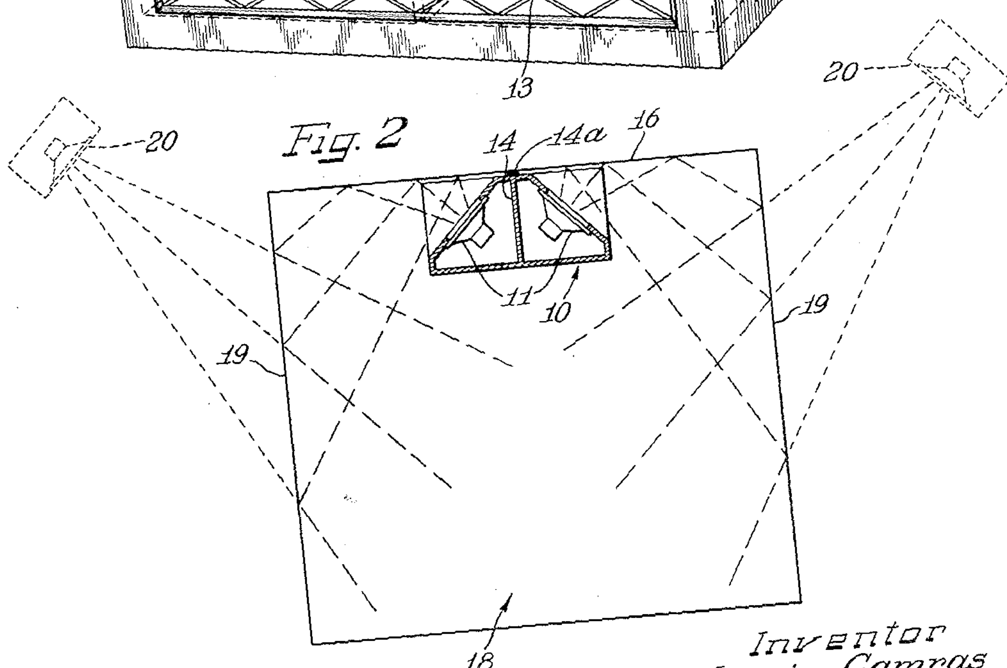

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Fig. 3

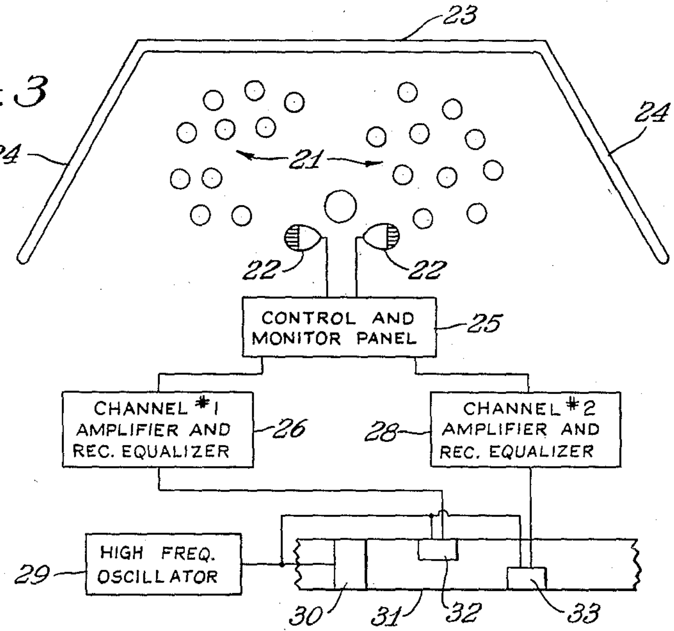
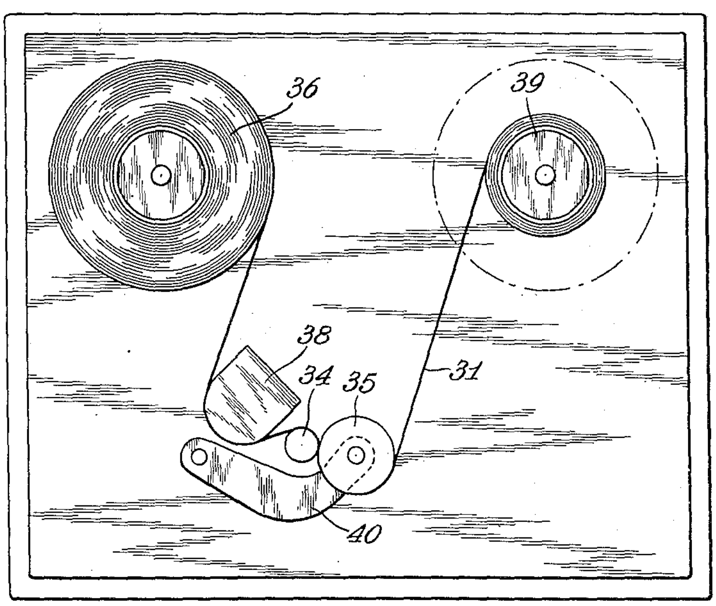


Fig. 4



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June 14, 1955 M. CAMRAS 2,710,662

SOUND PROJECTION SYSTEM

Filed Dec. 23, 1948 4 Sheets-Sheet 3

Fig. 5

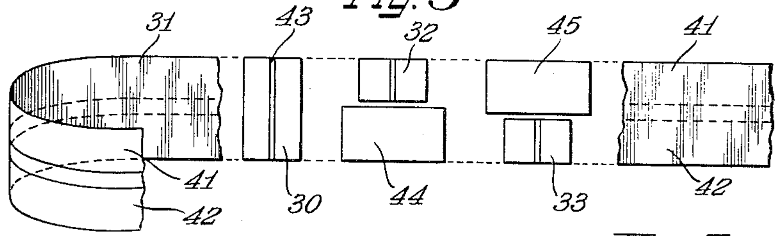
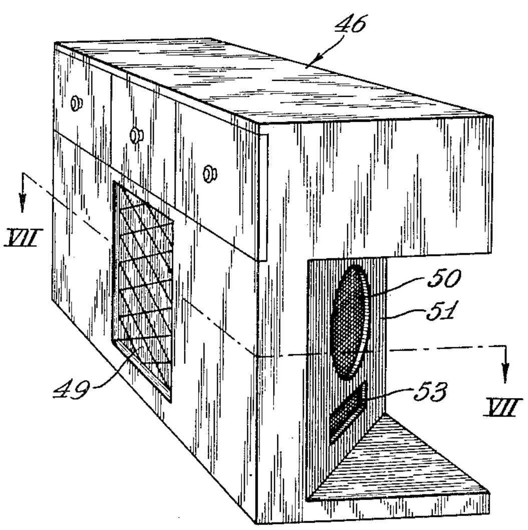


Fig. 7

Fig. 6



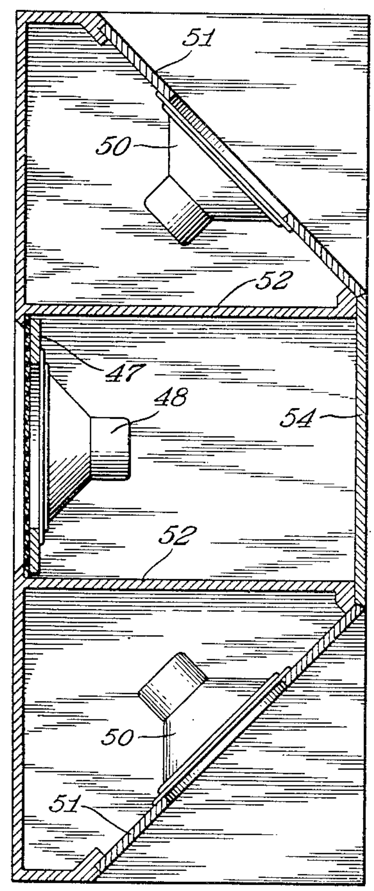


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Fig. 8

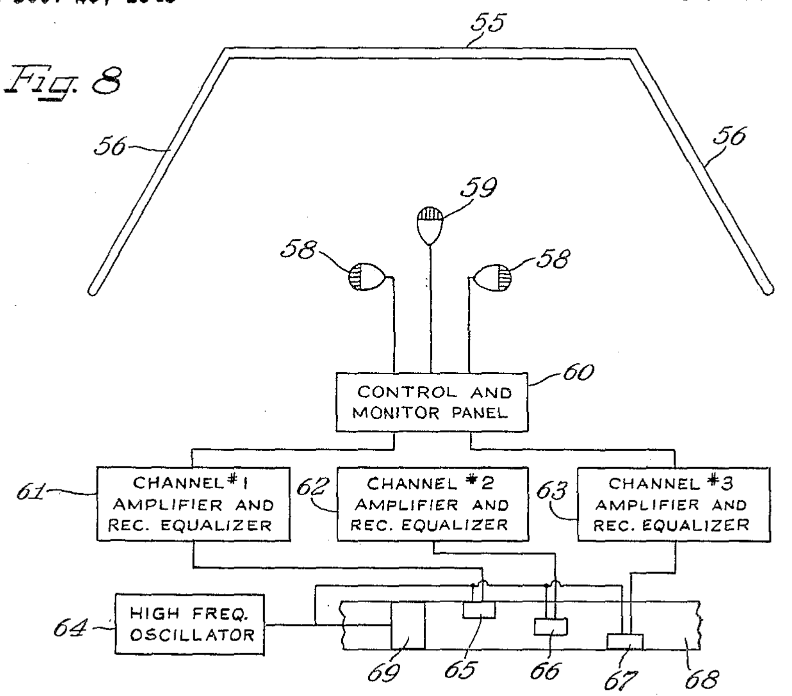
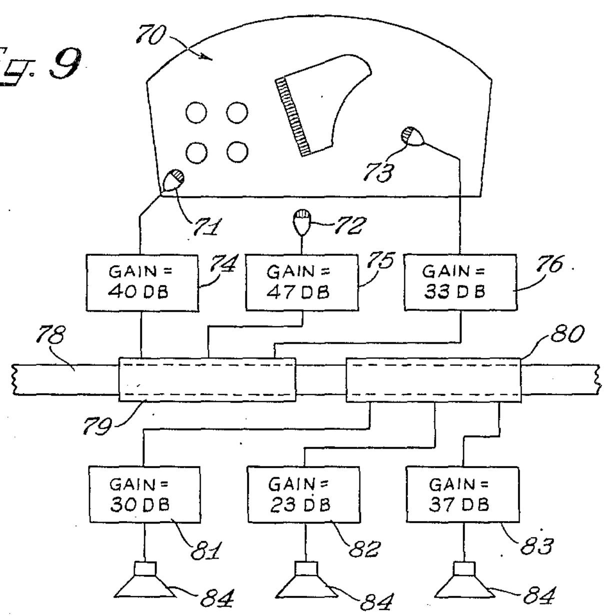


Fig. 9



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2,710,662

SOUND PROJECTION SYSTEM

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Application December 23, 1948, Serial No. 67,019

4 Claims. (Cl. 181—31)

This invention relates generally to a stereophonic sound reproduction system, and more particularly, to a method and means enabling high fidelity three-dimensional reproduction of sound with spatial effects.

One three-dimensional sound system which has already been tested for years is termed a binaural system. The reproduction of the spatial sound effects as they occur at the actual sound source picked up by this system is accomplished by having two microphones disposed five to six inches apart to simulate the ears of a listener. Each microphone is provided with its own amplifier and a corresponding ear piece of a headphone set. The listener, therefore, hears sound picked up near the source in the same manner that his or her ears would hear if the sound source was close by.

Since such a system limits the freedom of movement of the listener and also presents an economic difficulty in that a separate pair of ear pieces is required for each listener, it has not become too popular in fields where it might otherwise prove desirable, such as, the theater and home entertainment fields.

Stereophonic sound systems, or what might otherwise be termed three-dimensional loudspeaker systems on the other hand, have been advocated and tried in the past in the theater entertainment field. Such systems have, however, encountered economic difficulty because of the complicated assembly of numerous pieces of apparatus required for such productions.

Another difficulty heretofore experienced in such a system is that it has not been particularly adaptable to home use, where small rooms have presented an obstacle to the reproduction of spatial effects picked up at the sound source. In other words, the plurality of speakers in a stereophonic sound system placed in small rooms cannot be arranged to give the spatial sound effects, as, for example, might be picked up within an auditorium or in front of a large orchestra having a wide seating arrangement.

This invention has, therefore, for one of its principal features and objects the provision of a novel method and means for arranging simple sound reproducing elements to effect a stereophonic sound system.

It is another object of this invention to provide a novel method and means for making possible the adaptation of stereophonic sound systems to rooms of relatively small size.

Still another object of the present invention is to provide a simple stereophonic sound system comprising a relatively simple assembly of low cost apparatus.

Still another object of the present invention is to provide a novel means for recording sound for reproduction on stereophonic sound systems.

Another object of the present invention is to provide a novel sound diffusing projector which will provide pleasing audible results on single channel as well as stereophonic sound reproduction systems.

A further object of the present invention is to provide a novel means for reproducing recorded sound in stereophonic sound systems.

2

A further object of the present invention is to provide a novel sound diffusing projector.

A still further object of this invention is to provide a novel method of directing sound from a loudspeaker so as to give such sound a virtual source.

Another object of this invention is to provide a stereophonic sound reproduction system which particularly lends itself to compensation for multiple recordings made with unmatched gains in the separate recording channels.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its manner of construction and method of operation, together with other objects and advantages thereof may best be understood by reference to the following description, taken in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic perspective view of a console-type speaker unit embodying some of the principles of my invention;

Figure 2 is a diagrammatic plan view of a room with a console-type speaker unit therein indicating the principles of operation of the unit shown in Figure 1;

Figure 3 is a diagrammatic lay-out view of an arrangement of apparatus which may be used for recording sound in a system embodying the speaker unit shown in Figure 1;

Figure 4 is a diagrammatic top view of a recording unit which may be used in a system embodying my invention;

Figure 5 is a diagrammatic lay-out view of some of the active recording and reproduction elements of the recording unit of Figure 4;

Figure 6 is a diagrammatic perspective view of another console-type speaker unit embodying some of the principles of my invention;

Figure 7 is a cross-sectional view of the unit shown in Figure 6 as taken on line VII—VII;

Figure 8 is a diagrammatic lay-out view of an arrangement of apparatus which may be used for recording sound in a system embodying the speaker unit shown in Figures 6 and 7; and

Figure 9 is a diagrammatic lay-out view of apparatus for recording and reproducing sounds for a stereophonic sound system and by way of example showing a special gain control feature of a system embodying my invention.

As shown on the drawings:

The console-type speaker unit **10** shown in Figure 1 is provided with two loudspeakers **11** mounted in the lower portion on separate baffle boards **12** disposed in a vertical position behind the decorative grille **13** and arranged to direct the acoustic output of the speaker toward the back of the unit and out from each side. In order that the speakers may operate independently of each other, without fear of acoustic phase interference, each is mounted in a separate acoustic chamber formed by a vertical dividing panel **14** bisecting the space between the loudspeakers **11**. Air within the chamber is vented through a screened aperture **15** in each baffle board **12** just below the loudspeakers **11**. A supplemental separation is provided by a small projecting separator **14a** on the back of unit **10**. This member may be made of felt or any other suitable acoustical material, preferably soft, so that it will also provide a sealed partition between the speakers when the unit **10** is placed against a wall. Thus, when the speaker unit **10** is positioned with its back in close proximity against a wall **16** of a relatively small room **18**, as shown in Figure 2, the acoustic output of each of the speakers **11** is reflected first from the wall **16** and then travels at an angle to the side walls **19** from which the sound again reflects at an angle of reflection equaling the angle of incidence with the wall. By means of dotted lines representing the output of the speakers 11, Figure 2 indicates that the reflected sounds from the side walls 19 appear to emanate from an apparent source 20 beyond the walls 19 and outside of the room 18. This characteristic occurs especially with high frequency sounds which are normally utilized in human hearing to locate or localize sources of sound.

The positions of the apparent sources of sound 20 beyond each side of the room 18 is obviously dependent upon the positions in which the speakers 11 are placed and also upon the room dimensions and the room acoustics.

It is apparent, that if it is desired to relocate the virtual sources 20, an adjustment may be made so that speakers 11 will be redirected at the angle necessary to place the apparent sources in the desired positions.

If it is desired to place one of the apparent sources 20 closer to one of the walls 19, and to move the other virtual source 20 farther away, the speaker unit 10 need only be moved closer to the side wall which is to have the closest apparent source. In most cases, however, the two apparent sources 20 may be disposed at equal distances beyond walls 19 by placing speaker unit 10 at substantially an equal distance from each of the side walls 19.

Now, if speakers 11 were each arranged to reproduce sounds picked up by separate directional microphones placed near a sound source, in a manner such that each would respectively pick up sound on separate sides of the source, a stereophonic sound system would result. Not only would the acoustic system be stereophonic, but it would reproduce the spatial sound effects of a large room, even though the room in which the sound is reproduced may be small.

By way of example, an arrangement of apparatus which makes possible the stereophonic recording of sounds as may be produced by an actual source, such as an orchestra on a stage, is illustrated in Figure 3. The individual instrument sound sources 21, making up the combined orchestra source, are picked up by the microphones 22 centrally located in front of the orchestra. The microphones may be pointed in directions 180° from each other and spaced relatively close together as shown in Figure 3. The back-drop 23 of the stage is provided with wings 24 disposed at an angle to the back.

While it is preferable to place the microphones as shown in Figure 3, they may also be placed on each side of the sound source in relative locations where the relative sound sources will appear upon reproduction in a room such as room 18. Another possibility is that microphones be placed in positions such as those corresponding to position of the speakers in a dihedral speaker unit, as shown in Figures 2 and 7.

In general, directional microphones for picking up sound for reproduction in a stereophonic system may be spaced from each other by a distance ranging between a few inches to several feet and still simulate ear pickup. A number of experiments have shown, however, that the most desirable of such positions is that in which the microphones are spaced relatively close together with directional pickup patterns extending outward from 60° to 180° or more. Such a microphone arrangement is particularly advantageous when earphones are used and by such means gives a most realistic binaural effect. To enable the owner of a stereophonic sound projection unit of the type illustrated in Figure 1 to take advantage of such pleasing effects, a pair of phone jacks 17 are provided on the unit 10 for connection to the individual reproducing channels. A head set adapted for reproduction of the separate signals by each earphone may then be utilized with the unit as desired.

Referring again to Figure 3, the impulses picked up by microphones 22 are translated into audio electrical impulses and fed to control and monitor panel 25, from which the two sound source signals are fed to separate

amplifier and equalizer units 26 and 28, respectively, corresponding to channels Nos. 1 and 2. The amplifier output signals each have superimposed thereon a high frequency signal, supplied by a high frequency oscillator 29 to enable a high fidelity magnetic recording of the audio signals in accordance with the principles of magnetic recording described in detail in my United States Patent No. 2,351,004, issued June 13, 1944.

High frequency alternating current from oscillator 29 is also fed to a magnetic erase head 30 disposed across the magnetic surface of magnetic record member 31, whereby the record member is cleared of any residual magnetism before the audio signals with superimposed high frequency alternating current are impressed on the separate magnetic channels of the record member 31 by the stereophonic magnetic recording heads 32 and 33. The stereophonic heads 32 and 33 are staggered on each side and along the length of recording member 31 to provide magnetic isolation of the recording tracks, as will be explained subsequently.

A magnetic recording and playback machine which makes possible stereophonic reproduction of sound is illustrated in Figure 4 in which the general arrangement of the machine elements are shown. A drive capstan 34 with an associated pinch roller 35 drives the record member 31, drawing it from a slip supply reel 36 and moving it over a magnetic head assembly 38. After then passing between the drive capstan 34 and the pinch roller 35, the record member 31 is wound on a takeup reel 39. In driving the record member, the pinch roller 35 is freely movable about the pivot of its pinch roll assembly arm 40, and is pulled against the drive capstan 34 only under the tension of the record member 31. When the machine is stopped, the tension provided by the record member 31 releases, and the pressure exerted by the pinch roller 35, therefore, also ceases. A high speed rewind mechanism may be incorporated in the machine, and a forward speed may also be provided for convenience in editing the record member 31.

The arrangement of the magnetic erase head 30 and staggered stereophonic magnetic heads 32 and 33 as they are assembled on magnetic head assembly 38 for contact with separate magnetic channels 41 and 42 of magnetic member 31 is illustrated in Figure 5. The magnetic record member 31 is a tape member such as those having a cellulose acetate base with a coating of magnetizable material on one side which may be conveniently arranged for two-channel recording. The erase head 30 is disposed so that its air gap 43 extends across the entire width of the tape 31 and clears off both channels simultaneously. The recording heads 32 and 33 are staggered along the length of the tape to assure their magnetic independence of each other and to eliminate cross-talk between the recording channels. Corresponding to heads 32 and 33 are adjacent keepers 44 and 45, respectively, made of high permeability alloy material for short-circuiting the magnetic channel in a line extending across each channel at points adjacent the magnetic heads. Thus, while each magnetic head is actively operating in conjunction with a portion of its respective recording channel, the adjacent portion of the other channel is being short-circuited to prevent cross-talk. Without keepers, experiments have shown that the heads are sensitive to recordings on channels as far as one-eighth of an inch from the heads, the effect being especially pronounced at low frequencies.

A three-speaker stereophonic speaker unit is illustrated in Figures 6 and 7 in which the principal speaker 48 is mounted directly behind the decorative speaker grille 49 in a console-type speaker unit 46. The central speaker 48 is mounted on a baffle board 47 and is directed so that its acoustical output is projected to the front of the speaker unit 46, while two side speakers 50, mounted on baffle boards 51, are arranged to project their respective acoustical outputs toward the rear and sides of the unit **46**. Each of the speakers is provided with an individual acoustical chamber by dividing the space extending between the backs of the two-side speakers **50** into three parts by means of vertical dividing panels **52** disposed on each side of the central speaker **48**. Each of the chambers is vented by a screened aperture **53** just below the speaker in its respective speaker baffle board. The central acoustical chamber is provided with a removable back cover **54** to enable easy access to the speaker **48**, while access to the side chambers is accomplished by removing the speaker baffle boards **51**. The upper portion of the console unit **10** is provided with apparatus and manual control space, to enable the reproduction system with which the unit is used, to be self-contained. It will be apparent that the cover **54** provides a rear locating surface for establishing a parallel disposition of the housing to a wall of a room or the like.

Such a speaker unit may be used for three-channel stereophonic sound systems. Experiments have shown that for solo work and for announcements, a central channel adds realism by giving the effects of clarity and nearness. This is understandable when it is considered that sounds picked up at the source by the side microphones must travel a considerable distance farther than that picked up by the central microphone and the ratio of reverberant to direct sound is high. A similar effect occurs on playback through the side speakers.

An arrangement of apparatus for making three-channel sound recordings is illustrated in Figure 8. The arrangement is similar to that for a two-channel stereophonic recording, with the exception that a central channel is added. The backdrop **55** is arranged with two wing portions **56** to aid in reflecting sound from the source to the side microphones **58**. The central microphone **59**, corresponding to the central speaker **48** in a three-speaker dihedral speaker unit, is placed between the two side microphones **58** to pick up sounds emitted directly from the center of the source.

In this respect, the microphones might also be arranged in a unit similar to that in which the speakers of unit **46** are positioned, that is, the microphone unit could be provided with a microphone corresponding to each speaker of a receiving unit, and could be positioned to pick up direct sounds as well as those reflected from surfaces surrounding the sound source.

The sound impulses picked up by the three microphones are translated into audio electrical impulses and are fed to control a monitor panel **60** from which the three monitored signals are fed to three separate amplifier and equalizer units **61**, **62** and **63**, respectively, corresponding to channels Nos. 1, 2 and 3. The output of each such unit is superimposed by a relatively high frequency current supplied by high frequency oscillator **64** in the same manner as explained previously, before being fed to a set of magnetic recording heads **65**, **66** and **67**, which are arranged in staggered magnetic engagement with the tape record member **68**.

A magnetic erase head **69** also makes magnetic engagement with the record member **68**, and is disposed across the entire width of the record member **68** to allow clearing by the high frequency field created by current supplied from the high frequency oscillator **64**. To prevent magnetic interference between recording channels during operation of the heads **65**, **66** and **67**, keepers are provided adjacent each such head to cover the portions of the recording channels adjacent each recording head for the same reasons as explained for the two-channel recording system illustrated in Figure 5.

With a three-channel recording system available, it might be desirable under certain circumstances to use two channels for binaural audio recordings and the third as a control track to vary the volume of the audio channels and thus increase the dynamic range.

To control the relative gain of the separate channels, it is apparent that the channels can be arranged to be adjusted separately so that a standard sound intensity picked up by each of the microphones will set up the same value of magnetization on the corresponding channels of the magnetic record member. On playback, the gain may then be set so that equal values of magnetization will produce equal sound intensities in the corresponding speakers.

In practice, however, the maximum sound intensities picked up by the different spaced microphones during the recording of particular sounds are usually different depending on microphone characteristics and location, as well as the relative loudness of sounds during recording periods. It is a feature of the present invention, therefore, that a novel method of equalizing the overall gain of sound reproduction, regardless of recording microphone conditions and relative loudness of recorded sounds. By way of example, illustrated in Figure 9, this desired feature may be accomplished by having a test piece played by an orchestra **70** and then adjusting the gain of each channel to the maximum point that will not produce overload on the recording equipment at any time. Depending on the placement of microphones **71**, **72** and **73**, and the relative loudness of the different instruments, the gains of the corresponding amplifiers **74**, **75** and **76** may, in a particular case such as that illustrated, be set at 40 db, 47 db and 33 db, respectively.

If, after recording such signals on a three-channel record member **78** by means of a recording head assembly **79**, playback were attempted without further compensation for gain variances, the acoustical output of a plurality of speakers **84** would not recreate the desired space relations.

To recover such effects, however, the signals picked up by a magnetic playback head **80** may be amplified with the gain settings of amplifiers **81**, **82** and **83** adjusted to an inverse ratio to the gains of the recording amplifiers **74**, **75** and **76**. That is, the playback head **80** would feed the recorded signals to amplifiers **81**, **82** and **83** with gain settings adjusted to 30 db, 23 db, and 37 db corresponding to the recording gain settings of 40 db, 47 db, and 33 db, respectively. Thus, a method of gain control for multiple channel recording is enabled, which compensates for variances in recording equipment characteristics and acoustical phenomenon.

Although the embodiments of my invention have been described mainly in regard to multiple channel systems, it has been found that utilization of the described speaker units on single channel systems also produces desirable pleasing effects since they act as excellent sound diffusers. Such operation of the units causes a reproduction of the single channel signals in such a manner as to make it difficult for a listener to localize the source. In other words, the sound reproduced seems to come from substantially all directions.

While I have shown particular embodiments of my invention, it will, of course, be understood that I do not wish to be limited thereto, since many modifications may be made, and I, therefore, contemplate by the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

I claim as my invention:

1. A sound reproduction system comprising extensive side and end walls, a unitary housing small in comparison to said walls disposed closely adjacent said end wall, and a pair of speakers carried by said housing and facing obliquely toward said end wall and laterally away from said housing toward a respective side wall, the axis of each speaker forming an acute angle in a horizontal plane to said end wall of magnitude to afford reflection of sound emanating therefrom against said end wall, thence to the respective side wall and thence into a listening area in front of said housing, said loudspeakers directing their output in horizontally diverging angular directions against said end wall and being arranged and connected to displace the apparent sources of binaurally related

sound patterns to beyond the respective opposite side walls, whereby binaurally related sound patterns may be reproduced by the loudspeakers carried in closely spaced relation by the unitary housing while giving the effect of separate remotely spaced sound sources beyond the limits of the listening area.

2. A sound projection system comprising a housing having a front side for facing a listening area, said housing having two and only two loudspeaker units carried as a compact unit therewith and facing obliquely rearwardly and laterally outwardly from said front side and in opposite lateral directions, means in the housing for acoustically isolating the loudspeaker units, said housing being constructed to be disposed with said two loudspeaker units in close proximity to an extended planar surface large in comparison to the size of the housing with the front side of the housing facing toward a listening area in front of said surface and with the loudspeaker units directing their output in horizontally diverging angular directions against said planar surface and then against extended surfaces on the sides of said listening area to project sound into said listening area from apparent sources laterally outside of said listening area and greatly spaced in comparison to the spacing between said loudspeaker units.

3. A sound projection system comprising a housing having a front wall with a first loudspeaker disposed therein for directing sound directly to a listening area in front of the housing, said housing having a rear generally planar locating surface for establishing a parallel disposition of the housing in close proximity to an extended planar reflection surface, a further pair of loudspeakers carried as a compact unit with said housing and facing obliquely rearwardly and laterally outwardly relative to said front wall and in opposite lateral directions, and means in said housing for acoustically isolating said loudspeakers, said further pair of loudspeakers when disposed with said rear planar surface in parallel close relation to an extended reflection surface directing their output in horizontally diverging angular directions against said planar extended surface, the sound being reflected to extended side reflection surfaces on opposite lateral sides of said housing and thence into a listening area in front of said housing, whereby the apparent sources of sound emanating from said further pair of loudspeakers are displaced laterally beyond said extended side reflection surfaces to greatly displace the apparent sources of sound emanating from the pair of loudspeakers in comparison with the spacing between the pair of loudspeakers.

4. A sound projection system comprising a housing having acoustically isolated loudspeakers facing obliquely rearwardly and laterally outwardly with the axes of the loudspeakers diverging in the rearward direction and defining a horizontal angle therebetween, a planar extended rear surface at the rear of the housing and closely spaced to the housing in comparison to the front-rear dimension of the housing and intersecting the axes of said loudspeakers extended in the rearward direction, and additional surfaces disposed to receive sound emanating from said loudspeakers which is reflected from said planar extended rear surface to redirect the sound into the area in front of the housing.

References Cited in the file of this patent

UNITED STATES PATENTS

1,855,149	Jones	Apr. 19, 1932
1,915,954	Scofield	June 27, 1933
1,932,343	Holland	Oct. 24, 1933
1,945,710	Smoot	Feb. 6, 1934
1,978,456	Goshaw	Dec. 30, 1934
2,017,153	Kellogg	Oct. 15, 1935
2,093,540	Blumlein	Sept. 21, 1937
2,098,561	Beers	Nov. 9, 1937
2,114,680	Goldsmith	Apr. 19, 1938
2,137,032	Snow	Nov. 15, 1938
2,143,175	Waite	Jan. 10, 1939
2,173,222	Belar	Sept. 19, 1939
2,179,840	Bucky	Nov. 14, 1939
2,217,279	Karns	Oct. 8, 1940
2,343,471	Nixon	Mar. 7, 1944
2,491,982	Kincart	Dec. 20, 1949
2,520,798	De Boer	Aug. 29, 1950
2,532,917	Howell	Dec. 4, 1950
2,539,327	Reid et al.	Jan. 23, 1951
2,544,742	Volf	Mar. 13, 1951
2,561,338	Camras	July 24, 1951
2,610,694	De Boer	Sept. 16, 1952

FOREIGN PATENTS

486,095	Great Britain	Aug. 18, 1937
575,492	Germany	Apr. 28, 1933