United States Patent

[11] 3,614,320

[72] Inventor **John E. Volkmann**
Princeton, N.J.

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[73] Assignee **RCA Corporation**

[54] **STEREOPHONIC SOUND ENHANCEMENT SYSTEM WITH REVERBERATION CHAMBER**
6 Claims, 2 Drawing Figs.

[52] U.S. Cl. ..... 179/1 J
[51] Int. Cl. H04r 5/02
[50] Field of Search ..... 179/1.6, 100.2 RE, 1 J; 181/0.5 B, 30, 0.5

[56] **References Cited**

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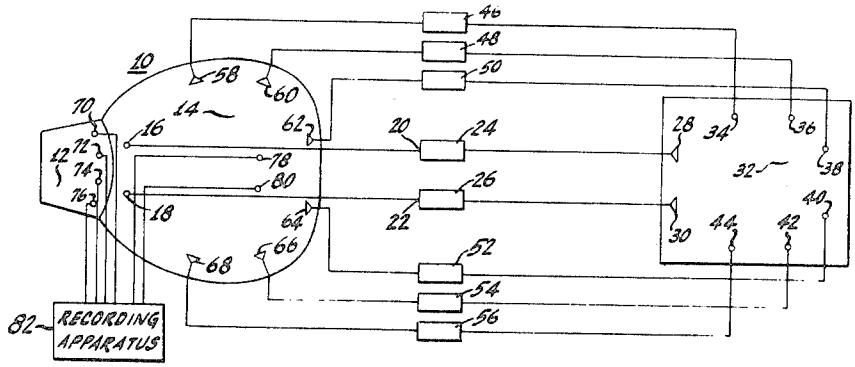
1,853,286	4/1932	Round et al.	179/1 (.6)
2,421,424	6/1947	Kreuzer	179/1 (.6)
2,017,153	10/1935	Kellogg	179/100.1
2,107,804	2/1938	Roux et al.	179/1.6
3,024,309	3/1962	Kleis	179/1.6

OTHER REFERENCES

Stereophonic Localization: An Analysis of Listener Reactions to Current Techniques; Eargle, John M.; IRE Transactions on Audio; September– October, 1960; pp. 174– 177.

Primary Examiner—Kathleen H. Claffy
Assistant Examiner—Randall P. Myers
Attorney—Eugene M. Whitacre

ABSTRACT: The reverberation characteristics of an auditorium or music hall are improved by picking up the sound originating in the auditorium with microphones, and reproducing the sound in a second room having a more optimal reverberation characteristic. A second set of microphones in the second room picks up the sound and its reverberations for transmission to a group of loudspeakers in the auditorium, where it is blended with the original sound.



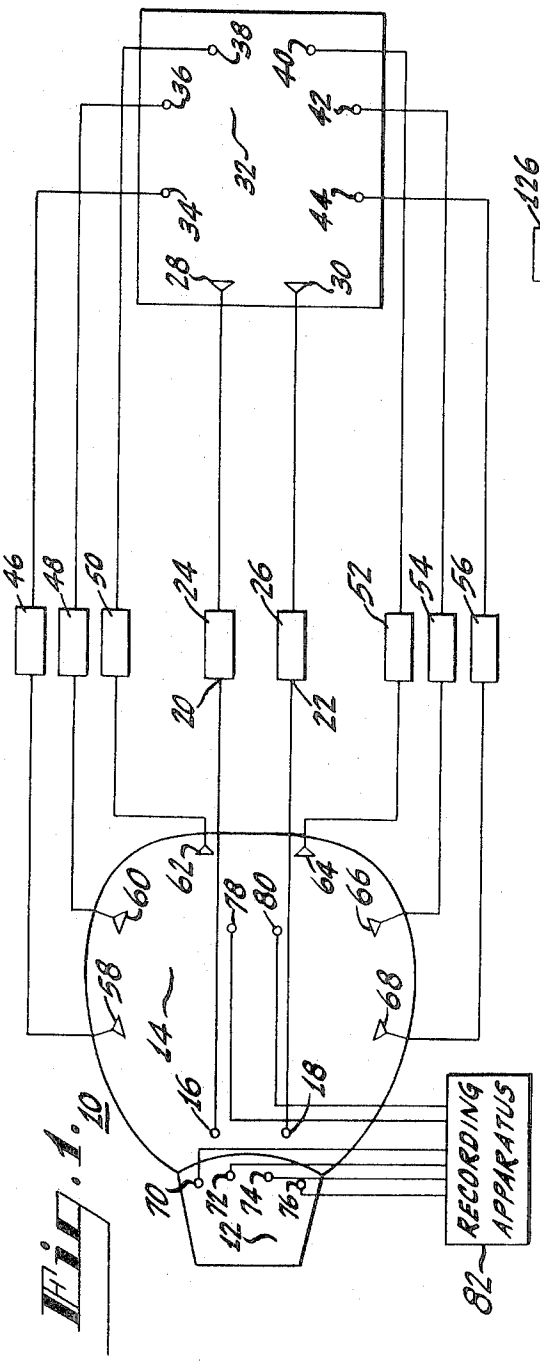


Fig. 1.

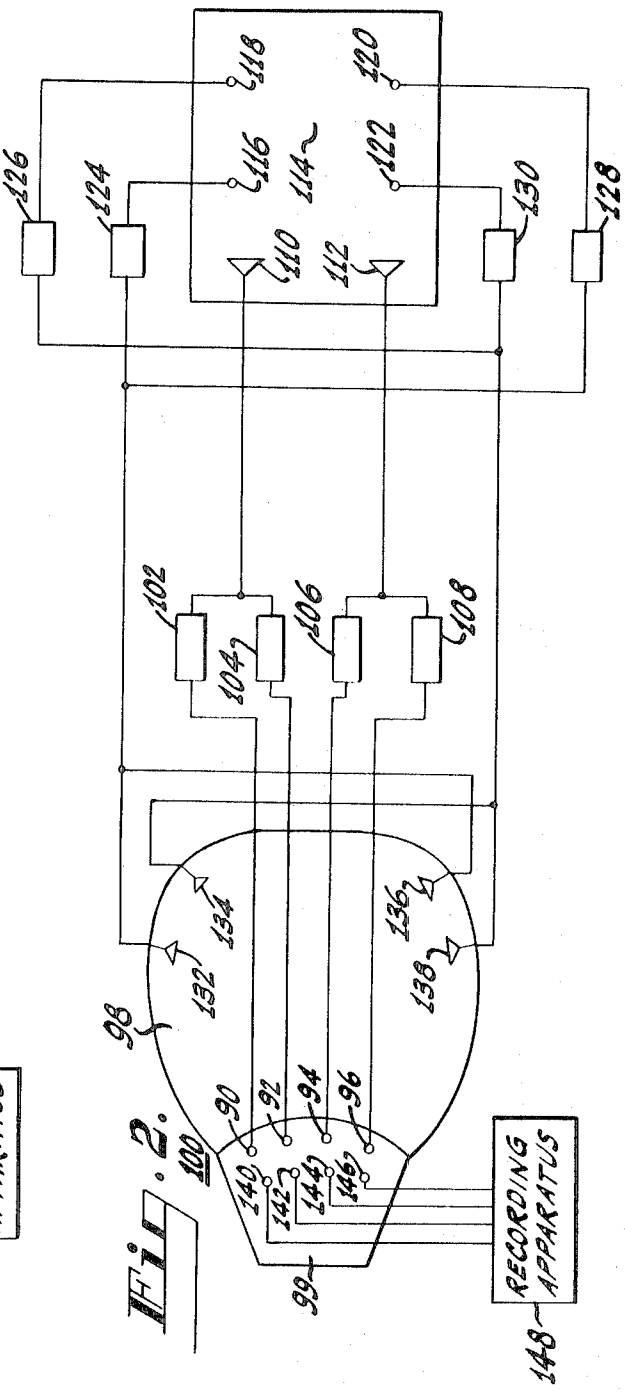


Fig. 2.

INVENTOR
JOHN E. VOLKMANN

BY J M Whitacre

ATTORNEY

STEREOPHONIC SOUND ENHANCEMENT SYSTEM WITH REVERBERATION CHAMBER

SOUND ENHANCEMENT

This invention relates to sound reproducing systems and more particularly to a system to provide for the enchancement of the reverberation characteristics of a music hall or auditorium.

A problem common to many music halls and auditoriums is that the reverberation time of the hall auditorium may be too short. Reverberation time is defined as the time it takes for a given sound intensity to decrease a fixed amount. A hall with too short a reverberation time has been referred to as a "dry" hall and such a hall does not provide the appropriate acoustical characteristics for optimum presentation and recording of music. Various methods and systems to solve this problem have been attempted.

One system known in the prior art consists of transmitting sound from an auditorium to an acoustical chamber of small dimensions relative to the auditorium and then transmitting the reverberated sound from the acoustical chamber back to the auditorium. Such a system is disclosed in boux et al., U.S. Pat. No. 2,107,804. The disadvantages of this system are that it provides the listener with a feeling that the sound is artificially reverberated or altered instead of naturally reverberated. This may be caused by the reverberated sound lacking spatial distribution and directional illusion, or by the reverberated sound having an effective mean free path which is considerably different than the natural mean free path of the music hall. Mean free path is defined as the average distance sound travels between successive reflections in a chamber.

An object of this invention is to provide an improved system for presenting or recording a sound program, such as music, in an auditorium with a given reverberation characteristic in a manner such that the auditorium appears to have enhanced reverberation characteristics.

A further object of this invention is to enhance the reverberation characteristics of a hall or chamber without significantly changing other acoustical characteristics of the hall or chamber.

In accordance with the invention, the natural reverberation characteristics of a secondary chamber is superimposed on the reverberation characteristics of a primary chamber in such a manner that the reverberation characteristics of both chambers are naturally integrated or blended together in the primary chamber with respect to time sequencing, spatial distribution, direction illusion, and amplitude levels, and without amplifying the direct orchestral sounds or detrimentally altering the inherent good acoustics (clarity, definition, blending, so-called presence, intimacy, etc.) of the early sound reflections in the primary chamber. The dimensions of the secondary chamber are such that the effective mean free path of the reverberated sound is of the order of that of the primary chamber.

Various other objects and advantages will appear from the following description of the several embodiments of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

The drawings diagrammatically represent different examples of means for carrying out the invention.

FIG. 1 is a schematic diagram of a system for recording sound in an auditorium with enhanced reverberations; and

FIG. 2 is a schematic diagram of another embodiment of a system for recording sound in an auditorium with enhanced reverberations.

Referring now to the drawings and in particular to FIG. 1, the music hall or primary chamber 10 which has a reverberation time characteristic that is not regarded as sufficiently long for the presentation or recording of music comprises a stage portion 12 and an audience portion 14. At least two pick-up devices or microphones 16, 18 are located in the area of the audience portion 14 adjacent the stage portion 12 in a position to pick up the direct sound wave fronts of the music presentation from the stage portion 12.

It will be understood that the microphones 16, 18 could also be located on the stage portion 12, the exact location of the microphone being dependent on the location of the sound source (orchestra). A pair of microphones 16, 18 are connected to the respective input terminals 20, 22 of a pair of amplifiers 24, 26 which may be located in the music hall 10 or exterior thereof. The output signals from the amplifiers 24, 26 are then respectively coupled to a pair of loudspeakers 28, 30 located in a secondary chamber or room 32 which is separate from the primary chamber 10. The loudspeakers 28, 30 are distributed in the secondary chamber 32 so as to reproduce stereophonically therein the sound wave fronts as they are picked up in the primary stage 10. This is accomplished by distributing loudspeakers 28, 30 in the secondary chamber 32 in a similar or corresponding spatial relationship to the positioning of microphones 16 and 28 in the primary chamber 10. The secondary chamber 32 has a reverberation time characteristic which is preferably longer than that of the primary chamber, and is of a time duration considered desirable for superposition in the primary chamber 10 during the presentation of sound therein as will be hereinafter described. The effective mean free path of the reverberated sound in the secondary chamber 32 is of the same order as that of the primary chamber 10. In other words, the average distance that a sound wave travels between reflections in the secondary chamber, with or without supplementary acoustic delay, is of the same order of magnitude as that in the primary chamber. This aids in effecting a spatial distribution and directional illustration in the reverberated sound waves produced in the secondary chamber 32. The total sound produced in the secondary chamber 32, which comprises the original sound introduced therein along with its increased reverberation, are picked up by a plurality of microphones 34, 36, 38, 40, 42, and 44 positioned within the secondary chamber 32 in an arcuate array as shown in FIG. 1. The outputs from each of the microphones 34–44 are coupled via respective amplifiers 46, 48, 50, 52, 54, 56 to respective loudspeakers 58, 60, 62, 64, 66 and 68, said loudspeakers being located in the primary chamber 10 and within the audience portion 14 of the primary chamber 10 so as to reproduce therein the reverberation sound wave fronts as they are picked up in the secondary chamber 32.

In operation of the system, the microphones 16 and 18 pick up primarily the direct sound wave fronts from the stage area 12. The spacing of the microphones 16 and 18 permits the sound to be transduced in stereophonic relation so that similar sound wave fronts can be recreated in the secondary chamber 32 by loudspeakers 28 and 30. The direct and reverberated sound picked up by the microphones 34–44 in the secondary chamber 32 is amplified and reproduced by their associated loudspeakers in the primary chamber 10 at a level such that the sound appears to come from the stage area 12, and the reverberated sound from the secondary chamber 32 is smoothly blended with the natural reverberant sound in the primary chamber 10.

For recording purposes, additional microphones 70, 72, 74, 76, 78 and 80 may be located on the stage 12 and audience 14 portions of the primary chamber 10. These microphones may be connected to respective input terminals of a suitable recording apparatus indicated by the block at 82. Recording apparatus 82 may comprise means for transcribing the sound audible in the primary chamber 20 and picked up by the microphones 70–80 on to recording tape or phonograph records for commercial purposes.

The amplifiers shown in the drawing may include equalizers, filters and acoustic delay means. Equalizers may be provided to selectively vary the phase and/or amplitude of the signals processed therethrough. Filters may be used to filter out or attenuate certain frequencies as desired. Acoustic delay means which may be electronic, mechanical, or acoustical may be employed to add additional time to delay to the system.

The secondary chamber may be any size or shape so long as the effective mean free path, with or without supplementary acoustic delay of the reverberated sound is comparable to or

of the same order of magnitude as that of the primary chamber. Also, two or more secondary chambers may be connected in series in order to further modify the reverberation characteristics of the primary chamber.

Referring now to the embodiment of FIG. 2, the system shown therein was used to increase the reverberation time of the auditorium in the Academy of Music in Philadelphia, Pa. This auditorium, when used for recording, was though to have a "dry sound" and had a reverberation time of about 1.4 seconds. With the system shown in FIG. 2, the reverberation time of the auditorium was increased to about 2.2 seconds. Specifically, with reference to FIG. 2, four microphones **90**, **92**, **94** and **96** were arranged on stage **99** of the Academy auditorium **100** in a position to pick up the direct sound wave fronts of the music presentation from the stage. Sound picked up by the microphones **90**, **92**, **94** and **96** was respectively coupled to amplifiers **102**, **104**, **106** and **108**. The outputs from amplifiers **102** and **104** were combined and fed to a first loudspeaker **110**, and the outputs from amplifiers **106** and **108** combined and fed to a second loudspeaker **112**, both of said loudspeakers being located in the main ballroom of the Academy which was used as the secondary chamber **114**. Four microphones **116**, **118**, **120** and **122** located in the secondary chamber **114** were respectively coupled to amplifiers **124**, **126**, **128** and **130**, the outputs of which were combined as shown in FIGURE to provide four signals for driving respective loudspeakers **132**, **134**, **136** and **138** in the audience portion **98** of the Academy auditorium **100**. For recording purposes, four microphones **140**, **142**, **144** and **146**, located on the stage portion **99** of the auditorium, were coupled to a recording apparatus **148**. It was found that the size and acoustical characteristics of the ballroom, along with the arrangement of the loudspeakers and microphones in the auditorium, and the ballroom, were such as to produce a realistic reproduction in the auditorium with an enhanced reverberation effect. The blending or integration of the sound originating in the auditorium with its reverberations in the ballroom was accomplished without affecting the time sequence, spatial distribution, and directional illustration of the music. The enchancement process was carried out without increasing the effective loudness of the direct orchestral sound and without altering the inherent good acoustical characteristics of the auditorium. The sound was transmitted from the auditorium to the ballroom and back again to be blended with the original sound so as to reinforce and enhance the sound as it was heard and recorded throughout the auditorium.

In addition to the embodiments shown, a variation of the present invention may comprise the use of plurality of secondary chambers along with means for selecting which secondary chambers are to be used to enhance the sound in the primary chamber. The reverberation characteristics of the total sound originating in the primary chamber may be varied by selecting a different secondary chamber into which this sound is to be fed. The microphones in the primary chamber may be so arranged with the selecting means so that the various sound transduced by the individual microphones may be fed to different secondary chambers. The sounds reverberated in the secondary chambers may be selectively fed to various loudspeakers arranged in the primary chamber. This embodiment will allow the reverberation of a particular sound in the primary to be altered without changing the reverberation of the other sounds.

What is claimed is:

1. A sound enchancement system comprising:

a primary chamber,

a secondary chamber having selected physical dimensions such that the mean free path of sound in said secondary chamber is of the same order of magnitude as the mean free path of sound in said primary chamber,

means for transmitting electrical signals representative of sound in said primary chamber to said secondary chamber and converting said electrical signals into sound, said means for transmitting electrical signals representative of sound in said primary chamber to said second chamber comprising a plurality of stereophonically related channels, and

means for transmitting electrical signals representative of the sound along with its reverberations from said secondary chamber to said primary chamber and converting said electrical signals into sound, said means for transmitting electrical signals representative of said sound along with its reverberations from said secondary chamber to said primary chamber comprising a plurality of stereophonically related channels, thereby to enhance the acoustical characteristics of said primary chamber.

2. A sound enchancement system as defined in claim **1** wherein,

said secondary chamber has a reverberation time which is longer than the reverberation time of said primary chamber.

3. A sound enchancement system as defined in claim **1** wherein,

said means for transmitting electrical signals representative of said sound in said primary chamber to said secondary chamber further includes pickup means in said primary chamber located near to where the sound originates from so as to pick up a direct sound wave front.

4. A sound enchancement system comprising:

a primary chamber;

a secondary chamber, having a reverberation time longer than the reverberation time of said primary chamber and having selected physical dimensions such that the mean free path of sound in said secondary chamber is of the same order of magnitude as the means free path of sound in said primary chamber;

first means for transmitting electrical signals representative of sound is said primary chamber to said secondary chamber comprising a plurality of stereophonically related channels and including pickup means, located in said primary chamber near to where the sound originates, for picking up a direct sound wave front, said first means further including reproducing means, located near wall in said secondary chamber corresponding in spatial array to the positioning of said pickup means in said primary chamber, for reproducing said sound-wave front of said primary chamber in said secondary chamber; and

second means for transmitting electrical signals representative of the sound along with its reverberations from said secondary chamber to said primary chamber and converting said electrical signals into sound, thereby to enhance the acoustical characteristics of said primary chamber, said second means comprising a plurality of stereophonically related channels.

5. A sound enchancement system as defined in claim **4** wherein,

said means for transmitting electrical signals representative of said sound along with its reverberations from said secondary to said primary chamber further includes in said secondary chamber, pickup means located near walls other than from where said sound wave front is originally introduced therein.

6. A sound enhancement system as defined in claim **5** wherein,

said means for transmitting electrical signals representative of said sound along with its reverberations from said secondary to said primary chamber further includes in said primary chamber reproducing means located near walls other than from where said sound wave front originates.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,614,320 Dated October 19, 1971

Inventor(s) John E. Volkmann

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 1, line 10, following "hall" insert -- or --; line 23, delete "boux" and insert -- Roux --. Column 2, line 17, delete "28" and insert -- 18 --; line 29, delete "illustration" and insert -- illusion --; line 62, delete "20" and insert -- 10 --; line 71, that portion reading "time to delay" should read -- time delay --. Column 3, line 8, delete "though" and insert -- thought --; line 26, that portion reading "in FIGURE" should read -- in the FIGURE --; line 39, delete "illustration" and insert -- illusion --. Column 4, line 34, delete "means" and insert -- mean --.

Signed and sealed this 11th day of April 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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