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Dahlquist

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[54] **MULTIPLE DRIVER DYNAMIC LOUD SPEAKER**

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[21] Appl. No.: **469,767**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 310,535, Nov. 29, 1972, Pat. No. 3,824,343.

[52] **U.S. Cl.** ..... **179/1 E;** 181/145

[51] **Int. Cl.²** **H04R 1/02**

[58] **Field of Search** ..... 179/1 E, 1 D; 181/144, 181/145, 148

[56] **References Cited**

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[57] **ABSTRACT**

The present invention is directed to an improvement in dynamic loud speakers and is characterized by the sonic frequencies of the midrange and treble bands being generated by wide dispersion dynamic transducers which are mounted on or acoustically associated with specially designed baffle members, which baffle members are surrounded by free space in an acoustically transparent frame. A crossover network of the gradual attenuation type divides the frequencies to be reproduced by the various transducers, the size of the baffles being selected so as to cooperate with the attenuation effects of the crossover network in a synergistic manner, markedly to increase the attenuation effects of the crossover member. The baffles are sufficiently small to avoid diffraction effects and yet sufficiently large to increase the air coupling and, hence, the efficiency of the transducers associated therewith toward the lower limits of frequency range desired to be reproduced by that transducer.

7 Claims, 5 Drawing Figures

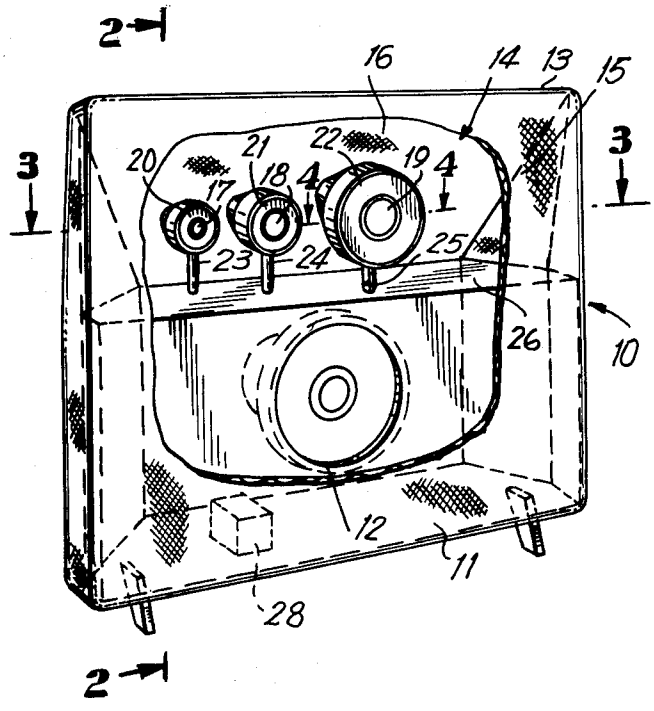


FIG. 1

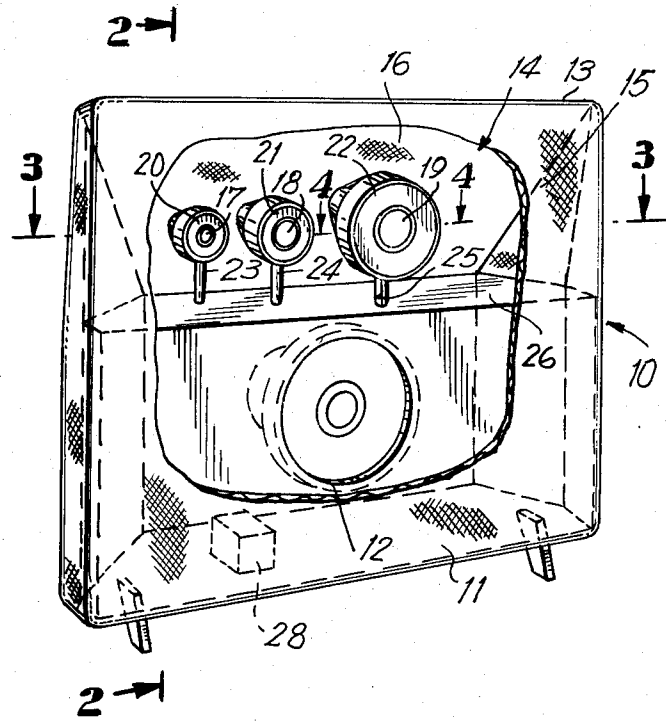


FIG. 2

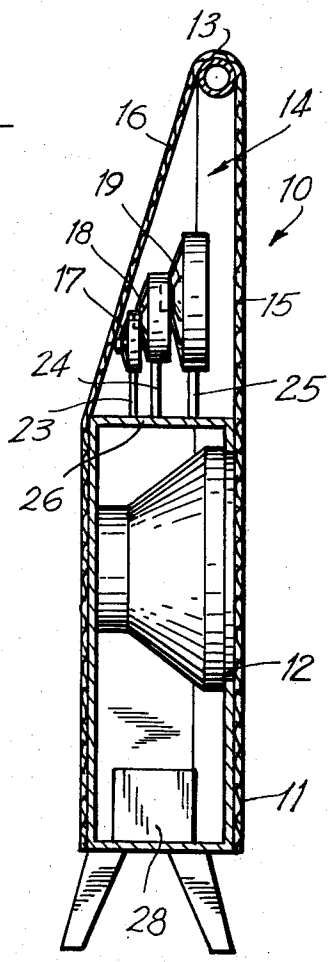


FIG. 4

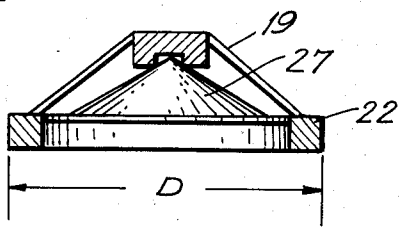


FIG. 3

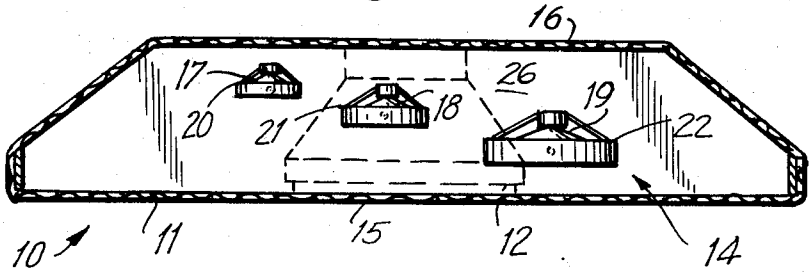
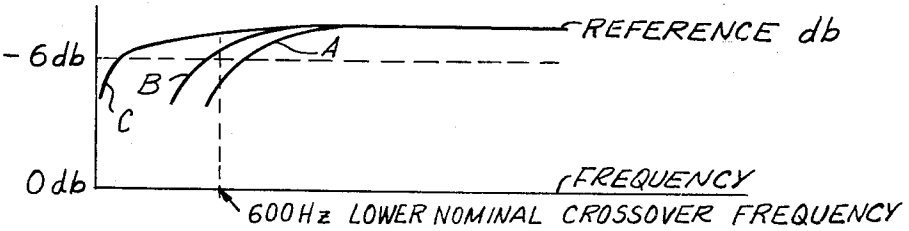


FIG. 5



MULTIPLE DRIVER DYNAMIC LOUD SPEAKER

This application is a continuation-in-part of my application Ser. No. 310,535, filed Nov. 29, 1972, now U.S. Pat. No. 3,824,343.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is in the field of a high fidelity sound reproducing apparatus and relates particularly to a high accuracy loud speaker assembly of the multiple driver, wide dispersion dynamic type.

2. The Prior Art

In my above referred to copending application (now U.S. Pat. No. 3,824,343), there is illustrated an improved high accuracy loud speaker system employing, for the reproduction of midrange and treble frequencies, wide dispersion transducers, i.e. cone or dome type speakers (other than horn type speakers) wherein the diaphragms are directly coupled to the air load. As more fully set forth in the noted application, the substantial distortions resulting from the midrange and treble reproducers being mounted on a baffle defining a wall of the enclosure are obviated by the free space mounting of the transducers. The advantages inhering in an apparatus in accordance with the aforementioned application are so fully set forth therein that further discussion need not be undertaken.

As is well known, wide dispersion dynamic transducers tend to provide optimal distortion-free performance within a limited range of frequencies, sound reproduced below the optimal range embodying progressively increasing percentages of distortion. For example, a dome tweeter which may reproduce the range of 800 to 5000 Hz with distortion products of less than 0.3 percent may introduce distortion products of 5 percent or more at 400 or 500 Hz. Where a transducer of the noted design is utilized in a conventional loud speaker configuration, avoidance of the transducer operating in its high distortion range is dependent upon the use of a crossover network which sharply attenuates the frequencies just above the range at which distortion increases significantly. However, a problem arises in that crossover networks having steep attenuation curves in the range of 10 decibels (db) per octave and over are not only extremely expensive but introduce, in part as a result of the type of inductances required, severe forms of electrical distortion in the audio signal, including time delay distortion, ringing and phase shift. Additionally, the discontinuity effects resulting from sounds of adjacent frequency ranges being abruptly separated and reproduced by spaced transducers detract from the realistic imaging desired in the reproduction of sound.

SUMMARY

The present invention is directed to the provision of a further improved loud speaker assembly.

In common with the apparatus of my copending application, the instant speaker utilizes a frame having an acoustically transparent front face and preferably a partially or completely acoustically transparent rear face, the frame including therein a bass reproducer means, such as an enclosure with an essentially conventional woofer for reproducing the frequencies up to about 400 to 600 Hz. Within the frame and externally of the woofer enclosure, there are provided a plurality of wide dispersion dynamic transducers, each of which is mounted on or acoustically coupled to a specially sized baffle, the baffles, in turn, being free space mounted within the frame and externally of the enclosure. The size of the baffles is calculated to increase the coupling and, hence, the efficiency of its associated transducer toward the lower end of the frequency range desired to be reproduced by that transducer, and rapidly to attenuate the propagation of frequencies below the desired frequency.

The attenuating effects of the baffles enables the frequency divider network to be of the less expensive and lower distortion gradual slope type, e.g. 6 db. per octave attenuation range, since the combined attenuating characteristics of the network and special baffle speaker may be in the order of 10 to 12 or more db. per octave. In other words, although the gradual attenuation crossover will admit to a given transducer partially attenuated signals below the range desirably produced by that transducer the sound actually propagated by the transducer below the noted range will be significantly attenuated as compared to the propagation effects of the same transducer conventionally mounted. As a result, there is achieved a combined attenuation effect due to the operation of the crossover and the special baffle which minimizes the propagation of sounds having significant distortion products.

It will thus be seen that the baffle acts in a cooperative manner with the crossover network, the size of the baffle being selected so as to assure good coupling for frequencies toward the lower end of the band pass range desired to be reproduced, and rapid attenuation of signals below the range, the baffles at all times being sufficiently small to preclude the generation of the undesirable defraction and time delay distortion effects enumerated in my copending application.

It is accordingly an object of the invention to provide a high accuracy, multiple driver dynamic loud speaker system.

A further object of the invention is the provision of a loud speaker system of the type described wherein the transducers reproducing the midrange and treble frequencies are acoustically associated with free space mounted baffles, the frequencies propagated by the individual transducers toward the lower end of their range being affected by the attenuation characteristics of the crossover network as augmented by the attenuation characteristics of the baffles with which the speakers are associated.

Still a further object of the invention is the provision of a speaker of the type described wherein the efficiency of the individual transducers in the midrange and treble bands is increased toward the lower end of the range desired to be reproduced attenuated sharply below said range.

Still a further object of the invention is the provision of a speaker of the type described wherein a gradual attenuation crossover network in the order of about 6 db. per octave may be employed, a sharp actual attenuation being achieved through the utilization of appropriately sized free space surrounded baffles supporting the transducers.

Still a further object of the invention is the provision of a speaker assembly of the type described wherein the midrange and treble speakers are acoustically associated with free space surrounded baffles, the effective baffle size being not greater than about one half of the length of the lowest wave length sound intended to be reproduced by that transducer.

To attain these objects and such further objects as may appear herein or be hereinafter pointed out, reference is made to the accompanying drawings, forming a part hereof, in which:

FIG. 1 is a perspective view of a loud speaker in accordance with the invention, parts of the grille material being deleted to illustrate details of construction;

FIG. 2 is a magnified section taken on the line 2—2 of FIG. 1;

FIG. 3 is a horizontal section taken on the line 3—3 of FIG. 1;

FIG. 4 is a magnified section taken on the line 4—4 of FIG. 1;

FIG. 5 is a graph depicting the theoretical frequency propagation effects of baffling of various types on a transducer operating at its lower band pass range.

In order more fully to appreciate the invention, it is considered helpful to include the following definitions:

The terms "transducer" or "direct radiating dynamic transducer" as used within the context of the instant application are intended to refer to diaphragm, cone or dome type permanent magnet speakers, as distinguished from electrostatic speakers or horn loaded speakers.

The term "nominal crossover frequency" is defined as that frequency whereat the audio signals fed to a transducer are attenuated by 3 db.

The term "gradual attenuation crossover" as utilized herein is intended to refer to a crossover network whose electrical characteristics are such as to attenuate at the upper and lower ends of the band pass at a gradual rate of the order of about 6 db per octave, in contrast to crossovers which attenuate rapidly, in the order of 10 or 12 db per octave.

"Coherent sound" refers to an audible signal containing complex information bits, wherein the information bits falling upon the area of the listener arrive in the same temporal relation as the electrical energy imputs to the loud speaker assembly, i.e. are largely free of phase shift and time delay distortion products.

"Time delay distortion" in a loud speaker refers to the distortion of a complex, (i.e. non-sinusoidal) wave form resulting from lack of synchronism among the energy outputs of the various drivers in a frequency divided speaker system. While the total energy output in a time delay distorted signal may be identical with that of an undistorted signal, the wave forms generated in the distorted signal will differ from those of the original signal. While some time delay distortion inheres in the energy output of even a single, unbaffled transducer, such distortion products are relatively small at the center of the band covered by the speaker but increase toward the upper and lower limits of the band.

The term "free space" or "free space mounting" as relating to a transducer or a baffle supporting a transducer refers to the characteristic that the baffle or transducer is supported within the acoustically transparent component of the loud speaker in such manner that the baffle or transducer is completely or substantially completely surrounded by free air space, as opposed to conventional techniques wherein the transducer is secured to a baffle comprising the front face of the speaker enclosure.

The term "effective baffle size" is intended to relate to the size of a baffle from an acoustical standpoint rather than purely to the physical dimension of the baffle supporting the transducer. For instance, if a first transducer is mounted on a baffle which is free space surrounded but disposed closely adjacent a second free space mounted baffle, the two baffles may act synergistically and, thus, the effective baffle size may be equivalent, from the acoustical standpoint, of a single baffle of the combined size of the two adjacent baffles.

In my above mentioned copending application, there is disclosed a sound reproducing apparatus wherein frequencies above the bass frequencies, e.g. those above about 400 to 600 Hz are reproduced by free space mounted wide range transducers. The application represents a substantial advance in the acoustical art in its discovery that lack of coherence in a sound source results from the mounting of transducers on an enlarged baffle since the edges of the baffle function as secondary radiating sources. The secondary sources, which are out of timed relation with the main propagated sound, result in the introduction of time delay distortion and various other distortion effects, as more fully explained in the noted application.

The prior application is thus directed to a solution of the diffraction effect problem by employing free space mounting of the transducers reproducing frequencies above the bass frequency range.

In accordance with the present invention, constituting a further advancement of the principles of my copending case, I have discovered that by mounting the transducers reproducing the frequencies above the bass frequencies upon baffles within a particular size range, I am able to achieve a coherent sound with higher efficiency, and to employ a lesser number of transducers reproducing the bands of the audio spectrum and, perhaps most importantly, to utilize a gradual attenuation electrical crossover network.

Referring now to the drawings, there is shown in FIG. 1 a loud speaker apparatus **10** including a bass reproducer enclosure **11** within which is mounted a conventional woofer assembly **12.** The bass reproducer may be of the bass reflex, acoustical suspension, transmission line or other type, and functions in known manner to reproduce those frequencies of the audio spectrul below about 600 Hz.

The enclosure **11** is mounted within a frame **13,** which is acoustically transparent in the upper area **14** above the bass reproducer **11.** The frame **13** includes an acoustically transparent front face or grille **15,** and a rear face **16** which is fully or partially acoustically transparent. Desirably, the portions within the upper area **14** rearwardly of the transducers **17, 18, 19** are free of acoustically reflective surfaces.

The transducers **17, 18, 19** are mounted on forwardly facing baffles **20, 21, 22,** respectively, surrounding the transducers or at least the forwardly directed diaphragm components thereof. The baffles and transducers are themselves free space mounted within the upper area **14,** as by mounting struts **23, 24, 25,** made fast to the upper surface **26** of the bass reproducer enclosure **11.**

The size or effective dimension of the baffles **20, 21, 22** forms a critical feature of the invention, the dimension referred to being that dimension of the baffle which is essentially perpendicular to the radiating axis of the diaphragms of the transducers. While the baffles **20, 21, 22** are illustrated as circular, it will be appreciated that rectangular or other shapes of baffles may be employed, in which case the critical dimension is the largest dimension of the rectangle, etc.

Thus, referring to FIG. 4, **27** represents the diaphragm of the transducer **19.** The effective dimension

D of the baffle **22** should be less than one half of the length of the sound wave in air at the lower nominal crossover frequency fed to the transducer **19**. More specifically, assuming a crossover network **28** having a 6 db per octave rate of attenuation, and further assuming that the crossover impresses on transducer **19** frequencies from 300 Hz to 1500 Hz with signals of 600 Hz attenuated by 3 db, it will be seen that the dimension D for the particular transducer **19** should not exceed about one half of the wave length of a sound wave at 600 Hz. Since a sound wave at 600 Hz has a length of approximately 1.9 feet, it will be appreciated that the baffle size should not exceed about one foot.

Preferably, the baffle size should be between about one quarter to one half of the wave length at the lower nominal crossover frequency or between about six inches to one foot for the above described transducer.

Referring to FIG. **5**, there is disclosed a graph depicting the response curves of a given transducer at the lower band pass range thereof, illustrating the effects of baffling.

Curve A represents the sound propagation effects of an unbaffled transducer capable of reproducing, with acceptably low distortion, frequencies as low as 500 Hz.

Curve B represents the propagation properties of a transducer baffled in accordance with the present invention.

Curve C represents the same transducer mounted to a baffle of the type conventionally employed in speaker systems heretofore known where the baffle is essentially co-extensive in size with the front of the enclosure.

It will be readily recognized from Curve A that the sound propagated by the unbaffled speaker begins to roll off at its lower end relatively sharply, whereby the frequencies which might effectively be reproduced without significant distortion are rapidly attenuated.

From Curve C, on the other hand, it will be seen that the transducer mounted on a large baffle is propagating, at substantial sound levels, frequencies below the nominal crossover frequency of 600 Hz and the distortion introduction frequency of 500 Hz.

The B curve, representing the speaker baffled in accordance with the invention, discloses that the transducer is propagating useful amounts of sound at the nominal crossover frequency and that the sound propagation rolls off rapidly below such frequency.

It will thus be apparent that by baffling the speakers as represented by Curve B, a substantial quantity of the sound propagated below the lower useful range by the transducer, as represented in conventionally baffled Curve C, has been eliminated. Additionally, the effects of rapid attenuation of useful sounds, as evidenced by Curve A, has been overcome.

By baffling in the manner of the present invention, full use is made of the low band pass capabilities of the transducer, resulting in an increased efficiency.

The size of the baffles, e.g. from about one half to one quarter of the wave length of sound at the nominal crossover frequency has been determined to be sufficiently small to preclude the generation of undesired diffraction effects, etc. fully discussed in my copending application.

Through the use of a baffling system as hereinabove described, I am enabled to employ a gradual attenuation crossover network, attenuation being effected in the order of about 6 db per octave, the remaining attenuation needed to avoid the propagation of high distortion products at the lower end of the band pass range being provided by the baffle.

I am, in short, in accordance with the present invention, enabled to provide a loud speaker capable of producing coherent sound wherein the full low distortion band pass reproducing capabilities of the transducers are utilized without the requirement for employing a rapid attenuation crossover network, with its inherent high expense and distortion producing propensities. Free space mounted baffles are, in effect, utilized to form an element of a crossover network, the size of the baffles being selected as aforesaid to reinforce those frequencies which it is desired to reinforce and rapidly attenuate those lower frequencies embodying substantial distortion products.

Having thus described the invention and illustrated its use, what is claimed as new and desired to be secured by Letters Patent is:

1. A multi-driver dynamic loud speaker assembly comprising a frame including an acoustically transparent front face, an enclosure within said frame, a base radiator transducer mounted within said enclosure, at least two additional direct radiator dynamic transducers positioned within said frame, each said dynamic transducer having acoustically associated therewith a baffle member supported within said frame externally of said enclosure, said baffle members being substantially completely surrounded by free space, the effective dimension of each said baffle member measured in a direction normal to the radiating axis of its acoustically associated transducer being not greater than about one half of the wave length of a sound wave at the frequency of the lower nominal crossover frequency of the signal fed to the transducer acoustically associated with said baffle, the area within said frame rearwardly of said at least two transducers being substantially free of sound reflective surfaces facing the front of said loud speaker assembly, and a frequency divider network means for dividing the electrical signals fed to said loud speaker assembly into at least three discrete frequency bands, and applying an appropriate said band to each said transducer.

2. A loud speaker assembly in accordance with claim **1** wherein said frequency divider network is of the gradual attenuation type, the attenuation rate being about 6 db per octave.

3. A loud speaker assembly in accordance with claim **2** wherein the effective dimension of said baffles is in the range of from about one half to one quarter of the wave length of a sound wave at the frequency of the lower nominal crossover frequency of the signal fed to the transducer associated with the respective baffle.

4. A loudspeaker in accordance with claim **2** wherein the frequencies reproduced by said direct radiator dynamic transducers below said lower nominal crossover frequency are attenuated at the rate of about 6 or more db per octave as a result of the combined effects of said baffles and crossover network.

5. A loudspeaker assembly in accordance with claim **1** wherein the effective dimension of said baffles is in the range of from about one half to one quarter of the wave length of a sound wave at the frequency of the lower nominal crossover frequency of the signal fed to the transducer associated with the respective baffle.

6. A multi-driver dynamic loud speaker system comprising frequency divider network means for dividing electrical signals fed to said system into at least three

discrete frequency bands, a frame including an acoustically transparent front face, an enclosure within said frame, a bass radiator transducer mounted within said enclosure, at least two additional direct radiator dynamic transducers positioned within said frame, each of said at least two transducers having acoustically associated therewith a baffle member, said baffle members being essentially planar and surrounding the radiating diaphragms of said transducers, the plane of said baffles being aligned substantially perpendicular to the radiating axis of the transducer with which it is acoustically associated, the longest effective dimension of each said baffle member, measured in said plane, being not less than about one quarter and not more than about one half the wave length of a sound wave at the frequency of the lower nominal crossover frequency fed to that respective transducer, said baffles being supported within said frame externally of said enclosure and being substantially completely surrounded by free space.

7. A loud speaker assembly in accordance with claim 6 wherein said frequency divided network means is of the gradual attenuation type, the attenuation rate being about 6 db per octave.

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