United States Patent

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[54] **OMNIDIRECTIONAL LOUDSPEAKER SYSTEM**
3 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** 181/31
[51] **Int. Cl.** **G10k 13/00,** H04r 1/28
[50] **Field of Search** 181/31

[56] **References Cited**

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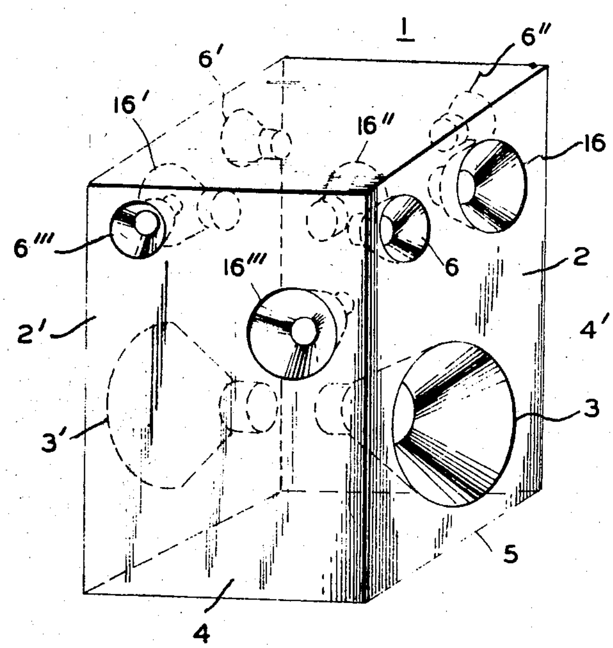
ABSTRACT: The present disclosure relates to a quadrant-type loudspeaker particularly adapted for the audiofrequency band, having a pair of opposing low-band speakers mounted at different distances from the floor or other resting surface for the loudspeaker system and a plurality of asymmetrically mounted high-, and in some cases, mid-frequency speakers.



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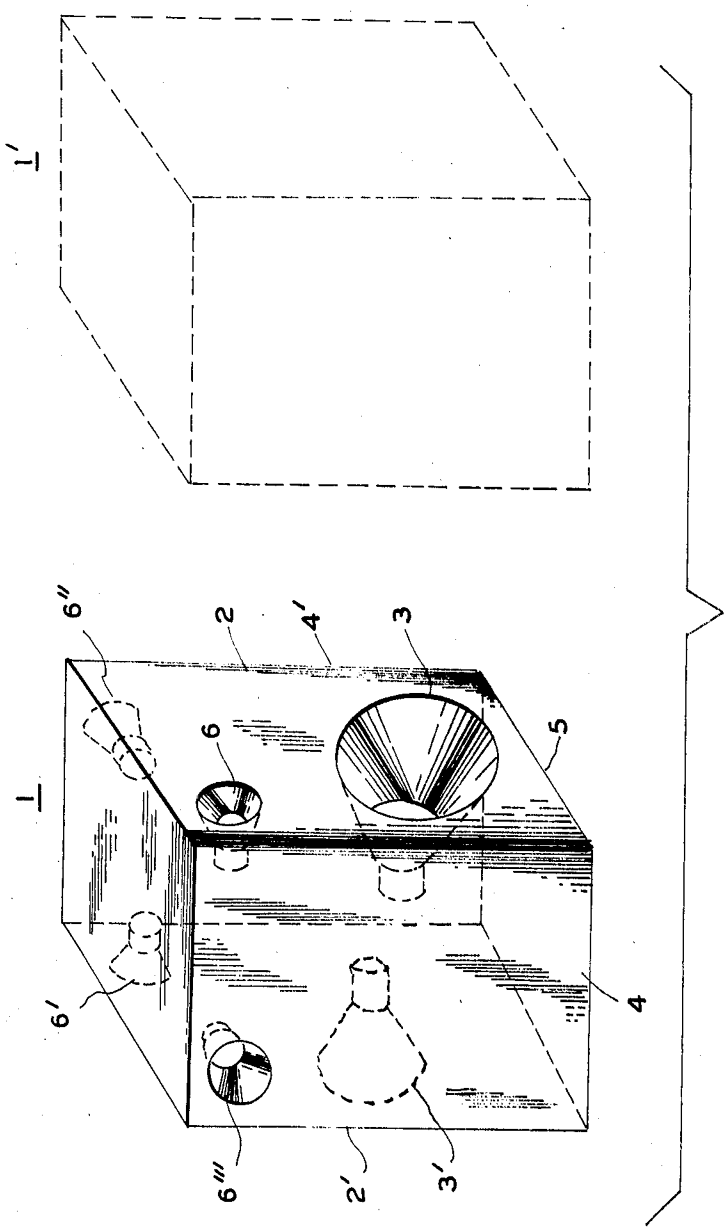

FIG.1

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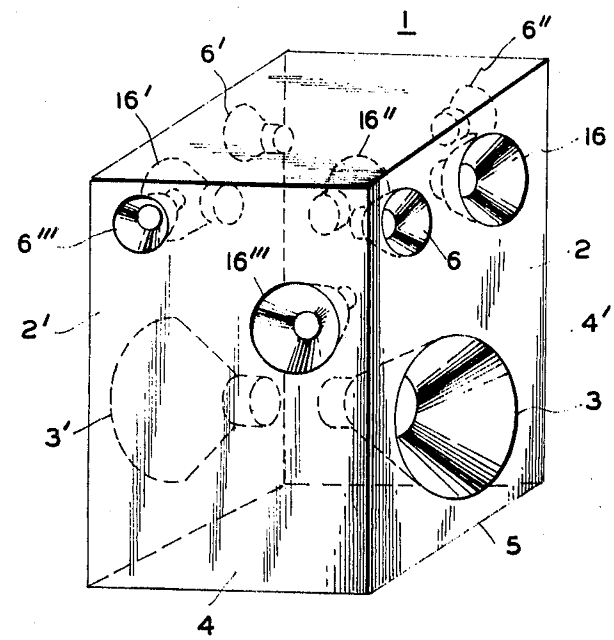

FIG.3

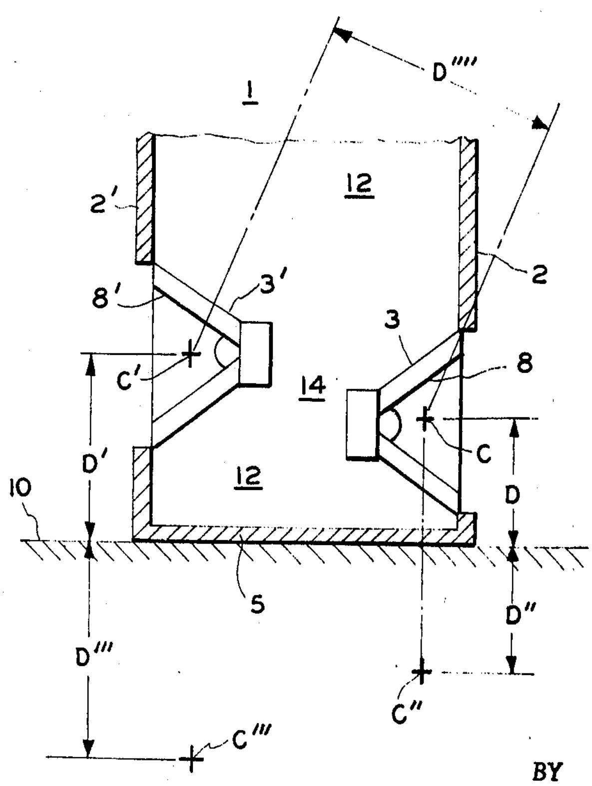

FIG. 2

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OMNIDIRECTIONAL LOUDSPEAKER SYSTEM

The present invention relates to loudspeaker systems, being more particularly directed to the so-called quadrant type of loudspeaker systems in which speakers or speaker assemblies are positioned in different quadrants and wherein the overall sound radiation pattern in the bands of interest is adjusted to be substantially uniform in all directions, or at least to provide what, to the listener, appears to be substantially uniform sound quality and amplitude in such omnidirections.

Attempts have been made throughout the years to provide so-called quadrant loudspeaker systems that will radiate substantially uniformly in all directions of azimuth about the speaker system. As an example, speakers have been located in the base of a housing, directed upward, sometimes with reflecting surfaces interposed in the upward direction of transmission of the sound from the loudspeaker, in order, by reflection, to cause distribution in all directions of azimuth of the sound emanating therefrom. Such reflecting structures in these assemblies not only disadvantageously acoustically load the loudspeaker system itself, but cause great irregularities in the frequency response of the loudspeaker assembly in the process of attempting to reflect sound substantially uniformly in all directions. Similar remarks apply to attempts to provide such acoustic omnidirectional radiation by downwardly directed loudspeaker systems using, for example, the floor as the reflector for causing the sound to be distributed in all directions.

Attempts have also been made to achieve these results by disposing a plurality of loudspeakers on a cylindrical or spherical surface contour in an attempt to achieve substantially omnidirectional uniform-response acoustic radiation. Since these loudspeaker systems were commonly constructed all employing the same type of driver mechanisms, the overall frequency response was restricted to that obtainable from each of the loudspeakers. In loudspeaker systems designed to operate when placed near a wall, it has been common engineering practice, when the ultimate quality of reproduction was desired, to divide the frequency range to be reproduced, into several frequency regions. Such loudspeaker drivers operating in these frequency regions have been commonly known as woofer, i.e. the low-frequency loudspeaker; middler, the mid-frequency loudspeaker; and tweeter, the high frequency loudspeaker.

The above-mentioned problems multiply themselves when attempts are made to operate a plurality of such speaker systems as, for example, in stereophonic applications where it is desirable that the listener be able to take a position at a plurality of locations with respect to a pair of such speaker systems and to obtain the illusion or impression of stereophonic sound reproduction.

Free-standing quadrant speakers and the like, moreover, differ in their characteristics from ordinary speakers contained in housings and the like that are adapted to be set next to a wall or put into a bookcase or located on a shelf or proximal to other surfaces in a room. While such speakers have heretofore been used in spaced pairs for the reproduction of stereophonic sound, they inherently carry with them the limitation that the listener must be within a relatively restricted angle in front of the speakers.

It is accordingly an object of the present invention to provide new and improved loudspeaker assemblies particularly, though not exclusively, adapted for use in stereophonic reproduction and that shall not be subject to the above-described limitations; but that, to the contrary, unlike prior art quadrant speakers, do not introduce a deleterious response in the frequency response of the loudspeaker systems and are not restricted to a limited angle on one side only of the loudspeaker system for stereophonic listening reception.

A further object is to provide a new and improved loudspeaker system of more general utility as well.

Other and further objects will be described hereinafter and are more particularly delineated in the appended claims. In summary, however, from one point of view, the invention contemplates a substantially omnidirectional quadrant loudspeaker system for the audiofrequency band comprising a four-sided housing, mounting substantially centrally in each of a pair of opposing sides thereof substantially similar low audiofrequency loudspeakers, one mounted with its center approximately a quarter of the midwavelength of the low audiofrequency band above the bottom of the housing and the other mounted substantially three-eighths of said wavelength above the said bottom, and a plurality of high audiofrequency loudspeakers at least one asymmetrically mounted off center in a corner of each side of the housing near the top thereof. Preferred constructional details are hereinafter set forth.

The invention will now be described with reference to the accompanying drawings, FIG. 1 of which is an isometric view showing a speaker assembly constructed in accordance with the preferred embodiment of the invention;

FIG. 2 is a cross section of the lower portion of FIG. 1; and

FIG. 3 is a similar view of a modification.

Referring to the drawings, a four-sided housing is illustrated at **1**, illustrated for purposes of explanation in the preferred, though not essential, form of a prismatic housing having pairs of opposing sides **2**, **2′** and **4** and **4′**. In accordance with the present invention, for reasons later explained, a low audiofrequency loudspeaker in the range up to about 1 kHz. is mounted as shown at **3** in the side **2**, very close to the bottom surface **5** of the housing **1**, which may rest, for example, upon the floor or other surface. For the purposes hereinafter discussed, the center of the speaker **3** is preferably located above said bottom surface approximately one-quarter of the mean wavelength of the low-frequency portion of the audiofrequency band; say one-quarter of about 500 Hz. (approximately 6¼ inches). In the opposing side **2′**, a substantially identical low-frequency speaker **3′** is similarly mounted, except that, in accordance with the invention, it is located somewhat higher from the bottom **5** of the housing **1**, namely, the order of three-eighths of the aforementioned wavelength, or approximately 9¼ inches. High frequency loudspeakers (approximately in the range of 5 kHz.) are respectively shown at **6** and **6′**, mounted in the upper left-hand corners of the respective sides **2** and **2′** near the top thereof, asymmetrically off center, for reasons later explained. Similarly positioned asymmetrical similar high-frequency loudspeakers are shown at **6″** and **6‴** located in sides **4′** and **4**, respectively. The system **1** may be used for monophonic, omnidirectional quadrant purposes, or as shown in FIG. 1, for stereophonic purposes together with an identical unit **1′** spaced therefrom as shown in dotted lines.

The high frequency loudspeakers **6**, **6′**, **6″** and **6‴** are in individual small enclosures to prevent low frequency acoustic signals existing within the housing **1** from reaching the diaphragms and thereby causing distortion. These individual enclosures contain damping material to attenuate whatever resonances might exist within these high frequency loudspeakers. All high frequency loudspeakers are connected in series-parallel arrangement to the high frequency output terminals of the frequency-dividing crossover network (not shown) which receives electrical signals from the amplifier. The high frequency loudspeakers **3** and **3′** share the common volume of the housing **1** and are connected in parallel to the high frequency output terminals of the frequency-dividing crossover network connected to the amplifier (not shown). The housing **1** is filled with damping material for reasons hereinafter explained.

In FIG. 2, a cross-sectional diagram of the arrangement of FIG. 1 is shown with sides **2** and **2′** being illustrated in cross section and containing loudspeakers **3** and **3′**. These loudspeakers have diaphragms **8** and **8′** which create the acoustical waves emanating from loudspeakers **3** and **3′**, with the effective centers of acoustic radiation being at points C and c′, different distances D and D′ above the bottom surface **10**, as later discussed.

If only loudspeaker 3 were part of this radiating system and were somewhere in free space, this loudspeaker would effectively act as a point source of acoustic radiation up to those frequencies where the effective diameter of the radiating cone 8 thereof is of the order of one-fourth wavelength or less of the sound in air. Since, however, the housing 1 is resting on a floor or other surface 10, reflections of the acoustic waves emanating from C will occur. If the floor 10 were perfectly stiff and therefore reflective of all incident acoustic energy, an image source C'' would effectively exist below the floor 10, this image source C'' being located directly below source C and at a distance D'' below the floor, with the distance D'' being equal to the distance D of source C above the floor 10.

With a perfectly reflecting floor 10, the original source C and the image source C' would operate in phase to create, at low frequencies, a doubling of acoustic sound pressure over that created by source C alone. At some higher frequency, the delay in arrival of the sound from sources C and C'' at the listener's ear, obviously located outside the enclosure 1 and above the floor 10, will add up vectorially and, at some particular frequencies, the effective output of sources C and C'' will cancel one another. For a listener located directly above the center C and sufficiently far away, this cancellation will take place at odd multiples of the frequency where the sum of distances D and D'' is equal to one-half wavelength of the sound in the air. For listeners located off to the side of the loudspeaker, this cancellation will occur at higher frequencies because the delay of the sound arriving from sources C and C'' will have been caused by a lesser difference in distance between source C and the listener's ear and source C'' and the listener's ear.

Since a floor is usually not perfectly reflecting, however, the image source C'' will not be equal in strength, but rather attenuated from the strength of source C and may also be shifted in phase since attenuation near a reflecting surface will also cause some delay. Consequently, the sharp nulls in output at certain frequencies described above will evidence themselves as attenuations in output rather than complete cancellation. This type of cancellation and attenuation at certain frequencies is the primary cause of the irregular frequency response of omnidirectional loudspeaker systems using a single low-frequency driver, either radiating upward or radiating downward in the enclosure.

The same description of cancellation and reinforcement described for source C with image C'' holds, also, for source C' and its image C'''. Since, however, source C' is located a different distance D' above the floor 10, cancellation and reinforcement of sound will occur at different groups of frequencies, these frequencies being lower than for source C because the distance D' is larger than the distance D.

The acoustic waves emanating from source C and from source C' will also arrive at the listener's ear at different times, since they are required to travel around the outside of the enclosure 1 and may therefore undergo a different amount of delay depending upon the relative distance from the two sources C and C', as measured from the listener's ear. The same analysis also holds for the source pairs C and C''', C' and C'' and C'' and C'''.

If the distance D' were selected to be equal to distance D and if the loudspeakers were set apart by a distance D'''' equal again to distance D, all the sources and their images, namely, C, C'', C' and C''', would be located on the corners of a square and cancellation due to all equidistant pairs of sources would occur at the same frequency with the exception of the source pairs located at opposite corners of this square. It may be readily appreciated that this would result in a most irregular frequency response and, indeed, this is the common fault of all prior loudspeaker systems involving identical drivers located substantially equidistant from each other in the same enclosure. In the present invention, on the contrary, the relative distances D, D' and D'''' have been chosen so that lowest possible cancellation frequencies are distributed in frequency and so that the lower effective multiples of this frequency grouping do not coincide within the operating frequency range of the loudspeaker drivers used in this loudspeaker system. At any critical frequency, consequently, only one pair of effective sources and images can contribute to substantial cancellation of sound, while the others still contribute signal. By this means, the most uniform sound pressure vs. frequency response at any point in the surroundings of this loudspeaker is provided.

Since loudspeakers 3 and 3' share a common volume within enclosure 1, the deleterious effects of direct coupling between loudspeakers 3 and 3' must also be counteracted. It is customary in loudspeaker design to provide within the enclosure a certain amount of sound-absorbing or damping material which minimizes undesired reflections of sound from the interior walls of the enclosure reacting back on the radiating diaphragm of a loudspeaker. In the case of a multiple loudspeaker system, the acoustic waves emanating from one loudspeaker must be prevented from causing undesirable effects at any other loudspeaker. In the present invention, it was found necessary to provide for higher absorption of sound within the enclosure 1 than customary for either single loudspeaker systems or loudspeaker systems containing multiple drivers but facing in the same direction. This higher absorbing material must not only be placed anywhere within the enclosure 1, such as indicated by 12, FIG. 2, but must be particularly concentrated in the region between the two loudspeakers, as indicated at 14.

At very low frequencies, the loudspeakers with their effective sources C and C' operate in phase, and the sound from one loudspeaker arrives at the other essentially in phase, and is essentially in phase within the whole enclosure 1. Enclosure 1 thus effectively acts as an acoustic capacitor providing an acoustic stiffness. At higher frequencies, however, the sound emanating from one loudspeaker diaphragm arrives at the other with some delay and at still different delays to all the interior surfaces of the enclosure 1. If no damping material were provided, these delays would be equal to the distance between the loudspeakers and their now interior images, divided by the speed of sound in air. Normally, in air, sound waves cause the air to expand and to compress, following the adiabatic curves. If, however, damping material is present, this damping material maintains the instantaneous temperature of the air at the same point because of its large thermal capacity compared to air, and the instantaneous sound waves and pressure excursions follow the equal temperature or isothermal curves. This, in effect, changes the speed of sound to a lower value approximately equal to one divided by the fourth root of two, or 1.22. Consequently, referring back to air without sound-absorbing material, the effective distance between radiating centers C and C' has been lengthened by the fourth root of two, and interior cancellations and reinforcements, as compared to outside distances, have been shifted into a new frequency range by that ratio, further improving the regularity of frequency response. Since the sound-absorbing material between loudspeakers 3 and 3' not only effectively increases the distance but also attenuates sound, coupling, particularly at the middle and higher portions of the frequency range covered by loudspeakers 3 and 3', has been minimized. This minimized coupling also improves frequency response of such a loudspeaker system.

FIG. 3 shows a modification of the loudspeaker system of FIG. 1, involving three groups of loudspeakers. Loudspeakers 3 and 3' are intended to cover the low frequency region typically encompassing the frequency range between 40 Hz. and 1,000 Hz. or less. Midfrequency loudspeakers marked 16, 16', 16'', and 16''' cover the frequency region between approximately 1,000 Hz or lower, up to 4,000 or 5,000 Hz. High frequency loudspeakers 6, 6', 6'', and 6''' cover the frequency region higher than that covered by the midfrequency loudspeakers.

Since so-called three-way loudspeaker systems, containing loudspeaker drivers each operating in three different frequency ranges, typically cover a wider range of acoustic frequencies than covered by one-way or two-way speaker systems, it is customary that the low-frequency loudspeakers **3** and **3'** in FIG. **3** be of the same size or larger than those of FIG. **1**. The upper frequency limit is thus proportionately lower, and the distances of mounting within enclosure **1** are proportionately larger.

The high-frequency loudspeakers are of the same nature as those of FIG. **1** and are again mounted in a similar arrangement on the four surfaces of the enclosure.

Midfrequency loudspeakers **16** through **16'''** each have their own acoustic enclosures mounted in the back of the diaphragms to prevent direct undesired coupling to each other and coupling to and from the low frequency loudspeakers **3** and **3'**. In order to avoid undesired coupling between these loudspeakers and their images and, therefore, irregular sound pressure versus frequency response, loudspeakers **16** through **16'''** have been mounted asymmetrically with respect to the vertical axis of panels **2** and **2'**, and **4** and **4'**. In order to have the cancellation frequencies due to reflections from the floor of loudspeakers **16** and **16'''** be as dispersed as those of the low-frequency loudspeakers **3** and **3'**, loudspeakers **16** and **16'''** are mounted at differing elevations with respect to the floor. Since, in the frequency range to be covered by the midfrequency loudspeakers, the dimensions of the enclosure are comparable or larger than a full wavelength at the lowest frequency covered by the midfrequency loudspeakers, it is only necessary that adjacent loudspeaker pairs be mounted at different elevations. Midfrequency loudspeakers **16** and **16'** mounted on surfaces **2** and **2'** are therefore mounted at a higher elevation than midfrequency loudspeakers **16''** and **16'''** in respective surfaces **4'** and **4**. By this means, irregularities in frequency response due to radiation from all loudspeaker systems are minimized.

Electrically, loudspeaker drivers **3** and **3'** are connected in parallel to the low-frequency output of the electrical crossover network connected to the amplifier. Loudspeakers **16**, **16'**, **16''** and **16'''** are connected in a series-parallel arrangement to the midfrequency output of the crossover network, and high frequency loudspeakers **6**, **6'**, **6''** and **6'''** are connected in a series-parallel arrangement to the high frequency terminals of this frequency-dividing crossover network as is well known.

In summary, conventional loudspeaker systems tend to be directional and can have good wide-range frequency response only within a restricted listening area. Often, presence of stereophonic program material is limited when listening to such loudspeaker systems because insufficient sound may reverberate from the sides and the rear of the listening area. Omnidirectional loudspeakers of the prior art are unfortunately omnidirectional only in the very low frequency range; and any baffle systems used to increase the omnidirectionality cause extremely irregular frequency response. The vital high frequency tones, furthermore, regardless of elaborate baffle systems, are perceptible only in a limited listening area. While loudspeaker systems of the reflective type in the prior art can give a satisfactory illusion of presence and depth when listening to stereophonic program material, these loudspeaker systems all employ loudspeaker drivers of identical design and, for good listening quality, require an additional electronic equalizer. This, in turn, substantially increases the required amplifier power for equal sound pressure such that these loudspeaker systems are a complex and expensive approach to achieve good quality listening.

The omnidirectional loudspeaker of the present invention, however, represents a no-compromise design. These loudspeakers can be placed virtually anywhere within the room, giving extraordinarily good wide-range response and stereophonic realism and presence throughout the room. No additional equalizers or special amplifiers, moreover, are required.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. A substantially omniquadrant loudspeaker system for the audiofrequency band that comprises a four-sided housing mounting substantially centrally in each of a pair of opposing sides of the housing substantially similar opposing low-audiofrequency loudspeakers, one mounted with its center about one-quarter the wavelength of the mean of the low audiofrequencies above the bottom of the housing and the other mounted thereabove about three-eighths said mean wavelength, and a plurality of high-audiofrequency loudspeakers, at least one asymmetrically mounted off center in each side of the housing near corners at the top thereof.

2. A loudspeaker system as claimed in claim **1** and in which mid-audiofrequency loudspeakers are provided, mounted near corners of said housing sides opposite said high-audiofrequency loudspeakers.

3. A loudspeaker system as claimed in claim **1** provided with damping material packed directly between the opposing low-audiofrequency loudspeakers.