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[54] **ACOUSTIC SPEAKER SYSTEM**

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[52] **U.S. Cl.** ..... **181/31 B**

[51] **Int. Cl.** **G10k 13/00,** H04r 7/18

[58] **Field of Search** ..... 181/31 B, 31 R

[56] **References Cited**

UNITED STATES PATENTS

2,701,025	2/1955	Kuhl	181/31 B
2,722,990	11/1955	West	181/31 B
2,904,123	9/1959	Nigro	181/31 B
3,627,948	12/1971	Nichols	181/31 B

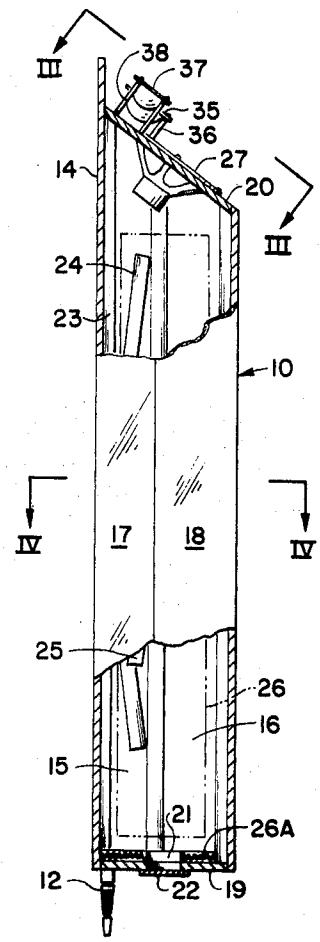
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[57] **ABSTRACT**

An acoustic speaker system is provided having a substantially air-tight speaker enclosure without uninterrupted parallel interior surfaces, said enclosure having a length to width ratio greater than 3 and preferably between 4 and 5. Dampening means are provided to reduce and disperse resonant vibrations of the enclosure. Low frequency, middle frequency and high frequency loudspeakers are rigidly and angularly mounted on an end portion of the enclosure in substantially parallel relation, preferably at an angle between 35° and 55° to an associated compound corner of a listening room. The middle and high frequency speakers are both preferably back enclosed and are positioned exteriorly of the low frequency speaker on stand-off supports, with the middle frequency speaker preferably positioned between the low and high frequency speakers. The speakers are positioned with the enclosure so that they are all capable of forwardly radiating into a closely spaced compound corner preferably between 1½ and 5 feet from the low frequency speaker and the low frequency speaker is capable of backwardly radiating into the enclosure. Cross-over means are also provided for selectively directing the electrical signals according to their frequency to the low frequency, middle frequency and high frequency speakers, respectively.

10 Claims, 6 Drawing Figures



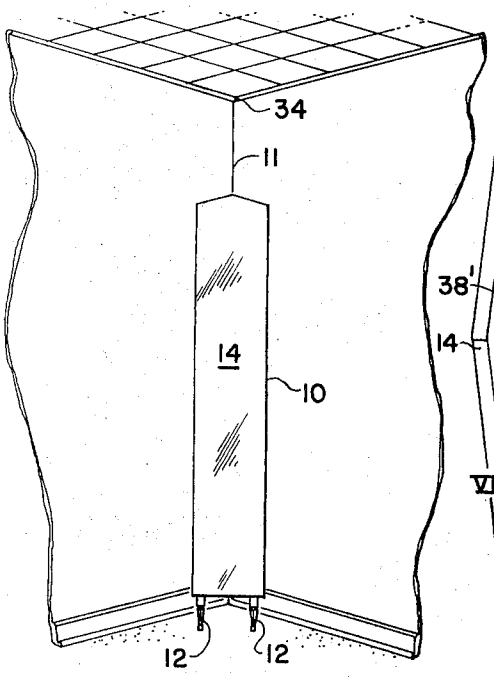


Fig. 1

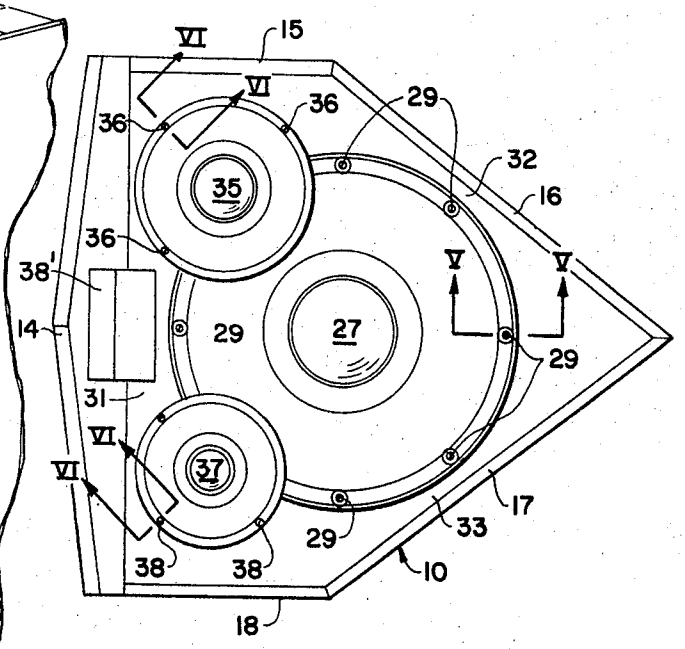


Fig. 3

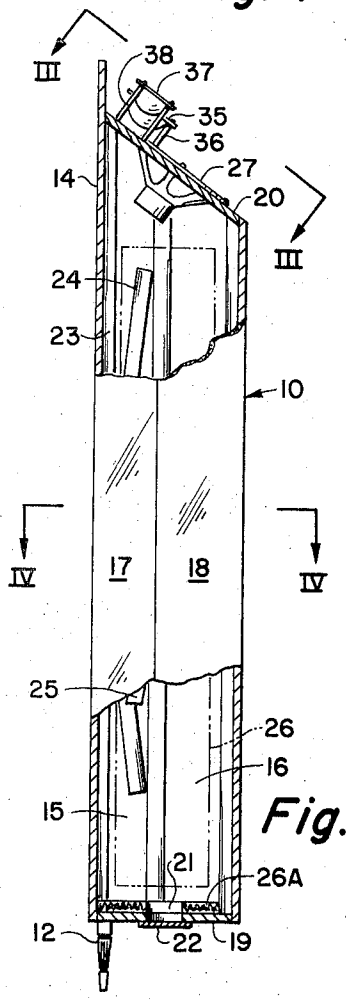


Fig. 2

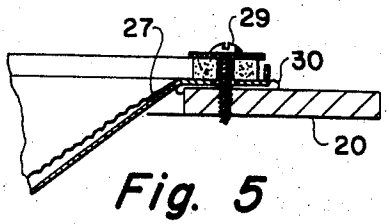


Fig. 5

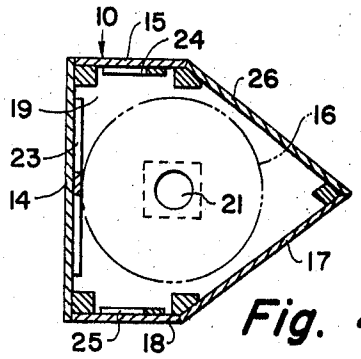


Fig. 4

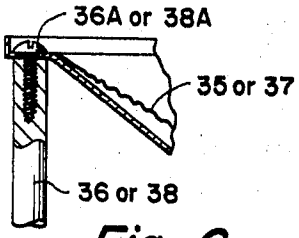


Fig. 6

ACOUSTIC SPEAKER SYSTEM

FIELD OF THE INVENTION

The present invention relates to loudspeaker systems and particularly acoustic coupler systems with high fidelity conical loudspeakers.

BACKGROUND OF THE INVENTION

The principal objective of high fidelity speaker systems is the production of an acoustical image that is as near a facsimile of the "live" performance as is possible. Unfortunately, known speaker systems fall short of the mark in varying degrees. Most speaker systems, exhausting from the front faces of rectangular boxes, radiate the musically critical midrange and treble frequencies through a relatively narrow dispersion angle. Such a compressed, directional sound field is very different from the sound of a "live" performance.

Back-wave enclosures have been provided to better reproduce bass or low frequency sounds. However, such back-wave enclosures exhibit resonant modes of vibration which contaminate the reproduced sound. This contamination is particularly pronounced in typical rectangular enclosures because they have lower fundamental resonant modes of vibration. Also contaminating the sound is the flexure of the incorporated speaker mounting board. So prevalent and accepted have these spurious sounds become, that many listeners confuse them with the true bass sounds, and in their absence, would say the system lacks bass response.

Further, such resonance and flexures reduce rather than increase the efficiency of the sound production. To illustrate, a 10-inch diameter cone speaker will radiate 0.1 watt of acoustic power (i.e., a very loud sound) at 100 Hz, with an excursion amplitude of about 0.060 inch. The diaphragm of such cone speaker moving forward will exert an equal backward force on the speaker mounting. Thus, if the mounting can move by as little as 0.003 inch, one-twentieth of the acoustic power is lost. Similar power losses result from flexure of other parts of the back-wave enclosure as well as standing waves within the enclosure.

Also known in the art has been the use of a three-speaker sound reproduction system. That is, a system with a low frequency, middle frequency, and high frequency speaker array with a cross-over network to selectively feed the low, middle and high frequency electrical signals to the respective speakers. Such a speaker system is indeed typical today in the high fidelity reproduction of sound. Such three-speaker systems do not, however, eliminate the above enumerated problems in using a back-wave enclosure for bass sound reproduction. Moreover, such a system typically experiences unevenness or non-linearity in the response curve at the cross-over frequencies, which affect the quality of the sound reproduction.

More importantly, known high fidelity speaker systems generally do not tailor the sound production to the acoustics of the listening room and to the recorded sound. Specifically, the typical speaker system, which radiates directly into the listening room at the level of the furnishings, has the sound shadowed and absorbed by the room furnishings, e.g., carpets, drapes, and upholstered furniture. To illustrate, the coefficient of absorption for a decorated plaster wall for a 1,000 Hz sound wave is typically 0.05 to 0.07, while the coefficient of absorption for upholstered furniture is typically 0.35 to 0.65 — 7 to 9 times more absorbing than the plaster walls.

Moreover, the recorded sound is not the same as that heard by a listener of a "live" audience. A listener in a good seat in an auditorium typically receives about 20 percent of the sound he perceives directly from the performer(s). About 80 percent of the sound perceived is via a virtually infinite number of reflections from the walls, ceilings and abutments of the auditorium structure. But what is recorded and transferred to discs or tapes is done by microphone(s) strategically placed adjacent or among the performer(s) so as to "better" hear and define the acoustic timbers and blends of the performance. For this reason, the recorded sound contains a substantially greater percentage of directly radiated sound than a listener perceives "live" in the auditorium. Available speaker systems do not usually take this difference into account. The sound production does not therefore approach what would be heard by a listener at the original performance.

The present invention overcomes these difficulties and disadvantages of prior high fidelity speaker systems. First, the invention creates the illusion of widely spaced performers by providing a very broadly radiated monophonic or stereophonic image. Second, it produces bass frequencies more efficiently while reducing and dispersing the resonant frequency modes of a back-wave enclosure. Third, it provides smooth and essentially inperceptible transitions at speaker cross-overs. And fourth, the invention reflects, disperses and intermixes the various frequences to produce and deliver to the listener a sound field akin to that which a listener would hear at a "live" performance. In addition, the invention provides a speaker system which can be unobtrusively positioned in otherwise unusable space in a listening room and which can be decoratively blended into the decor without sacrificing the sound production qualities.

SUMMARY OF THE INVENTION

A high fidelity acoustic speaker system is provided which produces an acoustic image that is very similar to the sound field radiated to the listeners at a "live" performance. The acoustic speaker system constitutes an environmental addendum to the listening room by providing a substantially uniform and enlarged monophonic or stereophonic image throughout the listening room.

The acoustic speaker system comprises a speaker enclosure having a length to width ratio greater than 3 and preferably between 4 and 5. Said enclosure has stiff side panels and first and second end portions which provide a substantially air-tight enclosure when fitted with a bass speaker as hereinafter described. Said side panels and end portions are provided without uninterrupted parallel interior surfaces. Said first end portion is substantially closed, having possibly only a small opening for tuning; and said second end portion is adapted to rigidly and hermetically mount speakers as hereafter described.

The enclosure contains dampening means for reducing and dispersing resonant vibrations of the enclosure. The dampening means preferably includes asymmetric bracing positioned on the interior surfaces of at least the parallel interior surfaces to reduce and disperse resonant modes of the panel, and absorption means within

the enclosure to reduce and disperse the air volume resonance of the enclosure.

A low frequency speaker is rigidly and angularly mounted and substantially hermetically sealed to said second end portion of the enclosure. The speaker is positioned by the enclosure so that it is capable of forwardly radiating into a relatively closely spaced, compound corner and capable of backwardly radiating into the enclosure. Preferably the low frequency speaker is mounted at an angle between 35° and 55° and most desirably at about 45° to the compound corner, and preferably is also positioned to radiate substantially symmetrically into the compound corner. Additionally, the low frequency speaker is relatively closely spaced when at a distance of less than 5 feet from the compound corner and preferably is positioned at a distance between 1½ and 5 feet from the compound corner.

A high frequency speaker and a middle frequency speaker are rigidly and angularly mounted at said second end portion of the enclosure. Said speakers are mounted substantially parallel to and spaced exteriorly and off-axis from the low frequency speaker on standoff supports, preferably to opposite sides of the compound corner. Said middle frequency speaker is mounted at a plane spaced between the low and high frequency speakers. Preferably said middle and high frequency speakers are also symmetrically positioned relative to said compound corner. Both the speakers are thus positioned so that they are capable of forwardly radiating into said compound corner. Said middle frequency speaker is back enclosed and said high frequency speaker is also preferably back enclosed.

The speaker system is completed by a cross-over means for selectively directing the electrical signals, according to their frequency, to the low frequency, middle frequency and high frequency speakers, respectively. Preferably said cross-over means selectively changes inputs from one speaker to another speaker at frequency regions where the efficiencies of the crossed-over speakers are relatively greater.

In addition, the enclosure of the speaker system is preferably pentagonal in shape and capable of nesting into a supporting corner or with one or more like enclosures. Said enclosure is also preferably supported on legs which are capable of transmitting mass vibrations from the enclosure to a supporting base or floor.

Other details, objects and advantages of the invention will become apparent as the following description of the present preferred embodiments of the invention and the present preferred uses for the invention proceeds.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the drawings, the presently preferred embodiments of the invention are illustrated in which:

FIG. **1** is a perspective view showing the acoustic speaker system of the present invention in place in the corner of a listening room;

FIG. **2** is a side elevation view, with portions broken away, of the acoustic speaker system shown in FIG. **1**;

FIG. **3** is a plan view taken along line III—III of FIG. **2**; and

FIG. **4** is a cross-sectional view taken along line IV—IV of FIG. **2**; and

FIG. **5** is a cross-sectional view taken along line V—V of FIG. **3**; and

FIG. **6** is cross-sectional views taken along lines VI—VI of FIG. **3**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, an acoustic speaker is shown having speaker enclosure **10** vertically positioned in supporting corner **11** of a listening room. The enclosure may be alternatively horizontally positioned, but preferably is vertically positioned for the reasons hereinafter stated. Enclosure **10** is preferably supported on legs **12** from base or floor **13** of the listening room. Legs **12** transmit mass vibrations of enclosure **10** to floor **13** so that the efficiency and realism of the system benefits from vibration of the floor.

Referring to FIGS. **2** through **6**, enclosure **10** is comprised of long and narrow side panels **14, 15, 16, 17** and **18.** The enclosure is thus provided with a length to width ratio greater than **3** and preferably between **4** and **5.** The enclosure is completed and made substantially air-tight by first end portion **19** and second end portion **20.** First end portion **19** is substantially closed having at most a small opening **21** covered by plate **22** to provide for tuning of the enclosure. Second end portion **20** is adapted for substantially air-tight mounting of low frequency speaker **27** as hereinafter described. The side panels and end portions are of extremely rigid and preferably highly dense material such as ½ gauge pressed wood (e.g., high density particle board). The rigidity of the panels is further increased by the shape factor of the enclosure, i.e., the length to width factor greater than 3, which results from the long, narrow side panels.

Dampening means including bracing **23, 24** and **25** and absorption means **26** are provided for reducing and dispersing resonant vibrations of the enclosure. Specifically, bracing **23, 24** and **25** are asymmetrically positioned on the interior panels **14, 15** and **18** to break up resonant vibrational modes of the respective panels. And absorption means **26** is provided within enclosure **10** by a roll of insulation such as glass fiber to dampen air volume resonances within the enclosure. Further, a felt pad **26A** is fastened to the interior surface of first end portion **19** to absorb backwaves against the end portion.

The geometry of enclosure **10** with the dampening means substantially avoids the generation of spurious sounds which contaminate the sound production. Plane parallel interior surfaces are avoided within the enclosure. The interior surfaces of first and second portions **19** and **20** are non-parallel; and all of the interior surfaces of the side panels are non-parallel except for narrow panels **15** and **18** which are interrupted by the asymmetrically positioned bracing **24** and **25.** The enclosure is thus provided without uninterrupted parallel interior surfaces.

Hollow enclosures with uninterrupted parallel panels and length to width ratios less than 3 will resonate in relatively narrow, clustered low-frequency regions of the sound spectrum and absorb substantial amounts of the produced sound from those regions produced by the speakers. In turn, these spurious resonant vibrations are retransmitted into the ambience of the listening room and adulterate the sound propagated from the speaker system. Non-parallel interior surfaces and

asymmetrically interrupted parallel interior surfaces of the enclosure, together with the rigidity of the structure, dampen and distribute the resonant vibrations over broad frequency regions, thereby dispersing the frequencies of vibration and reducing the amplitudes of the resonant vibrations to an inaudible state. The efficiency of the speaker system is also increased by reducing energy losses through resonant vibration.

In addition, the shape factor of enclosure **10**, with the length to width ratio greater than 3, distributes the air volume resonance modes of the enclosure over a more extended frequency region than the typical cubic and rectangular enclosures. The shape factor, together with the dampening means, thus reduces the volume resonance vibrations to the inaudible range and in turn contributes to a relatively more linear and uniform sound reproduction over the range of sound produced by the speaker system.

Preferably, enclosure **10** is pentagonally shaped as shown in FIG. **4**. This shape not only results in the attenuation of the resonance sound reproduction, but also provides for nesting of the speaker system in a supporting 90° corner **11** as shown in FIG. **1**. In addition, two speaker enclosures can be nested together at a 180° flat wall, three speaker enclosures can be nested together at a 270° outside corner, and four speakers can be nested together to form a 360° free-standing pillar. The speaker system is therefore provided with exceptional versatility for commercial and industrial, as well as residential applications. Further, such nesting in a supporting corner **11** — either horizontally or vertically — adds efficiency and realism to the produced sound of the system by mass vibration coupling to the walls and/or ceiling of the listening room.

Referring particularly to FIGS. **2** and **3**, a conventional low frequency or bass cone-type speaker **27**, such as a 10 or 12 inch bass driver, is rigidly mounted in opening **28** in second end portion **20** of enclosure **10**. Speaker **27** is fastened to end portion **20** by fastening means **29**, such as suitable wood or metal screws, and is sealed to end portion **20** by silicone putty or the like **30** to make a substantially air-tight fit to the end portion. As previously noted, end portion **20** is extremely rigid and is internally braced so that spurious sounds are not generated and energy is not lost by flexure of the speaker mounting. To further reinforce the mounting, speaker **27** is mounted to end portion **20** tangentially adjacent side panels **14, 16** and **17** at **31, 32** and **33**, respectively, most desirably within about 1 inch thereof. By this arrangement, the speaker **27** is directly supported by the side panels **14, 16** and **17**, so that resonant vibrations of end portions are further reduced and dispersed.

Speaker **27** is angularly mounted on end portion **20** and positioned by enclosure **10** so that it radiates into a relatively closely spaced compound corner **34** (see FIG. **1**). A compound corner is a corner that is an intercept between walls and ceiling, or walls and floor of a listening room — where the walls, and the walls and ceiling or floor meet at angles substantially less than 180° and typically at about 90°. Applied in the present invention, such a corner provides the beneficial acoustic properties of an exponential horn. The corner is also preferably non-absorptive; that is, it is not covered by carpeting, draperies or the other material which has a high coefficient of acoustic absorption. Speaker **27** is mounted preferably at an angle between 35° and 55° and most desirably at about 45° to the compound corner **34**, and is also preferably positioned to radiate substantially symmetrically into compound corner **34**. In addition, the speaker **27**, i.e., the diaphragm thereof, is relatively closely spaced from the compound corner **34** preferably at a distance between 1½ and 5 feet.

This positioning of speaker **27** relatively to compound corner **34** provides front loading of the bass speaker **27**. Radiation into the compound corner reinforces the low frequency sound by confining such radiation to an about ⅛th sphere solid angle. Higher radiation resistance and consequently better power handling and speaker efficiency results. Reduced frequency-modulation (i.e., Doppler) distortion also results because a much smaller diaphragm excursion is required to produce a given acoustic sound level.

Still referring particularly to FIGS. **2** and **3**, a middle frequency or mid-range conventional cone-type speaker **35** with a standard back enclosure is rigidly mounted on stand-off supports **36** by suitable wood or metal screws **36A** exteriorly of and off-axis from the low frequency speaker **27**. Also a high frequency of "tweeter" conventional cone-type speaker **37**, preferably with a standard hemispherical back enclosure, is rigidly mounted on stand-off supports **38** by suitable wood or metal screws **38A** exteriorly of and off-axis from the bass speaker **27**. Preferably, supports **36** and **38** are separate and comprise free-standing dowels as shown to enhance the speakers individual rim-diffraction patterns. Supports **36** and **38** are in any case extremely rigidly mounted on end portion **20** to avoid flexures of the mounting.

Speakers **35** and **37** are angularly positioned, preferably in separate planes as hereinafter described, substantially parallel to the bass speaker **27**. Further speakers **35** and **37** are positioned virtually opposite each other along the periphery of speaker **27** as shown in FIG. **3**, and symmetrically to compound corner **34** as shown in FIG. **1**. That is, from a front view as shown in FIG. **1**, mid-range speaker **35** is to the left of the central axis of speaker **27** and high frequency speaker **37** is to the right of the central axis of speaker **27**. By this arrangement, the axial radiation of speaker **35** is first reflected by the left wall of the listening room to the right wall, and from the right wall to the ceiling and into the room; and the axial radiation of speaker **37** is first reflected by the right wall of the listening room to the left wall, and from the left wall to the ceiling and into the room. The off-axis radiation from speakers **35** and **37**, of course, produce an infinite number of rays that characterize the polar radiation patterns of the speakers. This radiation pattern, together with the symmetrical radiation of the bass speaker **27** into and from compound corner **34**, disperses and intermixes the radiation of the speakers to produce a sound field closely analogous to that found in a good concert hall. Further, this coaction of the middle and high frequency speakers with the compound corner produces an exponential horn action above a cut-off frequency of about 250 Hz to reinforce and further increase the efficiency of the speaker system.

A further psycho-acoustic benefit of the invention is achieved by having compound corner **34** at the intercept between the walls and ceiling of the listening room as shown in FIG. **1**. The compound corner may be at the intercept of the floor and walls, for example, in the production of quadrasonic sound from two stacked ar-

rays each consisting of two speaker systems as here described positioned end-to-end; however, typically the compound corner will be at the intercept of walls and ceiling whether the enclosure is vertically or horizontally positioned.

By this typical arrangement, the sound radiation from the speaker system is not absorbed and shadowed by the furnishings of the room. Specifically, the sound radiating from the upper part of the listening room is substantially free of absorption with typical walls and of shadowing from furniture and other room furnishings, and directional beamng of the high frequencies are avoided. The listener therefore perceives the frequency and amplitude distribution of the sound field very nearly as it is being radiated. Further, the tonal quality of the sound field is substantially balanced throughout the listening room.

A still further benefit derived from radiating into a compound corner is the substantial increase in efficiency of the sound system. Amplifiers of moderate power can be used with any class of program material. To illustrate, utilizing the present invention, amplifiers capable of generating 25 watts per channel as a continual average over a frequency range of 20 to 20,000 Hz will produce a sound pressure level (SPL) of over 100 dB in most rooms of up to 6,000 cubic feet. The figure 100 dB is slightly over the maximum loudness that a full symphony orchestra can maintain on a continuous basis or, at least, more than such an orchestra can maintain except for short intervals.

Referring again to FIG. **2,** the middle-frequency speaker **35** is preferably positioned on a plane between the low frequency and high frequency speakers **27** and **37** as shown. The spacing between the planes of speakers **35** and **37** is selected by determination of the phase differences of the response from the two speakers at the frequency of the cross-over from one speaker to the other speaker. The resulting smooth transition between the speakers produces clear definition of the individual instrumental timbres and a natural, "transparent" quality in the sound produced.

Referring to FIG. **3,** the acoustic speaker system is also comprised of a cross-over means **38'**. Electrically this means is a standard unit consisting of a system of conventional pass-band filters which selectively direct the electrical signals according to their frequencies to the low-frequency, middle frequency and high frequency speakers, respectively. The cross-over is, however, important and novel in the selection of the cross-over point between speakers. Cross-overs are known to cause irregularities and dips in the response curve at the cross-over frequencies. It has, however, been found that these difficulties can be compensated for by selection of the cross-over point in a frequency range where the speakers being crossed-over have peak acoustic responses. These peak responses can be readily determined for each speaker simply by plotting a response curve, i.e., frequency vs. acoustic power, for the speaker. By crossing-over at the high points in the acoustic power responses from the speakers, the cross-over imperfection can be compensated and the response curve can be also made far more uniform over the entire acoustic spectrum.

Another benefit of the overall speaker system is its ability to blend with the decor of the listening room without sacrificing sound production qualities. The enclosure **10** may be painted, clad or encrusted by any desired material. Because there are no exhaust ports on the side panels, the artistic decoration is not limited by functional requirements of the system. More importantly, the entire speaker system can be positioned in otherwise unused corners, and any sort of furniture may be placed in front of or around the system without affecting the sound production qualities. These benefits provide the system with far wider flexibility in use and decoration than typical speaker systems heretofore available.

While the presently preferred embodiments of the invention have been shown and described with particularity, it is distinctly understood that the invention may be otherwise variously embodied and used within the scope of the following claims.

What is claimed is:

1. An acoustic speaker system comprising:

A. a speaker enclosure having a length to width ratio greater than 3, said enclosure of stiff side panels and first and second end portions and being substantially air-tight, said side panels being arranged without uninterrupted parallel interior surfaces, said first end portion being substantially closed, and said second end portion having interior surfaces non-parallel to the interior surfaces of said first end portion adapted to rigidly mount speakers;

B. dampening means within the enclosure for reducing and dispersing mechanical and acoustical resonant vibrations of the enclosure;

C. a low frequency speaker rigidly and angularly mounted on and substantially hermetically sealed to said second end portion of the enclosure, and capable of forwardly radiating into a relatively closely spaced compound corner and capable of backwardly radiating into the enclosure;

D. a high frequency speaker rigidly and angularly mounted at said second end portion substantially parllel to and spaced exteriorly from and off-axis from the low frequency speaker on stand-off supports and capable of frontwardly radiating into said compound corner;

E. a middle frequency back-enclosed conical speaker rigidly and angularly mounted at said second end portion substantially parallel to and spaced between and off-axis from the low and high frequency speakers on stand-off supports and capable of frontwardly radiating into said compound corner; and

F. a cross-over means for selectively directing the electrical signals according to their frequency to the low frequency, mid-frequency and high frequency speakers respectively.

2. An acoustic speaker system as claimed in claim **1** wherein:

1. said low frequency speaker radiates substantially symmetrically into said compound corner; and
2. said middle and high frequency speakers are symmetrically positioned relative to said compound corner.

3. An acoustic speaker system as claimed in claim **1** wherein:

1. said enclosure is vertically positioned adjacent said compound corner; and
2. said speakers are positioned at angles between 35° and 55° to said compound corner.

4. An acoustic speaker system as claimed in claim 3 wherein:

3. said enclosure is supported on legs, said legs capable of transmitting mass vibrations from the enclosure to a supporting base.

5. An acoustic speaker system as claimed in claim 1 wherein:

said enclosure is pentagonal in shape and capable of nesting with a supporting corner.

6. An acoustic speaker system as claimed in claim 1 wherein:

said cross-over means selectively changes inputs from one speaker to another speaker at a frequency range where the efficiency of the lower frequency speaker is relatively high.

7. An acoustic speaker system as claimed in claim 1 wherein:

the low frequency speaker is spaced between about 1½ and 5 feet from the compound corner.

8. An acoustic speaker system as claimed in claim 1 wherein:

the length to width ratio of the speaker enclosure is between 4 and 5.

9. An acoustic speaker system as claimed in claim 1 wherein:

the dampening means includes an asymmetric bracing means positioned on the exterior surface of at least some of the side panels of the enclosure to reduce and disperse the vibrational modes of the side panels, and absorption means within the enclosure to reduce and disperse volume resonance within the enclosure.

10. An acoustic speaker system as claimed in claim 1 wherein:

the low frequency speaker is mounted to said second end portion tangentially adjacent the side panels of the enclosure.

* * * * *