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(54) LOUDSPEAKER FOR LINE ARRAY SOUND SYSTEM

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(52) **U.S. Cl.** **381/349**; 381/182; 381/342; 381/345; 181/144

(58) **Field of Search** 381/339, 351, 381/352, 160, 300, 302, 304–305, 86, 89, 332, 335, 340, 342, 345–349, 353–354, 182, 186; 181/152, 159, 160, 144–145, 147, 199

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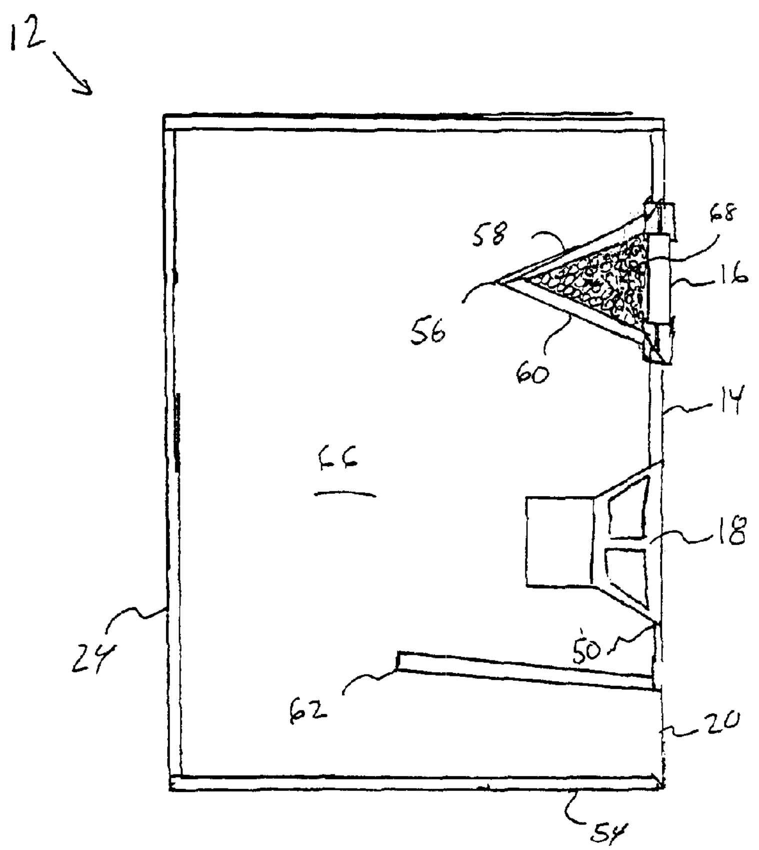
(57) **ABSTRACT**

A loudspeaker assembly includes a housing defining a bass-reflex enclosure. The housing has a trapezoidal cross-sectional shape in a vertical section running from front to back of the housing. A conventional low frequency cone woofer is mounted in an aperture in the front face of the enclosure. An elongated port is defined in part by one of the sides of the housing and its top and bottom sides. The elongated port has varying vertical and horizontal cross sectional dimensions to conform to the sides of the enclosure while maintaining a constant cross sectional area. A planar is mounted to the front face of the enclosure over a tuned rear chamber.

17 Claims, 5 Drawing Sheets



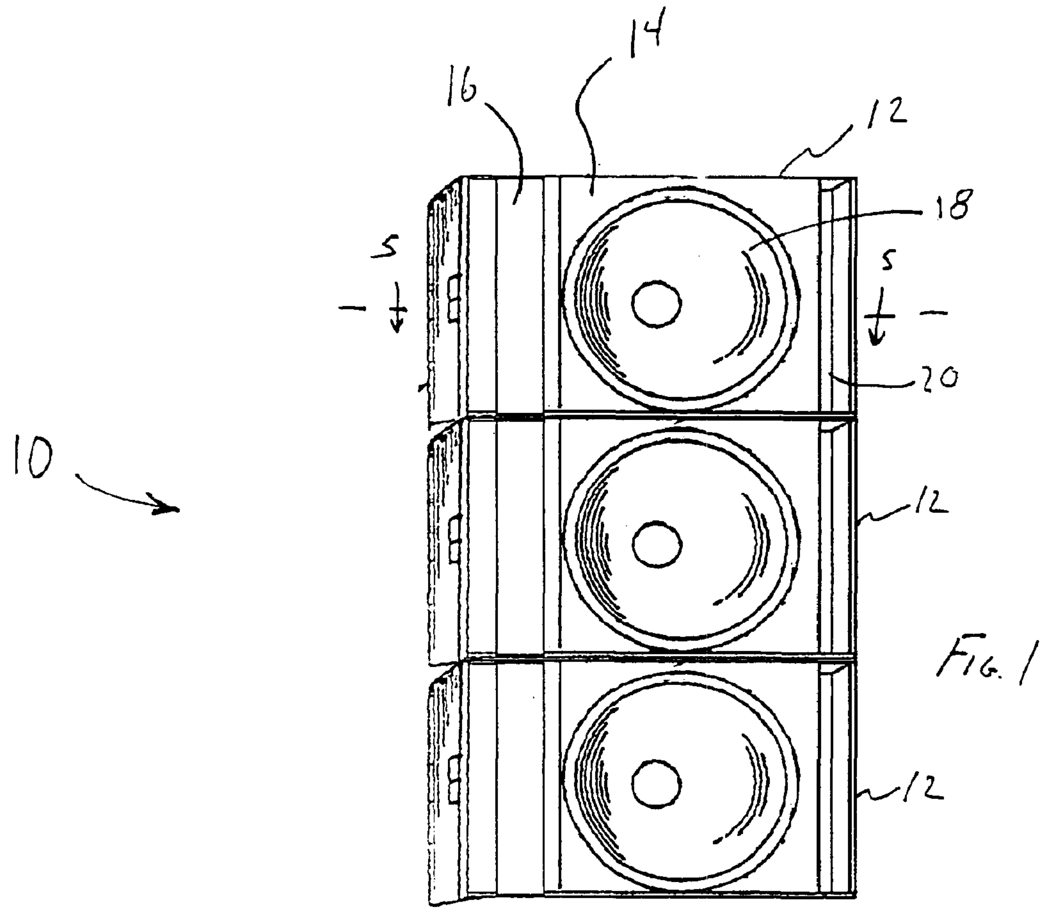


Fig. 1

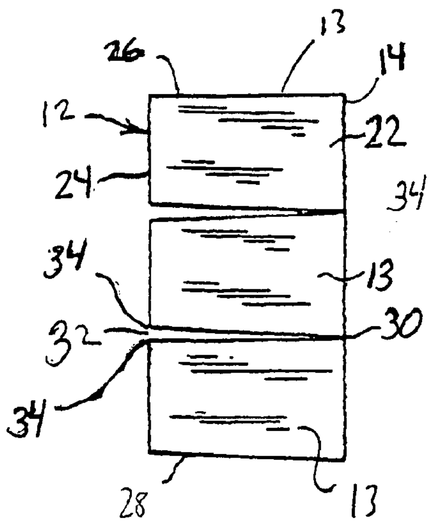


Fig. 2A

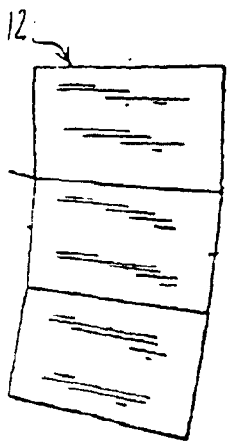


Fig. 2B

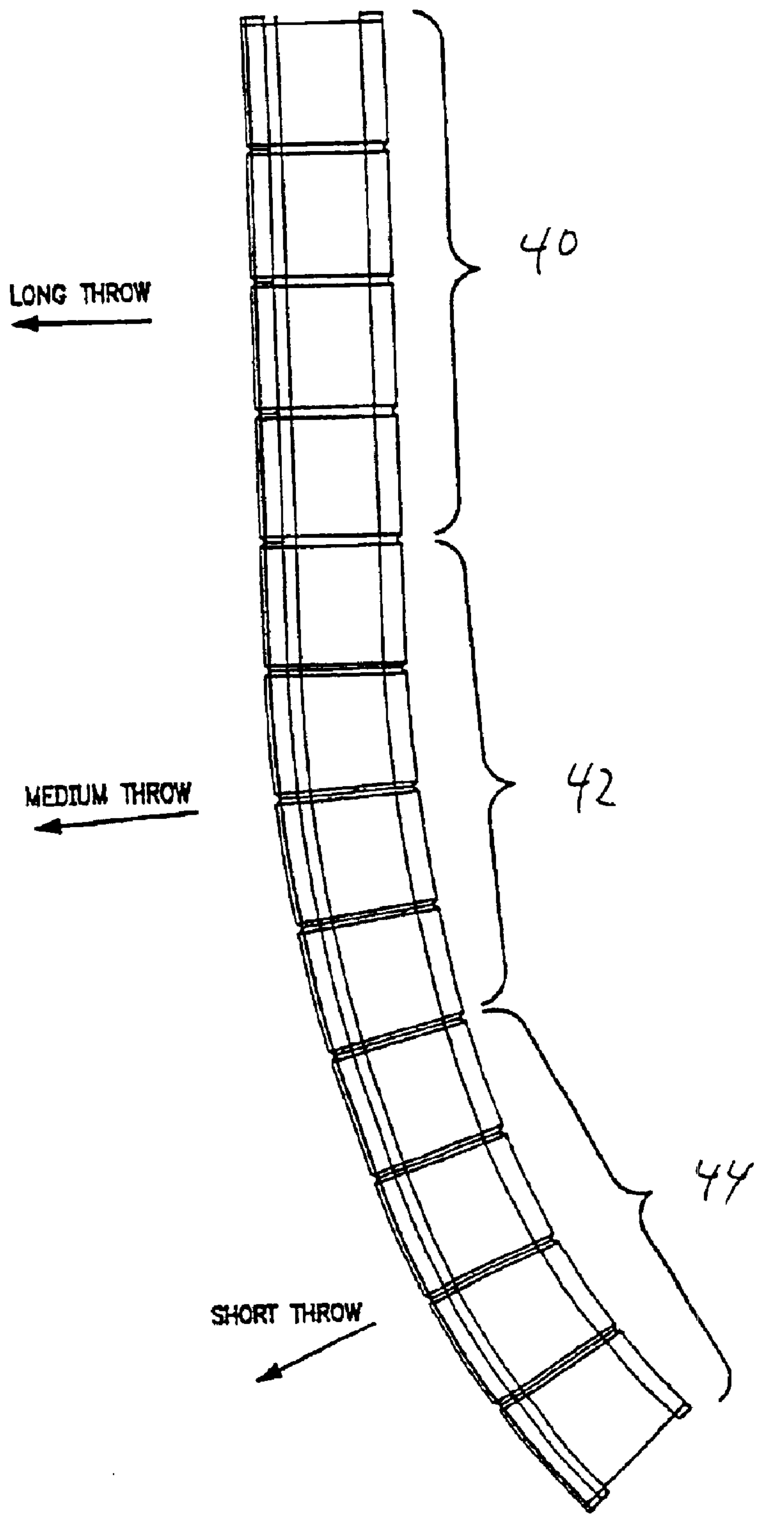


FIG. 3

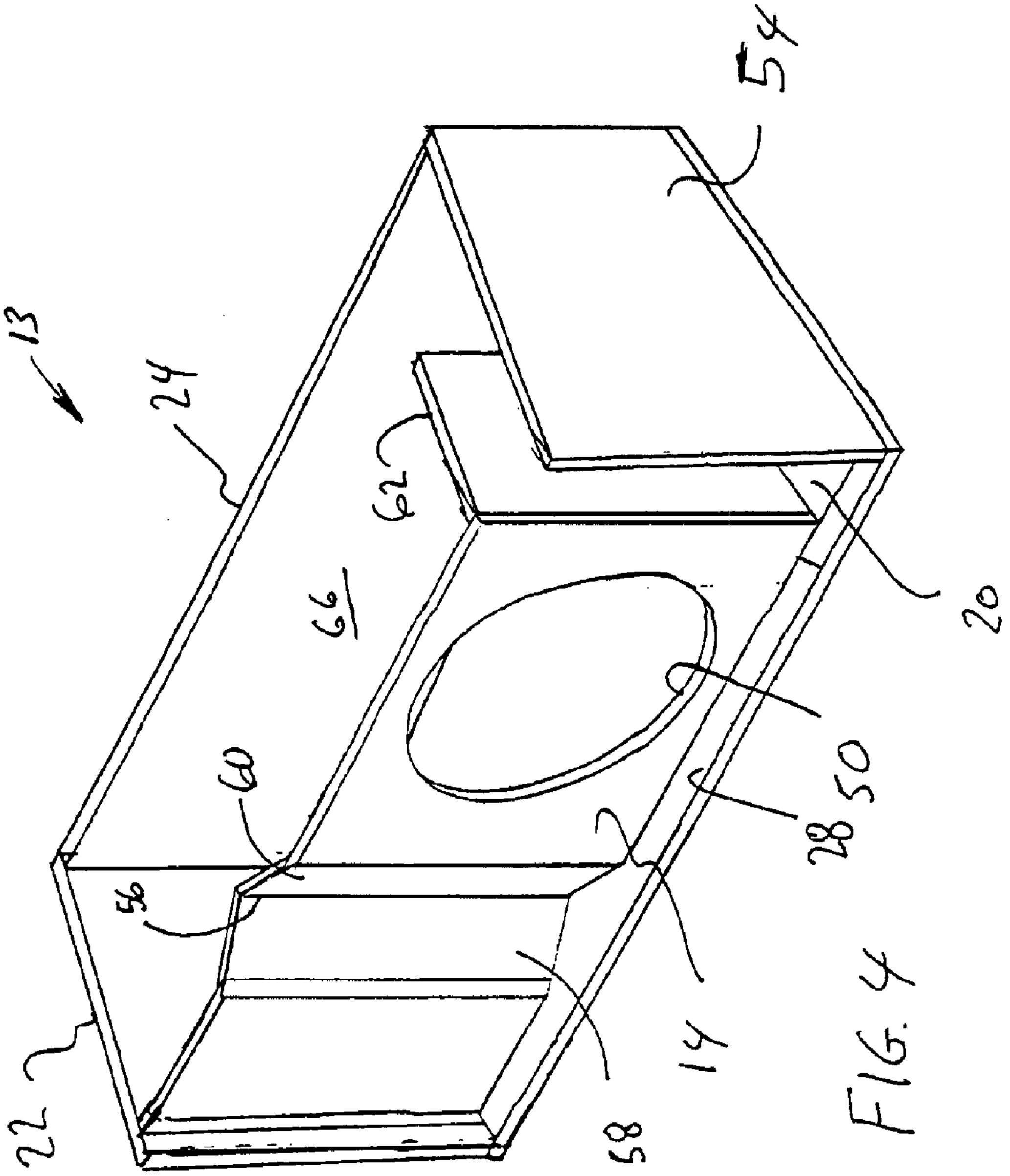


FIG. 4

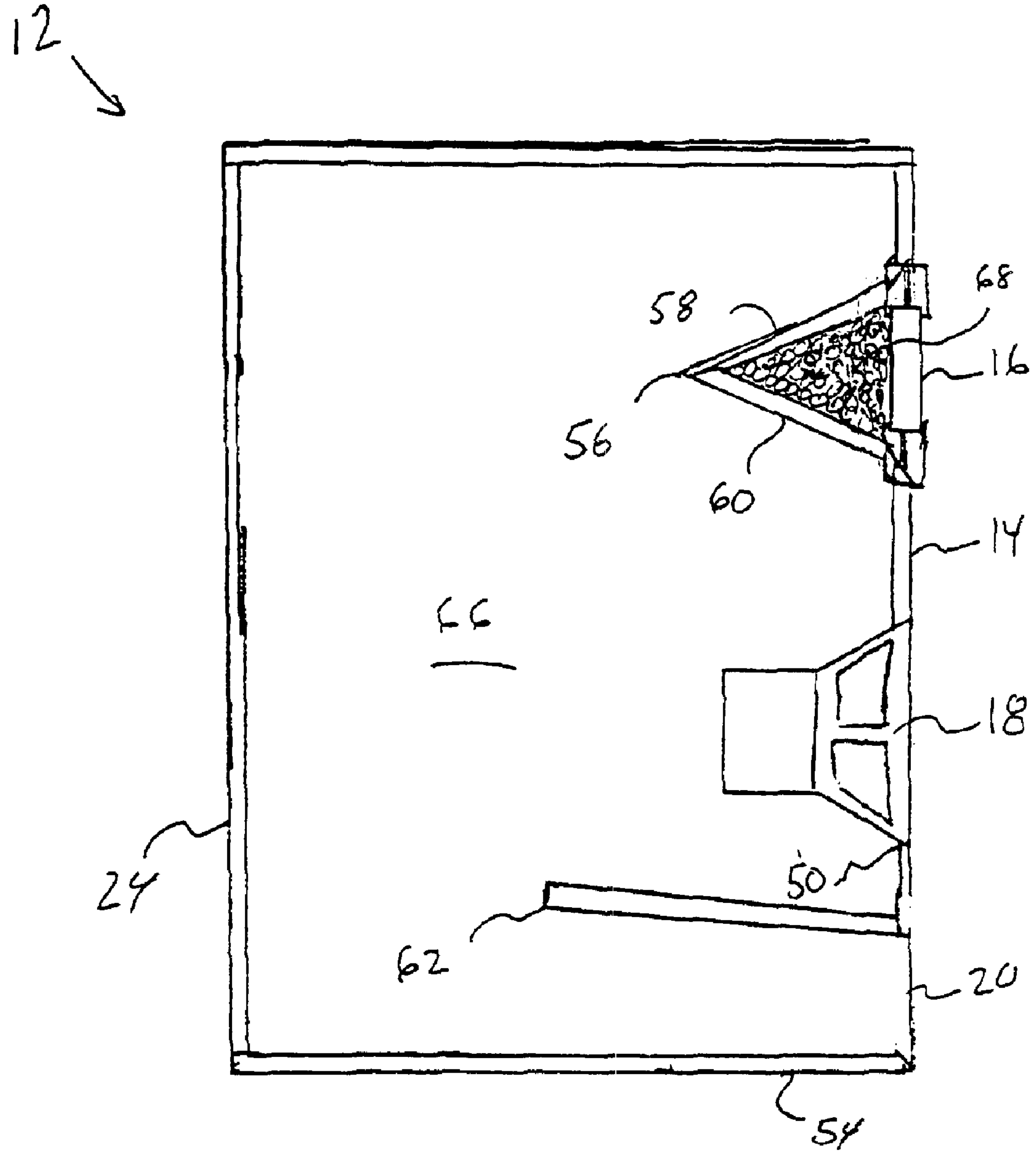


FIG. 5

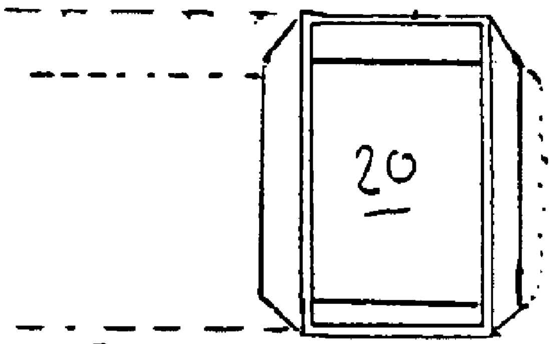


FIG. 6A

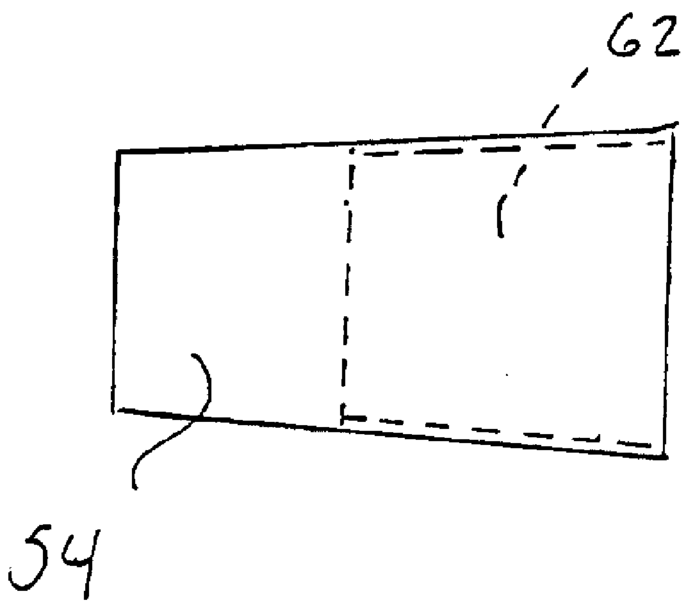


FIG. 6B

LOUDSPEAKER FOR LINE ARRAY SOUND SYSTEM

BACKGROUND OF THE INVENTION

1. Technical Field

The invention relates to an electro-acoustical devices and, more particularly, to a loudspeaker for use in constructing a line array of loudspeakers.

2. Description of the Problem

Large space, public sound systems rely on a combination of loudspeaker types to achieve efficiency, wavefront coherence, a broad and level audio frequency bandwidth and good coverage of an audience located in the space. A foundational element in many such public sound systems is a line array of multi-transducer loudspeakers. A line array, in its classical form, consisted of a vertical row of "closely spaced", cone type, direct radiator acoustical drivers set in a baffle. In this arrangement adjacent acoustical drivers are mutually coupled to reduce the spread of the sound in the plane comprising the axis of alignment of the drivers and to promote even diffusion of the sound energy in an expanding half cylinder having the axis of alignment as its center. Since line arrays are typically oriented vertically, this means that sound reproduced has a minimal vertical spread and enhanced horizontal audio qualities and exhibit greater efficiency.

Mutual coupling of the acoustic drivers results from the acoustic drivers being identical, producing the same sounds and being closely spaced. What constitutes "closely spaced" is a function of the highest audio frequency that the array is intended to produce, but roughly means that the center of each speaker cone should be spaced from adjacent cones by no more than a quarter wavelength of the highest frequency sound the array is intended to reproduce. Audible sound ranges in wavelengths from about 17 meters at 20 hertz to 1.7 cm at 20 Kilohertz. The smallest direct radiator speakers used are usually on the order 10 cm. allowing sound reproduction up to a frequency of about 3 Kilohertz. This provides for good speech intelligibility but is less suitable for amplification of music into large spaces.

The prior art exhibits repeated attempts to provide line arrays capable of reproducing the highest discernable frequencies by constructing devices which emulate certain characteristics of ribbon or "planar" type devices. Ribbon type audio transducers date back to the early twentieth century. An example of an early ribbon type audio transducer is disclosed in U.S. Pat. No. 1,809,754 for an "Electrostatic Reproducer" to Steedle. Ribbon devices resemble an elongated flat panel and produce sound from a vibrating flat surface. In effect a ribbon or planar is a line array of infinitesimal elements positioned directly adjacent one another, i.e. a line array having zero spacing between mutually coupled drivers. This in turn means that a planar has no practical upper frequency limit in the human audio range. Unfortunately, as observed by Adamson in U.S. Pat. No. 6,343,133, ribbon tweeters have had limits in sensitivity and power handling capacity preventing application of the devices in replacing high frequency compression drivers in systems for large spaces. Planars can also suffer from selective frequency cancellation due to out of phase reflection issues from the mounting enclosure used in linear array units.

Due in part to the perceived problems with planars, several attempts have been made to produce a device that behaves like a planer but is constructed using horn loaded, conventional mid or high frequency drivers. Such a device is usually intended to be used to reproduce sound over a broad frequency range. Precursors to and examples of these devices are represented by U.S. Pat. No. 4,344,504 to Howze, U.S. Pat. No. 5,163,167 to Heil, U.S. Pat. No. 6,343,133 to Adamson, and U.S. Pat. No. 6,394,223 to Lehman. The proposed systems have obtained some of the performance, high frequency fidelity and efficiency gains of a planar. However, horn loading introduces some distortion to sound reproduction. It would be desirable to produce a loudspeaker which overcomes the problems with incorporating ribbon devices used in line arrays and which minimizes the need to resort to horn loading to situations requiring greater output power than is currently the case.

SUMMARY OF THE INVENTION

According to the invention there is provided a multi-transducer loudspeaker assembly for use in line arrays in large audience settings. A preferred loudspeaker assembly includes a trapezoidal housing defining a bass-reflex enclosure. The housing's trapezoidal cross-sectional shape is in a vertical section running from front to back of the housing parallel to the primary axis of the array. A conventional low frequency cone woofer is mounted in an aperture in the front face of the enclosure. An elongated port for the woofer is defined in part by one of the sides of the housing and its top and bottom covers. The elongated port has varying vertical and horizontal cross sectional dimensions to conform to the sides of the enclosure while maintaining a constant cross sectional area. A planar is mounted to the front face of the enclosure over a acoustic reflection dampening indent on the front face.

Additional effects, features and advantages will be apparent in the written description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is a frontal view of several loudspeaker enclosures showing alignment of high frequency ribbon tweeters and exits for the low frequency sound;

FIGS. **2**A and **2**B are alternative arrangements of the loudspeaker enclosures.

FIG. **3** is an array of loudspeakers incorporating the present invention.

FIG. **4** is a perspective drawing of a housing for one of the loudspeaker enclosures of FIG. **1**.

FIG. **5** is a cross sectional view of the loudspeaker housing along section line **5**—**5** in FIG. **1**.

FIGS. **6**A and **6**B are a front elevation of an elongated port and a side elevation of a loudspeaker enclosure with the location of the same port shown in phantom.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the figures and in particular to FIG. **1** where an array **10** of multi-transducer loudspeaker units **12** is arranged in vertical alignment one on top of another. Loudspeaker units **12** each have a front face **14** from which sound radiates from a high frequency planar or ribbon tweeter **16**, a woofer **18**, and a low frequency, elongated port **20**. The particular types of transducers and ports for a loudspeaker unit **12** are aligned with like elements for adjacent loudspeaker units **12**.

As may be seen in FIGS. **2**A and **2**B loudspeaker units **12** are disposed in trapezoidal housings **13**. By trapezoidal it is meant that the housings **13** are characterized from bases **28** and upper covers **26** which converge from front to back of the units **12**. This same shape is sometimes referred to as a trapezium. The front face **14** and back wall **24** are parallel giving each housing **13** a side on trapezoidal appearance. The individuals sides of a trapezoidal housing **13**, such as side **22**, are trapezoidally shaped with front and rear parallel edges and top and bottom converging sides. In practice, loudspeaker units **12** are arranged in a vertical plane, either straight up and down as shown in FIG. **2**A, or in a curving manner such as shown in FIG. **2**B, or, as is most typically the case where large volumes need to be covered, as a mixture of shapes (straight vertical **40**, moderate curve **42**, tight curve **44**) as shown in FIG. **3**. The more nearly straight the array, the greater the vertical compression of the sound output from the array for reaching distant portions of an audience. Whatever the curvature, the front faces **14** meet edge to edge **34** to maintain spacing between acoustic transducers. Along the back faces **24** the units **12** may be arrayed step wise in a curved fashion meeting along edges **34**, or the units may be held vertically with a gap **32** between the trailing edges **34**.

Referring to FIG. **4**, housing **13** is shown with the top cover **26**, planar **16** and woofer **18** removed to better illustrate some of the improvements of the present invention to the art. Housing **13** comprises a base **28** on which rise end walls **22** and **54** which run from front to back of the housing. End walls or sides **22** and **54** are trapezoidal in shape with the base of the trapezoid being disposed to rise vertically from the base **28** adjacent the opposite ends of front face **14**. A shorter rear wall is disposed across the back of housing **14**. A port **20** communicating with the interior of housing **13** is opened in front face **14**. Base **28**, cover **26**, ported front face **14**, rear face **24** and end walls or sides **22** and **54** define an elementary bass-reflex enclosure. Port **20** is an elongated port with a rectangular section, being defined between end wall **54**, baffle **62**, which is a vertical wall placed inside housing **13**, and by the interior surfaces of base **28** and cover **26**. Since cover **26** and base **28** converge on one another from front to back, elongated port **20** does not have a constant vertical dimension. To compensate for the constantly changing vertical dimension of port **20**, baffle **62** is set obliquely with respect to end wall **54**, the horizontal spacing between the two walls increasing from front to back. This allows the cross sectional area of port **20** to remain substantially constant from front to back.

An aperture **50** for a woofer is cut in front face **14**. Port **20** provides a tuned outlet for sound from the reverse side of the woofer tuned by a bass-reflex enclosure **66**. Also disposed on front face **14** is a vertical indent **56** comprising first and second canted faces **58** and **60**. Typically, planars have been mounted in so-called infinite baffles with little to no effort has been made to provide these devices with a tuned rear chamber to extend the low frequency knee of the device. Indent **14** provides such a tuned rear chamber, extending the operating frequencies of the device down to the mid-frequency ranges. The depth of indent **14** should be approximately one quarter of a wavelength of the lowest frequency the planar is intended to produce. Faces **58** and **60** should intersect at an angle of between 30° and 60°. The effect is at the desired operating frequency no reflected standing wave is produced with sound output canceling properties. Housing **13** allows use elongated port **20** for the lowest frequency range to be produced, woofer **18** for low to mid range frequencies, and ribbon tweeter **16** for mid to high range frequencies.

Referring to FIG. **5** a loudspeaker **12** is illustrated in cross section illustrating the positioning of the active elements. In a preferred embodiment of the present invention loudspeaker units **12** incorporate ribbon tweeters **16** in a high power line array. One difficulty in the prior art in utilizing ribbon tweeters has been the tendency of some of the output power to be lost at certain frequencies from reflection of sound emitted from the backside of the ribbon, reflected by the line array unit and combined out of phase with forward emitted sound. Planar or ribbon tweeter **16** is positioned over an elongated, V-shaped indent **56**. Indent **56** is elongated in the direction of alignment of loudspeaker units **12**. With planar **16** positioned over indent **16** a void with a triangular section perpendicular to the direction of elongation is formed. This void is filled with a sound dampening material **68** such as wool or a synthetic fiber to limit ringing. Woofer **18** is set in aperture **50**. Between aperture **50** and end wall **54** is shown a baffle **62** which extends back into the enclosure from front face **14**, but which does not reach back wall **24**. The divergence of baffle **62** from wall **54** is illustrated. Elongated port **20** is formed between baffle **62** and wall **54**. FIGS. **6**A and B further illustrate the changing vertical and horizontal dimensions of elongated port **20**.

The invention provides an improved line array element which incorporates a ribbon tweeter or planar element. The use of a tuning rear chamber improves output from the planar element and also extends its frequency operating range. The loudspeaker also incorporates an improved port.

While the invention is shown in only one of its forms, it is not thus limited but is susceptible to various changes and modifications without departing from the spirit and scope of the invention.

What is claimed is:

1. A loudspeaker unit for a line array of neighboring loudspeaker units held in a plane of alignment, each loudspeaker unit comprising:

a housing;

a planar acoustical transducer having length and breadth disposed with respect to the housing to extend lengthwise from near one side of the housing to near an opposite side of the housing in parallel with the plane of alignment; and

a tuned rear chamber disposed behind the planar acoustical transducer including a reflection canceling surface defining the back of the tuning chamber; and

a low frequency acoustical driver mounted with respect to the housing.

2. A loudspeaker unit for a line array as set forth in claim **1**, further comprising:

the housing having front and back faces;

a bass-reflex enclosure defined by the housing having a forward directed port through the front face;

the low frequency acoustical driver being positioned in the front face;

the planar acoustical transducer being positioned parallel to and in front of the front face; and

an indent in the front face behind the planar acoustical transducer forming the tuned rear chamber for the planar.

3. A loudspeaker unit as claimed in claim **2**, further comprising:

parallel sides perpendicular to and connected between the front and back faces; and

the housing having a trapezoidal cross-sectional shape perpendicular to the front and back faces of the housing and parallel to the parallel sides.

4. A loudspeaker unit assembly as claimed in claim **3**, further comprising:

the forward directed port comprising an elongated rectangular passage having varying side to side and top to bottom dimensions to conform to exterior walls of the trapezoidal housing while maintaining a substantially constant cross-sectional area from end to end of the forward directed port.

5. A loudspeaker unit as claimed in claim **4**, further comprising:

the indent comprising two walls intersecting along a line at an angle of between 30 degrees and 60 degrees to form a cavity behind the planar acoustical transducer, the line formed being parallel to the plane of alignment and spaced from the planar acoustical transducer by one quarter of the wavelength of a designed lower frequency limit for output from the planar acoustical transducer; and

sound dampening material in the cavity.

6. A loudspeaker unit as claimed in claim **5**, wherein the loudspeaker unit is incorporated in a linear array of a plurality of the loudspeaker units.

7. A loudspeaker unit as claimed in claim **1**, further comprising:

the tuned rear chamber being formed behind the planar acoustical transducer by two converging vertical walls intersecting at an angle of between 30 degrees and 60 degrees to form a cavity behind planar acoustical transducer, the vertical walls and the planar forming a triangle with the depth of one quarter of the wavelength of a designed lower frequency limit for output from the planar acoustical transducer; and

sound dampening material in the cavity.

8. A loudspeaker unit as claimed in claim **7**, wherein the loudspeaker unit is incorporated in a linear array of a plurality of the loudspeaker units.

9. Apparatus comprising:

a housing defining an interior space and having first and second sides, the first and second sides being spaced from and parallel to one another and being trapezoidal in shape, each with a base edge positioned at the front of the housing and upper and lower converging sides oriented toward the top and bottom of the housing, a front face positioned between the base edges of the first and second sides, a rear face positioned between edges of the first and second sides opposite the base edges, and a cover and a base positioned respectively between the upper and lower converging edges of the first and second sides such that the cover and base have a maximum spacing with the interior space adjacent the front face and a minimum spacing adjacent the rear face;

an aperture in the front face for a loudspeaker cone;

an elongated port open to the interior space and through the front face, the top and bottom of the elongated port being defined by portions of interior faces of the cover and the base; and

sides to the elongated port which converge from back to front of the port to maintain a constant cross-sectional area in the elongated port from back to front of the port.

10. An apparatus as claimed in claim **9**, further comprising:

the elongated port having as one side an interior face of the one of the sides of the housing; and

a second side provided by an interior baffle which diverges from the interior face from front to back to maintain a substantially cross sectional area.

11. An apparatus as claimed in claim **10**, further comprising:

an indentation in the front face running from an edge of the front face adjacent the cover to an edge of the front face adjacent the base and angled with respect to the front face; and

a planar acoustical transducer positioned over the indentation to generate a null standing wave over the operating frequency of the planar acoustical transducer within the indentation.

12. An apparatus as claimed in claim **11**, further comprising:

sound absorbing material between the planar acoustical transducer and the sides of the indentation.

13. An apparatus as claimed in claim **12**, further comprising:

the indentation having first and second intersecting sides having an angle of intersection of between 30 and 60 degrees and a maximum depth from the planar acoustical transducer at the point of intersection of one quarter of a wavelength at a lower knee frequency.

14. An apparatus as claimed in claim **13**, further comprising:

a low frequency loudspeaker with a cone disposed in the aperture.

15. A multi-transducer loudspeaker assembly for use in a line array, comprising:

a trapezoidal housing;

a low frequency cone woofer mounted with respect to the trapezoidal housing

an acoustically tuned rear chamber indent running in the direction of extension of the line array defined by the trapezoidal housing; and

a planar acoustical transducer mounted to the front of the housing over the acoustically tuned rear chamber.

16. A multi-transducer loudspeaker assembly for use in a line array as set forth in claim **15**, further comprising:

the trapezoidal housing defining a bass-reflex enclosure;

the trapezoidal housing being narrower at the back than at its front; and

the low frequency cone woofer being mounted in an aperture in a front face of the bass-reflex enclosure.

17. A multi-transducer loudspeaker assembly for use in a line array as set forth in claim **16**, further comprising:

a port from the bass-reflex enclosure aligned from back to front of the enclosure with constantly varying width and height and a constant cross sectional area along its entire length.

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