United States Patent

Raichel et al.

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[54] STEREO SPEAKER SYSTEM

[72] Inventors: **Daniel Raichel**, Wyckoff; **Chris G. De Vries**, Jersey City, both of N.J.

[73] Assignee: **Dathar Corporation**, Paterson, N.J.

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

[51] **Int. Cl.** **G10k 13/00**, H04r 1/28

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

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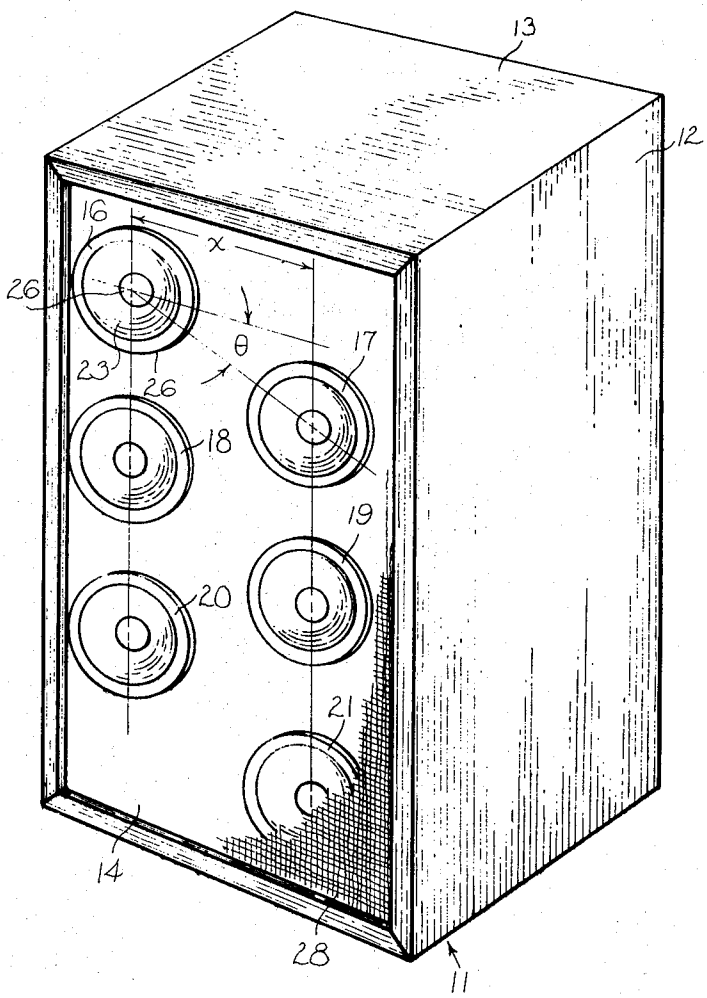
Primary Examiner—Stephen J. Tomsky

Attorney—Donald P. Gillette

[57] **ABSTRACT**

A speaker system having an array of speakers and a sealed enclosure, the number of speakers in the array being a multiple of six and the arrangement of the array being such that there is a multiple of three equally spaced speakers in each row and a multiple of two equally spaced rows. The center-to-center distance between adjacent rows is a function of the diameter of the speaker. The speakers in adjacent rows are not arranged in a rectangular array but in a parallelogram array and the angle between the centerline through speakers in one row and the center of the most closely adjacent speaker in the next row being between 30° and 60°. If two such speaker systems are connected in a stereo system, they are arranged so that the placement of the speakers in one enclosure is a mirror image of the placement of the speakers in the other enclosure.

9 Claims, 5 Drawing Figures



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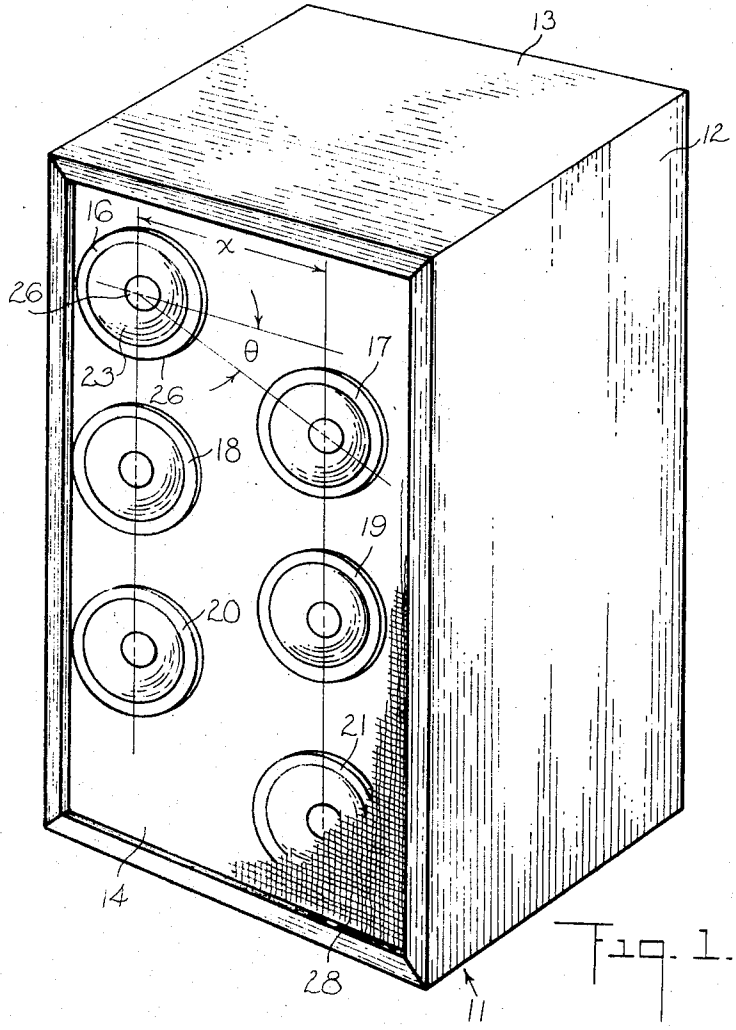

Fig. 1.

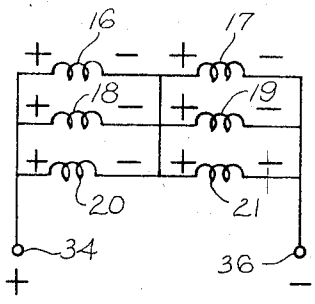

Fig. 3

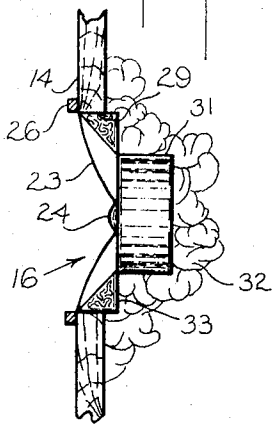

Fig. 2

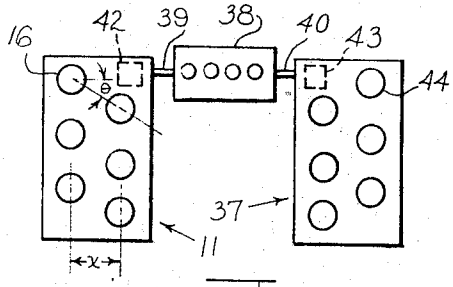

Fig. 4

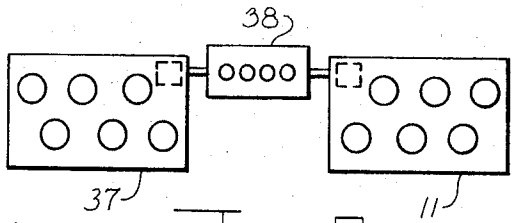

Fig. 5

INVENTORS
DANIEL R. RAICHEL
CHRIS G. de VRIES
BY
Donald P. Gillette
ATTORNEY

STEREO SPEAKER SYSTEM

FIELD OF THE INVENTION

This invention relates to the speaker system having a multiplicity of speakers in a completely airtight enclosure and particularly to coaxial speakers angularly oriented and pneumatically and electrically connected in a parallelogram array within an airtight enclosure.

BACKGROUND OF THE INVENTION

The majority of stereo speakers available today utilize the same configuration, i.e., the use of a large woofer for low frequencies, one or two midrange frequency speakers, and a tweeter for high frequencies. Utilization of those speakers is achieved through the use of electrical crossover networks. The fidelity obtained is proportional to the quality of the speakers used.

An infrequently used arrangement of speakers within an enclosure utilizes identical speakers rectilinearly arranged in straight lines vertically and horizontally within a single enclosure. This arrangement is called an array. Heretofore, an array was unsatisfactory for ultrahi-fidelity because of a lack of adequate frequency response, particularly at the lower range.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with the present invention speakers, or, more properly, drivers, are arranged in a completely airtight enclosure in an array consisting of $T=M\times N$ where T is the total number of drivers and is a multiple of 6 and M is the number of drivers per row and is a multiple of 3 and N is equal to the number of rows and is a multiple of 2. The center of the drivers are not spaced according to a square or rectangular arrangement but according to a parallelogram in which the acute angle is between 30° and 60° and the spacing X between the centers of adjacent rows of the drivers is given by the formula $X=1.25D\pm D/20$ where D is the speaker mounting diameter.

Low-frequency response errors are algebraically summed by a pneumatic coupling of multiple drivers through an acoustic resistance. Because the error of any one driver tends to be different from the error of the other drivers in the array, the total error is reduced. The interior of the speaker enclosure is loaded with fiber glass, and the acoustic resistance and the fiber glass loading cause the pneumatic coupling to decrease with increasing frequency, thereby increasing the rear loading on the speakers in the midfrequency range.

A broad direct-radiating source is also achieved because of a tight forward-radiating pattern. A higher apparent efficiency results from an inverse of the radiating loss of this quasi-column pattern. Because of the small angle and time/phase relationship differences of sound arriving from one array, a listener will be unable to distinguish speakers in the array.

The speaker system of this invention is preferably used in pairs for stereo reproduction and the arrangement of the drivers in the two enclosures of a pair has a mirror image relationship.

It is one of the main objects of the present invention to provide a speaker system, particularly for stereo use, that has an improved response and forms a broad direct radiating source. Other objects will become apparent from the following specification and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a single-speaker system according to the present invention;

FIG. 2 is a cross-sectional view of the mounting of one of the drivers in the speaker of FIG. 1;

FIG. 3 shows the electrical connection for the drivers in the speaker in FIG. 1;

FIG. 4 shows one arrangement of two speakers of the type in FIG. 1 connected to reproduce stereophonic sound; and

FIG. 5 shows a physical rearrangement of the speakers in FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

The speaker **11** in FIG. 1 includes an airtight enclosure made up of two sides **12**, a top **13**, a front **14**, and a back and bottom which are not shown. In the front panel **14** are six individual dual-cone drivers **16–21**. The driver **16** has a cone **23** and a central dust cap **24**. At the perimeter of the cone **23** is a mounting ring **26** attached to the front surface of the panel **14**. All of the other speakers **17–21** are similar to the driver **16**.

In accordance with this invention, six is the minimum number of drivers that can be used, and they are arranged in two vertical rows, one of which consists of the drivers **16**, **18**, and **20** and the other, of the drivers **17**, **19**, and **21**. The drivers in each row are equally spaced apart and the centers of the drivers in the two rows are spaced apart by a distance X, which is an important dimension in achieving the acoustical properties of the invention. If it is desired to use more than six drivers, they should be in multiples of six and should be arranged so that there are multiples of two rows and multiples of three drivers in each row. Thus the next size speaker system must be 24 drivers arranged in four rows of six drivers each in order to preserve the unique radiation pattern.

A grille cloth **28** of special characteristics is made a part of the enclosure **11** and normally covers the drivers **16–21**. Most of it has been cut away in FIG. 1 so that the drivers will be visible. The weave of the cloth should be approximately 30±5 percent porous, which is less than the usual grille cloth that is about 50 to 80 percent porous. In addition, the cloth **28** must be taut enough so that no wrinkles appear in it, and the material must not move easily in response to a slight touch. The actual tautness should be such that a pressure of 30 grams at the center of 1 square meter of the stretched material will cause deflection of about 1 mm.

When the grille cloth is applied to the speaker system **11** in this manner, it acts as a diaphragm to the upper midrange frequencies and produces acoustic loading to the low range of frequencies. At very high frequencies it acts as a diffractor and absorber. The perpendicular distance between the grille cloth **28** and each of the dust caps **24** must be greater than approximately 2 inches in order to achieve the proper diffractive effect of the sound.

Each of the six drivers **16–21** is a full range unit. They are closely spaced in the airtight enclosure **11** which is characterized by walls having a very high modulus of stiffness so that no rattling will occur and so that the enclosure will not act as a radiating source, and there is relatively high acoustic coupling which causes the resonant frequency of each driver to be different from that of every other one. This is in addition to normal resonant differences stemming from manufacturing tolerances and is akin to the principle of staggered tuned circuits in a broadband amplifier. In the present invention, the resonance of the individual drivers becomes inaudible and the overall response spectrum assumes a smoother contour.

The spacing X is a function of speaker size and is defined by the following equation:

$$X=1.25D\pm D/20$$

where D is the speaker mounting diameter. In one operative embodiment of the invention, six 5-inch drivers were used in a cabinet having a height of about 25 inches, a width of about 14 inches, and a depth of about 10⅝ inches.

The three drivers **16**, **18**, and **20** in one row are not set directly opposite the three drivers **17**, **19**, and **21** in the other row but are offset slightly to form a parallelogram array. The angle θ, which is the complement of the acute angle of the parallelogram, is another important parameter of the present invention. It can range from approximately 30° to approximately 60° and in the aforementioned embodiment the angle was 45°. The angle actually used depends on the radiative dispersion of the speakers and increases with increasing dispersion. The relationship between the dispersive angle ϕ and the angle θ is given by the equation:

$$2/\phi=3/\theta$$

where both ϕ and θ are measured in degrees. The aforementioned system in which the speakers were displaced at an angle

θ of about 45° had speakers with dispersive angles of approximately 30°.

The dual-cone drivers should be such that the ratio of the low-frequency cone diameter to the dust cap diameter is greater than about 8:1. Thus, a driver having an outer diameter of 8 inches should have a dust cap of 1 inch or less.

It is difficult to measure precisely the efficiency with which the system of the present invention transforms electrical energy into acoustical energy, but it is of the order of 6 percent, which is greater than the normal 3 percent for the so-called bookcase speakers of approximately the same size.

FIG. **2** is a cross-sectional view of part of the enclosure **11** in FIG. **1** and shows the way that the driver **16** is mounted in a well **29** in the front panel **14**. The mounting ring **26** of the driver **16** is attached to the front surface of the panel **14**, and the driver has its operating magnetic components **31** extending from the rear surface of the panel **14**. The interior of the enclosure **11** is filled with sound-absorbing material **32**, such as fiber glass. An important aspect of the invention is the provision of an annular collar **33** of sound-absorbing material that surrounds the mounting elements of the driver **16** and fills the well **29**. The material of which the collar **33** is made may also be fiber glass so formed as to maintain a relatively fixed shape with a cross section that just fills the well **29** and does not make contact with the cone **23** of the driver **16**. This permits regular fiber glass batting **32** to be applied over the driver without missing any voids and without fear of having any of the absorbing material contact the cone **23** of the driver **16** or the cones of any of the other drivers.

FIG. **3** shows the electrical connection of the drivers **16–21** in FIG. **1**. With this type of series-parallel connection, the total impedance between the input terminals **34** and **36** may be maintained at a reasonable value. In the aforementioned embodiment it was found that the speaker system would handle 120 RMS watts per channel or 240 watts for a stereo system while keeping the impedance at a nominal 8 ohms at 400 Hz. No crossover network was required.

FIG. **4** shows two of the speaker systems with enclosures **11** and **37** arranged for stereophonic reproduction. A stereo amplifier **38** supplies power by way of connections **39** and **40** to the enclosures **11** and **37** respectively. The actual connections are made at connectors **42** and **43** in the rear corner of the enclosures **11** and **37** respectively. In order to maintain the proper acoustical characteristics of the system the parallelogram arrays of drivers in the enclosures **11** and **37** are such that the acute angles of each of the arrays are at the outer, upper corner and the lower, inner corner of each enclosure.

FIG. **5** shows that the same relative parallelogram arrays are maintained when the enclosures **11** and **37** are placed on their sides in the usual bookcase arrangement. However, in order to maintain this relationship in which the outer upper corner has the acute angle of the parallelogram, the enclosures **11** and **37** must be reversed in connection to the stereo amplifier **38**. Doing so makes it possible to maintain a broad distribution of the sound, and the effective source is nearly ellipsoidal owing to the array effect. This amounts to cutting a large, more-or-less diamond-shaped hole in a wall behind which the sound is generated instead of cutting the usual small circle characteristic of previously existing speaker systems. Thus, the apparent sound comes from a broader source and the waves reaching the listener have an apparent larger radius of curvature than is true in the usual speaker system.

What is claimed is:

1. A speaker system comprising:

A. An airtight enclosure comprising a panel; and

B. A multiple of six drivers mounted on said panel and arranged in a multiple of two rows with a multiple of three drivers in each of said rows, the drivers in each of said rows being equally spaced and said rows being parallel to each other, said drivers being arranged in a parallelogram array with the acute angles of said parallelogram being between 30° and 60°.

2. The speaker system of claim **1** in which each of said drivers has a dual cone comprising an outer cone and a dust cap, and the ratio of the diameter of said outer cone to said dust cap is at least approximately 8:1.

3. The speaker system of claim **1** in which said panel comprises a plurality of wells, one for each of said drivers, and each of said drivers comprises a mounting ring attached to the external surface of said panel with the remainder of each of said drivers extending through said well into the interior of said enclosure.

4. The speaker system of claim **3** comprising, in addition, an annular collar of sound-absorbent material within each of said wells and surrounding each of said drivers but separated from the cones of said drivers.

5. The speaker system of claim **4** in which the interior of said enclosure is substantially filled with sound-absorbent material.

6. The speaker system of claim **1** in which all of said drivers are substantially identical.

7. The speaker system of claim **1** in which said rows are spaced apart by a distance X determined by the equation

$$X=1.25D\pm D/20$$

where D is the speaker mounting diameter.

8. The speaker system of claim **1** in which said acute angle is the complement of an angle θ determined by the equation

$$2/\phi=3/\theta$$

where ϕ is the dispersive angle of said drivers.

9. The speaker system of claim **1** comprising, in addition,

A. A second airtight enclosure comprising a panel; and

B. A multiple of six drivers mounted on said last-named panel and arranged in a multiple of two parallel rows with a multiple of three equally spaced drivers in each of said rows, said drivers being arranged in a parallelogram array with the acute angles of said last-named array being between 30° and 60°, said second enclosure facing in the same direction as said first-named enclosure and laterally spaced therefrom and with the respective acute angles of the arrays in each of said enclosures being at the upper, outer corners of the respective panels.

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