

Dec. 1, 1959

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2,915,588

PRESSURE WAVE GENERATION

Filed Aug. 6, 1956

2 Sheets-Sheet 1

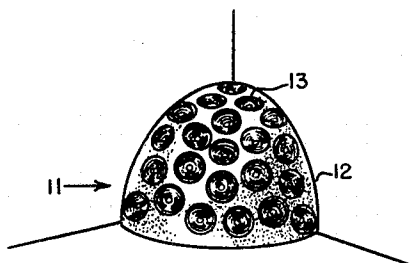


FIG. 1

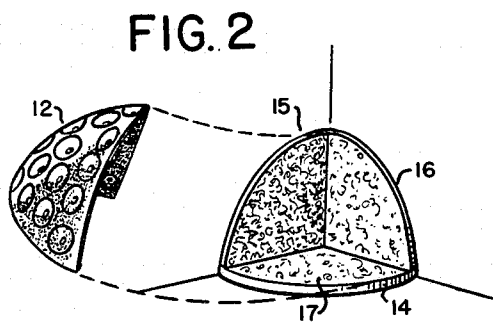


FIG. 2

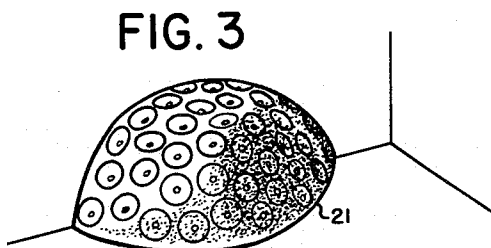


FIG. 3

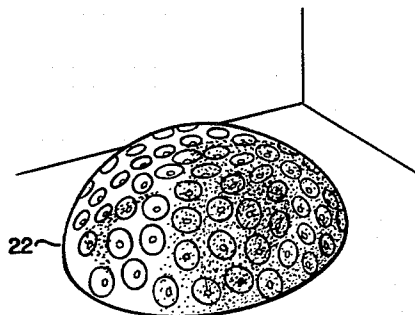


FIG. 4

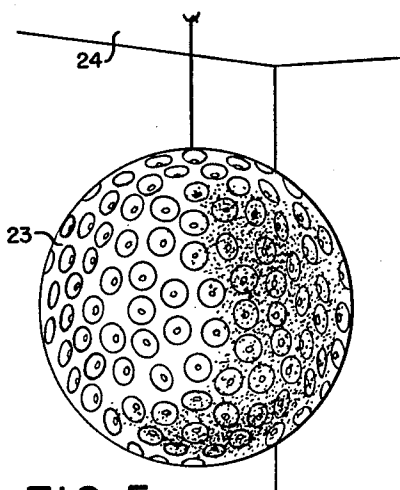


FIG. 5

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2 Sheets-Sheet 2

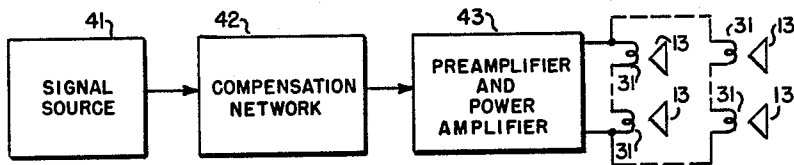


FIG. 7

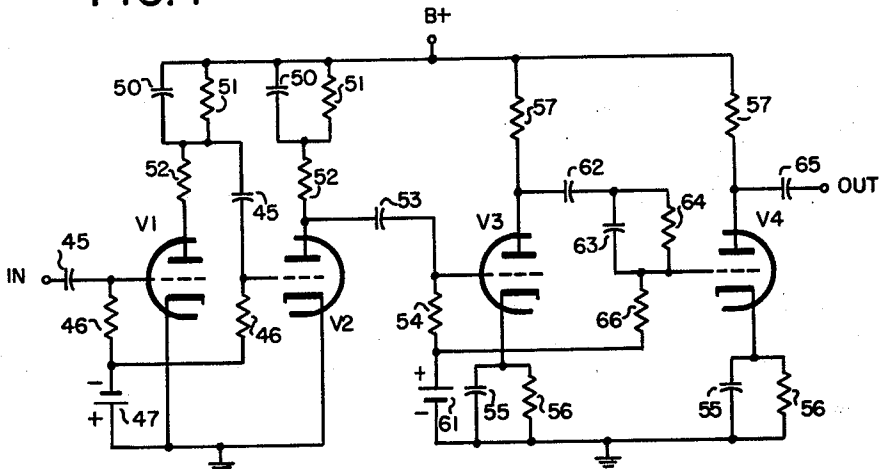


FIG. 8

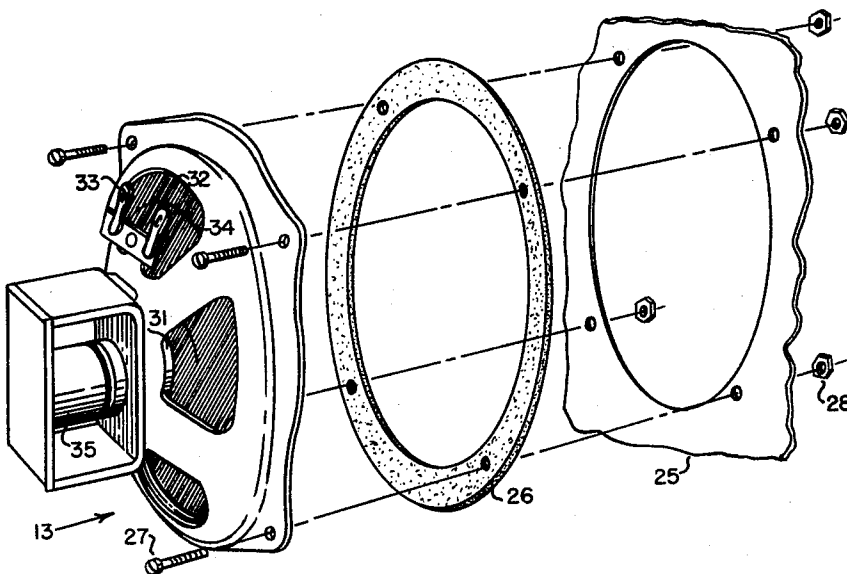


FIG. 6

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2,915,588

PRESSURE WAVE GENERATION

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Application August 6, 1956, Serial No. 602,195

37 Claims. (Cl. 179—1)

The present invention relates in general to apparatus for generating pressure waves and in particular to a transducer for generating sonic waves in an acoustic medium in response to an electrical input signal. Apparatus embodying the inventive concepts for the reproduction of sound characterized by an input electrical signal is capable of efficiently reproducing with remarkable fidelity the entire audio spectrum despite its low cost and compact arrangement.

Broadly speaking, a transducer is a device which translates electrical signals into corresponding mechanical displacements, and/or vice-versa. For example, a loudspeaker is a transducer whose mechanical displacement in response to an electrical signal, launches a pressure wave in air. Since the latter transducer is normally used for the reproduction of sound, desirable characteristics sought to be attained in the design of a loudspeaker system include, the ability to reproduce signals encompassing the entire audio spectrum without harmonic or intermodulation distortion, efficient conversion of electrical to acoustical power, omnidirectional radiation characteristics, and integration of the program source; that is to say, all the sound should appear to come from a single source.

While prior art systems have attained some of these characteristics, the better systems have utilized a plurality of speakers, each speaker being energized with a signal having a selected portion of the audio spectrum. The signals may be coupled to the respective speakers from a single power amplifier through a passive cross-over network, by separate power amplifiers which are in turn energized by an electronic cross-over network, or by combinations of the two.

Although satisfactory reproduction of the high frequency signals has been obtained with electrostatic speakers and compression tweeters, the solid angle uniformly energized with acoustic energy by such speakers is limited. In addition, electrostatic speakers require a high voltage source to supply a biasing potential.

Greater difficulties have been experienced in reproducing the low frequencies. To improve the low frequency response, efforts have been directed toward the design of special enclosures in which the low frequency loudspeaker is housed. One such type of enclosure is known as a folded horn and is designed with a view toward providing an improved impedance match between the loudspeaker and air, the design procedure being based largely on the concept of radiation resistance. Radiation resistance is a measure of the ability of a pulsating diaphragm, such as a vibrating loudspeaker, to couple acoustic energy into air, the greater the radiation resistance, the higher the degree of coupling. Accordingly, a folded horn is designed to present a large radiation resistance to the speaker diaphragm. Although improvements in low frequency response result from the use of such structures, the better units are of complex design, bulky and expensive. Furthermore, the frequency range over which the impedance match obtains is limited.

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Another common approach utilizes a bass reflex cabinet having one or more ports and housing an enclosed loudspeaker supported upon a baffle. The volume of the cabinet is designed so that at a selected frequency, the back wave from the loudspeaker emerges from the port substantially in phase with the frontal wave. Design of such enclosures involves a compromise since waves of other frequencies emerge from the port in phase opposition to the frontal wave.

As a result of these and other difficulties, the loudspeaker has been the weakest link in high fidelity sound reproduction systems. Other approaches to strengthening this link include, placing a large plurality of closely-spaced relatively small loudspeakers in a wall, or upon a baffle comprising several intersecting planar surfaces. For reasons which will be better understood from the discussion below, the last-mentioned arrangements have failed to achieve a major portion of the desirable characteristics enumerated above.

Difficulties encountered in attempting to generate low frequency sound waves will be better understood by a consideration of the nature of a pressure wave in an acoustical medium. An acoustical medium is a compressible medium capable of responding to pressure changes with corresponding changes in density. Thus, a pressure wave may be activated in the medium by imparting forces thereon in a cyclical manner. For example, the action of a single loudspeaker set in the wall of a room whereby it imparts forces upon the air therein in response to a low frequency electrical signal is much like a piston moving in and out. If a hollow hard-surfaced cylinder having the same diameter as the piston and concentric about its axis were placed against the wall, substantially equal axial forces would be imparted upon the air column within the cylinder, and movement of the pressure wave therein would be substantially axial; that is, the particle velocity at any point within the cylinder is substantially axial, there being negligible velocity components orthogonal to the cylinder axis. Now if the cylinder is removed and the piston moved in and out, the air particles which are compressed at points of high density seek regions of lesser density, and since the cylinder no longer confines them to axial motion along the piston axis, velocity components orthogonal to the cylinder axis are imparted to the particles. Many of the particles then impart forces to particles along the sides instead of on other particles farther out from the piston along an axial direction. Stated in terms of a propagating wave, removal of the cylinder results in the direction of propagation formerly entirely axial, having components orthogonal to the axis. The pressure intensity of the wave along the axis is accordingly reduced. To compensate for this effect, the excursion of the piston must increase appreciably. In the case of a single loudspeaker, the excursions are often so great that operation of the latter is over its non-linear region, thereby introducing unwanted harmonic and intermodulation distortion.

As is well known in the art, at a distance, a loudspeaker excited by a low frequency electrical signal looks like a point source which radiates spherical waves. It has been discovered that improved low frequency response can be obtained by providing effectively a vibrating surface upon which a smooth match of the boundary conditions for generating spherical waves may be obtained; that is to say, the surface is so designed that particle velocities of the acoustic medium in the vicinity of the vibrating surface are substantially along the direction of its movement, there being negligible velocity components orthogonal to such movement. In this manner, difficulties, such as the above-mentioned propagational phenomenon are believed to be virtually eliminated, and the vibrating surface is capable of exciting

low frequency waves in the adjacent acoustic medium in an efficient manner with little distortion. At the same time, such a surface performs well at the middle and high frequencies.

Accordingly it is a primary object of the present invention to provide means for efficiently generating pressure waves of relatively long wavelength in an acoustical medium.

Another object of the invention is the provision of transducing means capable of effecting the efficient translation of low frequency electrical signals into corresponding pressure wave variations in an acoustic medium.

A further object of the invention is the provision of a loudspeaker system capable of responding to a low frequency electrical signal by efficiently exciting a sonic wave in air which accurately follows the variations of the driving electrical signal.

Still another object of the invention is to attain the foregoing objects in a loudspeaker system which has equal capabilities when responding to signals in the entire audio spectrum, excites sonic waves of substantially equal intensities in all directions at all frequencies, introduces negligible intermodulation or harmonic distortion, provides an effect to the listener that the sound is coming from an integrated program source, is relatively light weight and compact, of pleasing appearance, and yet relatively inexpensive.

According to broad aspects of the invention, at a surface defined by points substantially equidistant from a point of origin, such as the center of a sphere, the surface being in contact with an acoustic medium, substantially equal cyclical forces orthogonal to the surface are imparted to the medium at the surface. Thus, particles adjacent the spherical surface defined by the points move inward and outward along radial lines relative to the point of origin in response to the forces, thereby exciting a substantially spherical wave in the acoustic medium whereby a smooth match of the boundary conditions therefor are obtained along the surface. In other words, substantially equal in phase pressure variations are excited in the acoustic medium at and orthogonal to the surface.

In another aspect of the invention, the surface at least partially encloses a relatively small volume which is adjacent to a markedly larger volume having the acoustic medium. The remainder of the small volume is bounded by planar surfaces which are coplanar with at least some of the bounding surfaces of the large volume, the planar surfaces being along radii which extend from the point of origin to the spherical surface. Where the large volume is rectangular and the small volume is bounded by more than one planar surface, the latter planar surfaces are mutually perpendicular.

In a particular form which the invention takes for generating sonic waves in air in response to an electrical input signal, the surface is covered with a plurality of closely-spaced loudspeakers connected together so that all the diaphragms move in phase in response to the input electrical signal.

Other features, objects and advantages of the invention will become apparent from the following specification when read with reference to the accompanying drawing in which:

Fig. 1 illustrates a preferred embodiment of a loudspeaker system according to the invention especially suitable for location in the corner of a room;

Fig. 2 shows the speaker system of Fig. 1 with the front spherical speaker-covered surface removed in order to illustrate the preferred means for enclosing the volume along the walls and floor of the corner;

Fig. 3 illustrates a surface which is one-fourth the surface of a sphere and covered with loudspeakers, especially suitable for generating spherical waves when enclosing a volume adjacent two orthogonal planar surfaces, such as one wall and the floor;

Fig. 4 illustrates a hemispherical speaker-covered surface suitable for generating spherical waves according to the invention when enclosing a volume adjacent a single planar surface, such as the floor of a room;

Fig. 5 illustrates a suspended speaker-covered spherical surface capable of generating spherical waves in a large open volume;

Fig. 6 is an exploded view illustrating a typical speaker utilized in the preferred embodiment of the invention and the means for attaching the speaker to the spherical surface;

Fig. 7 is a block diagram of apparatus for driving the novel loudspeaker systems to effect faithful reproduction of electrically transmitted sound; and

Fig. 8 is a schematic circuit diagram of a representative embodiment of the compensation network of Fig. 7.

With reference now to the drawing and more particularly Fig. 1 thereof, there is illustrated a representative embodiment of the invention as a loudspeaker system 11 especially suitable for location in the corner of a room. A one-eighth spherical surface 12 is covered with a plurality of loudspeakers like loudspeaker 13.

In Fig. 2, the surface 12 is removed and the sides 14, 15 and 16, which enclose the volume adjacent the walls and floor are seen to be planar surfaces which are substantially 90° sectors of circles. Each of the latter surfaces is preferably lined with a sound absorbent material such as fiberglass insulation and are joined together at preferably tight-fitting joints. They may be formed of wood which is glued, nailed or screwed together. Surface 12 is secured to the structure thus formed by the same or other suitable means. The closely-spaced loudspeakers, like loudspeaker 13 are symmetrically positioned about holes in the surface 12, preferably in a manner which effects an air-tight seal as described below. Thus, the speaker-covered surface 12, together with sides 14, 15 and 16 enclose a relatively small substantially air-tight volume. As a practical matter, the volume need not be air-tight to achieve substantial portions of the desired results. In fact, those skilled in the art may deliberately place openings in the volume in order to achieve different acoustical characteristics without departing from the inventive concepts.

As indicated above, it is desirable to place the loudspeakers as close together as practicable in order to more nearly approximate the desired vibrating spherical surface when all the loudspeakers are excited in phase.

Before describing certain features and characteristics of the embodiment of Fig. 1, other forms which the invention may take will be discussed. With reference to Fig. 3, a surface 21, which is one-fourth the surface of a sphere is illustrated covered with speakers like speaker 13 and located at the intersection of a wall and floor. The embodiment of Fig. 4 is a hemispherical speaker-covered surface 21 which is illustrated enclosing a relatively small volume adjacent to the single planar surface formed by the floor of a room. The remaining representative embodiment, illustrated in Fig. 5, is a speaker-covered spherical surface 23 which is represented as suspended from the ceiling of a room.

Each of the embodiments described above is capable of achieving the objects of the invention. By exciting all the speakers on a surface in phase with a low-frequency electrical signal, substantially equal radial forces are imparted upon the air adjacent the surface to launch a spherical wave in the air, substantially free of the low frequency propagational effects described above. Moreover, at higher frequencies the relatively small loudspeakers act like many tweeters, each oriented in a different direction to produce a substantially omnidirectional radiation pattern over the listening areas in the room. Furthermore, since each speaker diaphragm need only move a fraction of its normal displacement when used alone to produce a given volume level in the room, substantially linear operation of each speaker results, there-

by reducing speaker harmonic and intermodulation distortion to a remarkably low level, even at low frequencies.

By combining the speakers in the manner described, the loudspeakers employed may be inexpensive and have relatively poor low frequency characteristics when singly excited by an electrical signal, yet yield an improved response when co-acting according to the invention. Moreover, since the diaphragm displacement of each speaker is so small and the propagational effect virtually eliminated by arranging the speakers on the spherical surface according to the invention, electrical compensation may be easily provided to yield the desired frequency response characteristics while maintaining harmonic and intermodulation distortion levels low. Such an electrical compensation network is described below.

With reference to Fig. 6, there is illustrated a typical suitable loudspeaker 13 of a conventional small type and the details of securing it to the spherical surface. The speaker utilizes a permanent magnet 35 to set up a magnetic field in which voice coil 31, secured to diaphragm 32, vibrates in response to an electrical signal applied at terminals 33 and 34. Portion 25 is a fragmentary drawing of any of the surfaces 12, 21, 22, or 23 viewed from the inside of the enclosed volume. Speaker 13 is secured to portion 25 by screws and nuts like screw 27 and nut 28 respectively with rubber washer 26 interposed between the surface and speaker rim to effect a substantially air-tight seal. Other means for securing the speakers to the surface will be apparent to those skilled in the art.

Before discussing the electrical means for driving the novel loudspeaker systems, characteristics of the various illustrated embodiments will be described. The speaker-covered spherical surface 23 of Fig. 5 is designed to radiate into a solid angle of 4π ; the hemispherical surface 22 of Fig. 4, into a solid angle of 2π ; the one-fourth spherical surface of Fig. 3, into a solid angle of π ; and the one-eighth spherical surface 12 of Fig. 1, into a solid angle of

$$\frac{\pi}{2}$$

Thus, if the planar surfaces adjacent the enclosed volumes are perfect acoustical reflectors, and the surfaces have the same radius of curvature, the number of speakers required for each embodiment to generate a pressure wave of given intensity at a given radial distance from the respective surfaces is in the ratio of 1 : 2 : 4 : 8 for the surfaces 12, 21, 22 and 23 in Figs. 1, 3, 4 and 5 respectively. For example, the twenty-two speakers upon surface 12 located in a corner generate sound intensities equivalent to 176 speakers upon surface 23 suspended in space. It is thus seen that the system 11 is the preferred embodiment for use in most rooms.

However, the other embodiments are not without utility. For example, the embodiment in Fig. 3 is useful where a corner is not available in a room or where it is desired to place the system against but a single wall and the floor or ceiling. The system in Fig. 4 is especially useful when it is desired to direct sound 360° about a source such as might be required at an outdoor meeting in a large amphitheater.

The embodiment of Fig. 5 may be advantageously utilized where it is desired to obtain wide coverage in the vertical as well as horizontal planes. For example, such a system might be suspended in the center of a large arena to cover the entire volume with the sound. Not only are the advantages enumerated above realized, but the objectionable echos prevalent in spaced speaker systems, which make understanding of the announcements difficult are virtually eliminated by the present system.

With reference to Fig. 7, there is illustrated a block diagram of an electrical system for driving the novel speaker systems in a manner which provides high fidelity reproduction of the entire audio spectrum. A signal source 41, such as a phonograph, microphone, tuner or

the like energizes a compensation network 42 which boosts the high and low frequency ends of the audio spectrum to compensate for the fall off in response of the individual loudspeakers at these ends. The latter network then energizes preamplifiers and power amplifier 43 which in turn drives the speaker voice coils 31 of the loudspeakers 13. The loudspeakers may be connected in parallel, series or series-parallel, as long as they are connected so that electrical signals of like polarity actuate each speaker diaphragm in the same radial direction, that is to say, the speakers are driven in phase. Normally, the type of connection is arranged to present the proper load impedance to the driving power amplifier.

Certain additional advantages result when the speakers are connected in series to present a relatively high impedance to the power amplifier. The latter may then be of the transformerless type, thereby markedly reducing the cost of the system while at the same time eliminating a component subject to distortion causing non-linearities. Furthermore, such power amplifiers may be similar to the cathode follower type, capable of exceptionally high linearity and virtually free from oscillation.

With reference to Fig. 8, there is illustrated a schematic circuit diagram of an example of a compensation network which provides the desired low frequency and high frequency boosts while uniformly passing the middle range of frequencies. Tubes V1 and V2 together with the associated components comprise the low frequency compensation circuit. The In terminal is coupled to the grid of V1 by capacitor 45, both the grids of V1 and V2 being supplied with a biasing potential from battery 47 through resistor 46. The cathodes of V1 and V2 are grounded while their plates are coupled to the B+ terminal by identical resistance capacitance networks comprising resistor 52 shunted by capacitor 50 serially connected to resistor 51. Resistor 51 is much larger than resistor 52; hence, at low frequencies capacitor 50 presents a high impedance which in turn results in a high effective plate load impedance, thereby providing a high gain at low frequencies. At higher frequencies, capacitor 50 acts as a short circuit around resistor 51 and the plate load impedance is then effectively resistor 52 and the gain is then relatively low. A capacitor 45 couples the plate of tube V1 to the grid of tube V2. The plate of the latter tube is coupled by coupling capacitor 53 to the grid of tube V3, tubes V3 and V4 and associated circuitry comprising the high frequency compensation network. The grids of tubes V3 and V4 are supplied with a biasing potential from battery 61 through resistors 54 and 66 respectively. Each plate is coupled to the B+ terminal by relatively high value resistors 57. Each cathode is connected to ground by resistor 56 shunted by capacitor 55, the latter parallel network supplying a portion of the high frequency compensation in the following manner.

At lower frequencies capacitor 55 is effectively an open circuit and resistor 56 introduces degeneration into the circuit, thereby effecting a relatively low gain. At higher frequencies, capacitor 55 presents a low impedance across resistor 56 and increased gain of the triode amplifier is then realized. Additional high frequency compensation results from the characteristics of capacitor 63, resistor 64 and resistor 66, capacitor 62 serving as a coupling capacitor. The compensated signal is provided at the Out terminal by coupling the latter to the plate of tube V4 through coupling capacitor 65. The Out terminal may be coupled to a cathode follower stage when the distance between compensation network 42 and the following stage is an appreciable distance.

While the compensation network is indicated as driving the preamplifier, it may be placed between the preamplifier and the power amplifier. Those skilled in the art may also introduce the compensation directly into the power amplifier and/or the pre-amplifier without the addition of extra tubes. Other compensation networks may be designed by those skilled in the art, the circuit

described above serving only as an example of such networks.

The desired frequency response of the compensation network may be determined in the following manner. The speaker system is placed in a corner set up in an anechoic chamber and a calibrated microphone positioned to face the speaker system. A power amplifier energizes the speaker system with a signal originating from an audio oscillator, the amplifier output being adjusted so that the calibrated microphone responds to a pressure wave of constant intensity over the audio spectrum. The output voltage from the power amplifier is measured and plotted as a function of frequency to yield the desired frequency response characteristic of the compensation network.

A speaker system constructed as illustrated in Fig. 1, and utilizing twenty-two standard Carbonneau four-inch loudspeakers on a resinated fiberglass surface, which is one-eighth the surface of a sphere, with fiberglass insulation lining the inner planar surfaces of the enclosed volume, reproduced sounds recorded on a high-fidelity test record and encompassing substantially the entire audio spectrum with unusual realism, virtually free of distortion, when energized with a power amplifier coupled to the preamplifier by the compensation network of Fig. 8. Two serially-connected 11-speaker chains were connected in parallel to provide an impedance of twenty-two ohms. This combination was connected to the 16-ohm output of the power amplifier, the latter output being shunted by a 58-ohm resistor to provide the correct impedance to the amplifier.

The compactness of the novel system will be better appreciated when it is realized that the exemplary system described in the preceding paragraph utilizes a surface which is one-eighth the surface of a sphere having a radius of but nineteen inches. Yet, remarkable reproduction of the entire audio spectrum is attained, even at the low frequencies where wavelengths in air are beyond twenty feet, and much larger than the relatively small dimensions of the novel speaker system.

Typical circuit parameters for the network of Fig. 8 are:

Capacitors 53, 62 and 65	-----microfarad----	0.1
Capacitor 45	-----do-----	0.5
Capacitors 50	-----do-----	1.0
Capacitors 55	-----micromicrofarads----	220
Capacitor 63	-----do-----	5
Resistors 52	-----ohms----	560
Resistors 51	-----do-----	33,000
Resistors 57 and 66	-----do-----	100,000
Resistor 54	-----do-----	150,000
Resistor 46	-----do-----	510,000
Tubes V1, V2, V3 and C4	-----½ 12AX7-----	
Battery 47 potential	-----volt----	1.0
Grid-cathode potential tubes V3 and V4	-----volts----	-1.5
B+ potential	-----do-----	275

The novel loudspeaker systems have been illustrated as being positioned on the floor of a room in Figs. 1-4; however, it is to be understood that the planar surfaces may be oriented in any manner. For example, the embodiment of Fig. 1 may be positioned in a corner of the room formed by the ceiling and two walls. This is especially advantageous in a room with a rug on the floor, the rug serving to subdue reflections and reduce the effects of standing waves.

While the particular embodiment described herein has been directed to spherical surfaces with a plurality of loudspeakers thereon, the inventive concepts are not to be construed as limited thereby. For example, those skilled in the art may construct electrostatic loudspeakers having vibrating spherical surfaces according to the invention. Other loudspeaker covered surfaces may be employed to generate the desired spherical waves by prop-

erly phasing the energy applied to the loudspeakers to create a constant phase front equidistant from a point of origin. Furthermore, some of the advantages of the invention may be derived by enclosing a volume with three orthogonal planar surfaces and a speaker covered surface without departing from the inventive concepts.

Although the examples described in detail herein have concerned loudspeaker systems, the principles of the invention are equally applicable wherever it is desired to generate spherical pressure waves in an acoustic medium. For example, the inventive concepts may be employed for generating pressure waves in water, such as might be utilized in connection with fathometer or sonar systems. Another use of the invention concepts may be found in the delay line art wherein it is sought to generate pressure waves in acoustic mediums such as mercury.

It is apparent that those skilled in the art may make numerous modifications of and departures from the particular embodiments described herein without departing from the inventive concepts. Consequently, the invention is to be construed as limited only by the spirit and scope of the appended claims.

What is claimed is:

1. For generating pressure waves in an acoustic medium, apparatus comprising a surface defined by points substantially equidistant from a point of origin, means including said surface for enclosing a substantially fluid-tight volume, and means responsive to an electrical signal for imparting in substantial time coincidence substantially equal forces upon said medium at and substantially orthogonal to said surface along nearly the entire area of said surface to propagate a substantially spherical wave through said medium whereby a substantially smooth matching of the boundary conditions along said surface is obtained.

2. For generating pressure waves in an acoustic medium, apparatus comprising a surface defined by points substantially equidistant from a point of origin, means including said surface for enclosing a substantially fluid-tight volume, and means for cyclically imparting in substantial time coincidence substantially equal forces upon said medium at and substantially orthogonal to said surface along nearly the entire area of said surface to propagate a substantially spherical wave through said medium whereby a substantially smooth matching of the boundary conditions along said surface is obtained.

3. For generating pressure waves in an acoustic medium, apparatus comprising, a surface defined by points substantially equidistant from a point of origin, means including said surface for enclosing a substantially fluid-tight volume, and means responsive to an electrical signal for setting up pressure variations of substantially equal magnitude in said medium at and substantially orthogonal to said surface along nearly the entire area of said surface.

4. Apparatus for generating pressure waves in an acoustic medium comprising, an outward surface which at least partially encloses a volume having a point of origin, means including said surface for enclosing said volume substantially fluid-tight, and means responsive to an electrical signal for imparting forces upon said medium along nearly the entire area of said outward surface to propagate a substantially spherical wave through said medium, said wave having a substantially inphase pressure front along a reference surface within said medium, outside said volume and defined by points substantially equidistant from said point of origin, at least one of said points lying upon said outward surface, whereby a substantially smooth matching of the boundary conditions along said outward surface is obtained.

5. The apparatus of claim 4, wherein said outward surface is the surface of a sphere.

6. The apparatus of claim 4 wherein said outward surface is the curved surface of a hemisphere.

7. The apparatus of claim 4 wherein said outward surface is the curved surface of one-fourth of a sphere.

8. The apparatus of claim 4 wherein said outward surface is the curved surface of one-eighth of a sphere.

9. Apparatus for generating sonic waves comprising, a volume having a point of origin and enclosed substantially fluid-tight by a surface, at least a portion of said surface being curved and defined by points which lie substantially equidistant from said point of origin, and a plurality of closely-spaced loudspeakers disposed upon substantially the entire curved surface.

10. Apparatus for generating sonic waves comprising, a volume having a point of origin and enclosed substantially fluid-tight by a surface, at least a portion of said surface being substantially curved and defined by points which lie substantially equidistant from said point of origin, a plurality of closely-spaced loudspeakers disposed upon substantially the entire curved surface and oriented to emit sonic waves outward relative to said volume in response to an electrical signal, a voice coil and diaphragm associated with each loudspeaker, input terminals, and means for coupling the voice coils of said loudspeakers to said input terminals whereby the diaphragms of said loudspeakers move in the same direction relative to said curved surface in response to the application of an electrical signal to said input terminals.

11. The apparatus of claim 10 wherein the curved surface is the surface of a sphere.

12. The apparatus of claim 10 wherein the curved surface is the curved surface of a hemisphere.

13. The apparatus of claim 10 wherein the curved surface is the curved surface of one-fourth of a sphere.

14. The apparatus of claim 10 wherein the curved surface is the curved surface of one-eighth of a sphere.

15. Apparatus for generating sonic waves comprising, a volume enclosed substantially fluid-tight by a surface having a substantially curved portion and at least one planar portion, and a plurality of closely-spaced loudspeakers disposed upon nearly the entire surface of said curved portion and responsive in phase to an electrical input signal.

16. Apparatus for generating sonic waves comprising, a volume enclosed substantially fluid-tight by a surface having a substantially curved portion and at least one planar portion, a plurality of closely-spaced loudspeakers disposed upon substantially the entire curved portion and oriented to emit sonic waves outward relative to said volume in response to an electrical signal, input terminals, a voice coil and diaphragm associated with each loudspeaker, and means for coupling the voice coils of said loudspeakers to said input terminals whereby the diaphragms move in the same direction relative to the curved portion in response to the application of an electrical signal to said input terminals.

17. Apparatus for generating sonic waves comprising, a volume enclosed substantially fluid-tight by a substantially hemispherical surface, a plurality of closely-spaced loudspeakers disposed upon substantially the entire curved portion of said surface and oriented to emit sonic waves outward relative to said volume in response to an electrical signal, input terminals, a voice coil and diaphragm associated with each speaker, and means for coupling the voice coils of said loudspeakers to said input terminals whereby the diaphragms move in the same direction relative to said curved portion in response to the application of an electrical signal to said input terminals.

18. Apparatus for generating sonic waves comprising, a volume enclosed substantially fluid-tight by a plurality of intersecting orthogonal planar surfaces and a curved surface which is a portion of a spherical surface, a plurality of closely-spaced loudspeakers disposed upon substantially the entire curved surface and oriented to emit sonic waves outward relative to said volume in response to an electrical signal, input terminals, a voice coil and diaphragm associated with each speaker, and means for

coupling the voice coils of said loudspeakers to said input terminals whereby the diaphragms move in the same direction relative to said curved surface in response to the application of an electrical signal to said input terminals.

19. The apparatus of claim 18 wherein there are two planar surfaces and said curved surface is the curved surface of one-fourth of a sphere.

20. The apparatus of claim 18 wherein there are three planar surfaces and said curved surface is the curved surface of one-eighth of a sphere.

21. Apparatus for generating pressure waves in an acoustic medium within a relatively large volume, comprising a relatively small substantially fluid-tight volume bounded by a curved surface defined by points substantially equidistant from a point of origin within said small volume and one or more planar surfaces which are coplanar with at least some of the bounding surfaces of said large volume, said planar surfaces being along radii which extend from said point of origin to said curved surface, and means responsive to an electrical signal for setting up pressure variations of substantially equal magnitude in said medium at and substantially orthogonal to said surface.

22. For generating pressure waves in an acoustic medium, apparatus comprising a surface defined by points substantially equidistant from a point of origin, means including said surface for enclosing a substantially fluid-tight volume, and means responsive to electrical signals, including low frequency electrical signals, for imparting in substantial time coincidence substantially equal forces upon said medium at and substantially orthogonal to said surface along nearly the entire area of said surface to propagate a substantially spherical wave through said medium whereby a substantially smooth matching of the boundary conditions along said surface is obtained, the distance between said point of origin and said surface being less than the wavelength of a wave generated in said medium in response to said low frequency signals.

23. Apparatus for generating sonic waves comprising, a substantially fluid-tight volume bounded by three intersecting orthogonal planes and a three-edged surface, a plurality of closely-spaced loudspeakers disposed upon substantially the entire three-edged surface and oriented to emit sonic waves outward relative to said volume in response to an electrical signal, input terminals, a voice coil and diaphragm associated with each loudspeaker, and means for coupling the voice coils of said loudspeakers to said input terminals whereby the diaphragms move in the same direction relative to said three-edged surface in response to the application of an electrical signal to said input terminals.

24. Apparatus for generating sonic waves in air comprising, a substantially fluid-tight volume bounded by three intersecting orthogonal planes and a continuous surface having portions thereof which are oriented relative to said planes at an angle different from ninety degrees, and means responsive to an electrical signal for setting up pressure variations of substantially equal magnitude in the air at and substantially orthogonal to said surface along nearly the entire area of said surface.

25. Apparatus for generating sonic waves in air comprising, a substantially fluid-tight volume bounded by three intersecting orthogonal planes and a continuous surface having portions thereof which are oriented relative to said planes at an angle different from ninety degrees, a plurality of closely-spaced loudspeakers disposed upon substantially the entire continuous surface and oriented to emit sonic waves outward relative to said volume in response to an electrical signal, input terminals, a voice coil and diaphragm associated with each loudspeaker, and means for coupling the voice coils to said input terminals whereby the diaphragms move in the same direction relative to said continuous surface in response to the application of an electrical signal to said input terminals.

26. Apparatus for generating sonic waves in air comprising, a substantially fluid-tight volume bounded by three intersecting orthogonal planes and a continuous surface having portions thereof which are oriented relative to said planes at an angle different from ninety degrees, and a plurality of closely-spaced loudspeakers disposed upon substantially the entire continuous surface.

27. A loudspeaker baffle comprising, a surface defined by points substantially equidistant from a point of origin, means including said surface for substantially fully enclosing a volume, and a plurality of closely-spaced openings therein arranged whereby a loudspeaker may be secured to said surface about an opening the spacing between adjacent openings being less than the maximum distance across any one of said openings.

28. A loudspeaker baffle comprising, a surface defined by points substantially equidistant from a point of origin, a plurality of closely-spaced openings therein which are small enough to enable an associated loudspeaker to surround each opening when secured to said surface and large enough to enable substantially the entire loudspeaker diaphragm to be exposed, and means including said surface for substantially fully enclosing a volume, the spacing between adjacent openings being less than the maximum distance across any one of said openings.

29. The loudspeaker baffle of claim 28 wherein said surface is the surface of a sphere.

30. The loudspeaker baffle of claim 28 wherein said surface is the curved surface of a hemisphere.

31. The loudspeaker baffle of claim 28 wherein said surface is the curved surface of one-fourth of a sphere.

32. The loudspeaker baffle of claim 28 wherein said surface is the curved surface of one-eighth of a sphere.

33. Apparatus for radiating sonic waves into a first relatively large volume comprising, means for enclosing a substantially fluid-tight second volume much smaller than said first volume, that portion of said enclosing means exposed to said first volume being a substantially spherical surface, any other portions of said enclosing means being surfaces generally parallel to bounding surfaces of said large volume, said spherical surface being formed with a plurality of closely-spaced openings covered by vibratable diaphragms, and means responsive to an electrical signal for vibrating said diaphragms in phase in a direction generally perpendicular to said spherical surface.

34. Apparatus in accordance with claim 33 wherein said portion of said enclosing means exposed to said first volume is a full spherical surface.

35. Apparatus in accordance with claim 33 wherein said portion of said enclosing means exposed to said first volume is a hemispherical surface.

36. Apparatus in accordance with claim 33 wherein said portion of said enclosing means exposed to said first volume subtends a solid angle of $\pi/2$ radians.

37. Apparatus in accordance with claim 33 wherein said portion of said enclosing means exposed to said first volume subtends a solid angle of $\pi/4$ radians.

References Cited in the file of this patent

UNITED STATES PATENTS

1,687,231	Speed	Oct. 9, 1928
2,352,696	DeBoer	July 4, 1944
2,629,044	Marfisi	Feb. 17, 1953