US007551062B2

(12) United States Patent
Croft, III et al.

(10) Patent No.: US 7,551,062 B2
(45) Date of Patent: Jun. 23, 2009

(54) **DIRECTIONAL ACOUSTIC DEVICE**

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(73) Assignee: **American Technology Corporation**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/901,270**

(22) Filed: **Sep. 14, 2007**

(65) **Prior Publication Data**

US 2008/0129470 A1 Jun. 5, 2008

Related U.S. Application Data

(63) Continuation of application No. PCT/US2006/009358, filed on Mar. 14, 2006.

(60) Provisional application No. 60/661,812, filed on Mar. 14, 2005, provisional application No. 60/672,608, filed on Apr. 19, 2005, provisional application No. 60/710,425, filed on Aug. 22, 2005, provisional application No. 60/714,646, filed on Sep. 7, 2005.

(51) **Int. Cl.**
G08B 3/10 (2006.01)

(52) **U.S. Cl.** **340/384.7**; 340/384.73; 340/384.1; 367/93; 367/94

(58) **Field of Classification Search** 340/384.7, 340/384.73, 384.1; 367/93, 94
See application file for complete search history.

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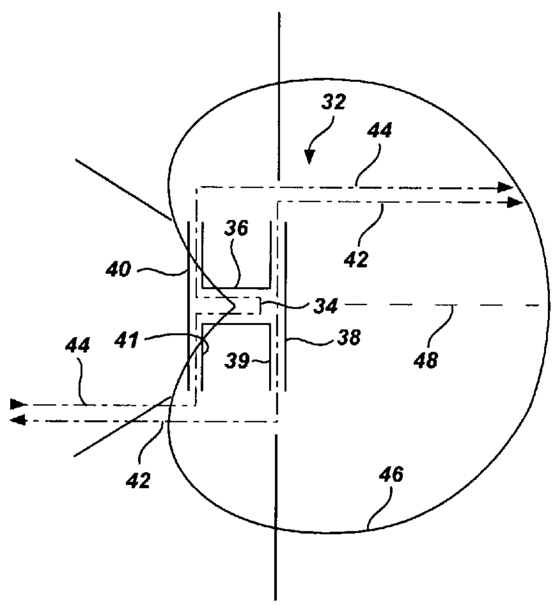
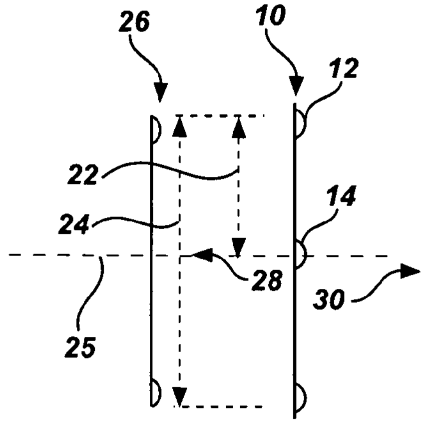
Primary Examiner—Toan N Pham
Assistant Examiner—Travis R Hunnings
(74) *Attorney, Agent, or Firm*—Thorpe North & Western LLP

(57) **ABSTRACT**

A directional acoustic device configured for producing a directional output along an acoustic axis, including at least one transducer configured to create at least two wave trains which are directed along differing pathways by at least one wave guide, and so disposed that in directions more than ninety degrees off the acoustic axis the SPL of the output is greatly diminished by cancellation effects between the wave trains; improvement over previous gradient and quarter-wave pipe directional systems being enabled.

46 Claims, 34 Drawing Sheets





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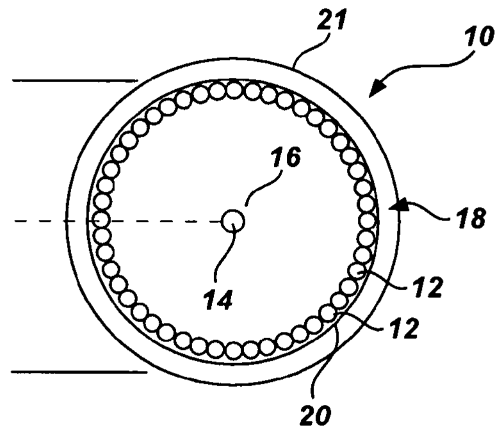

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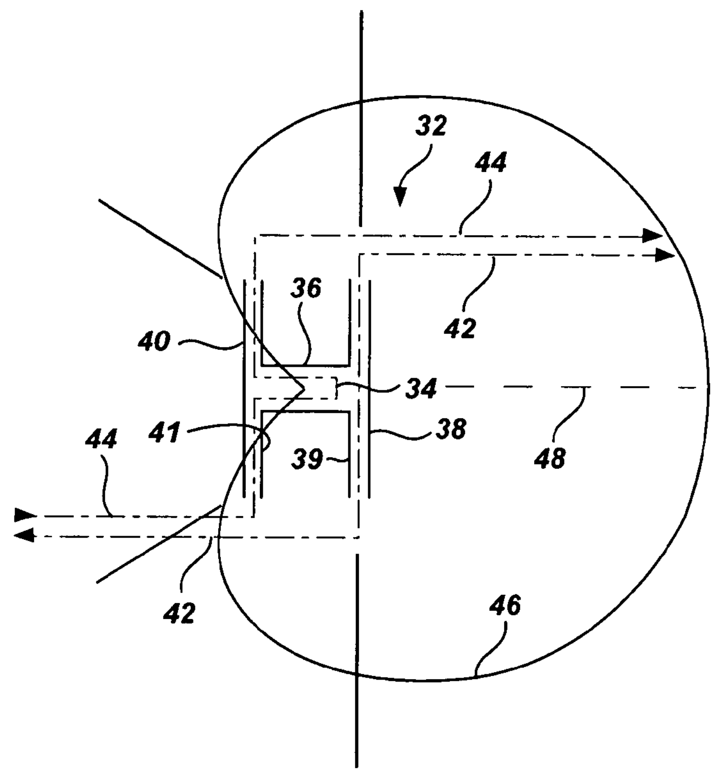

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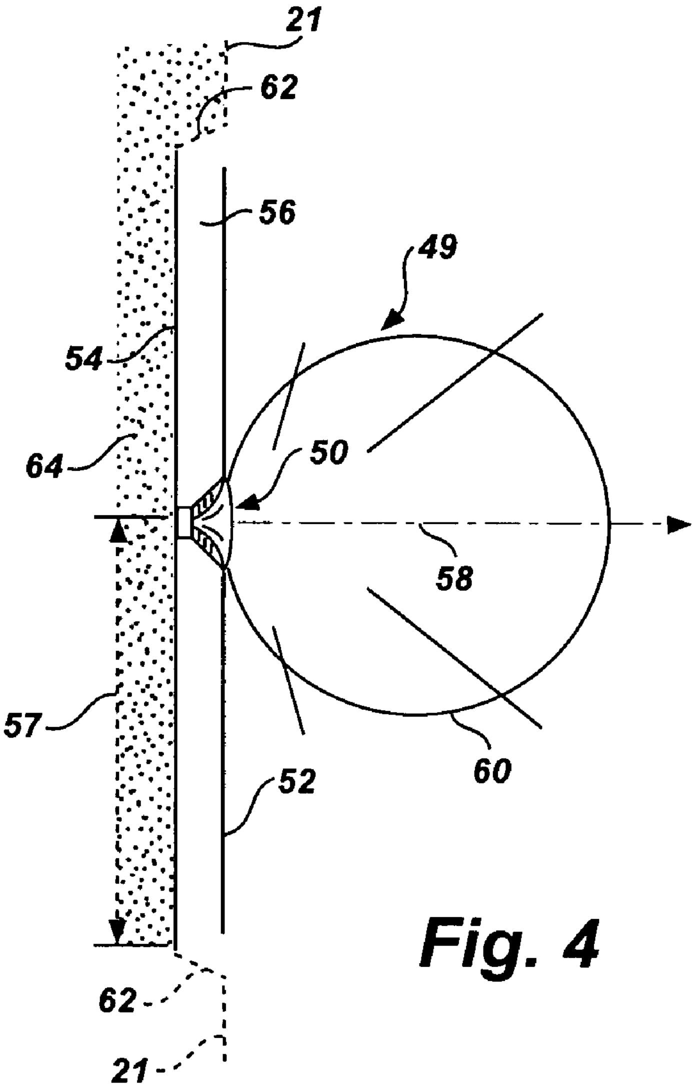

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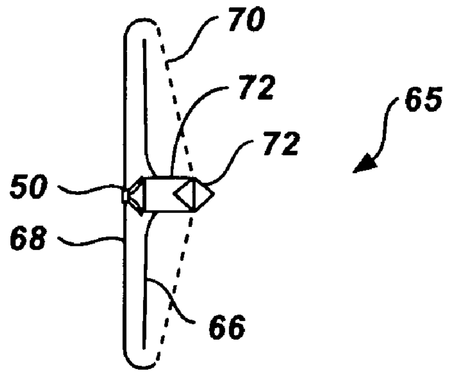

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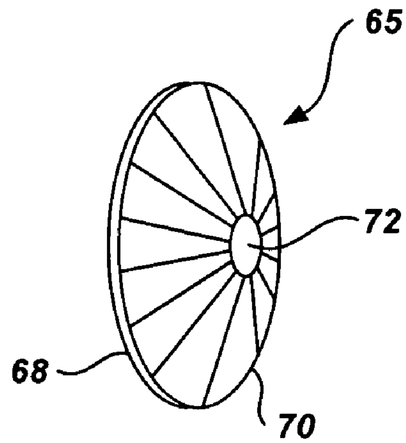

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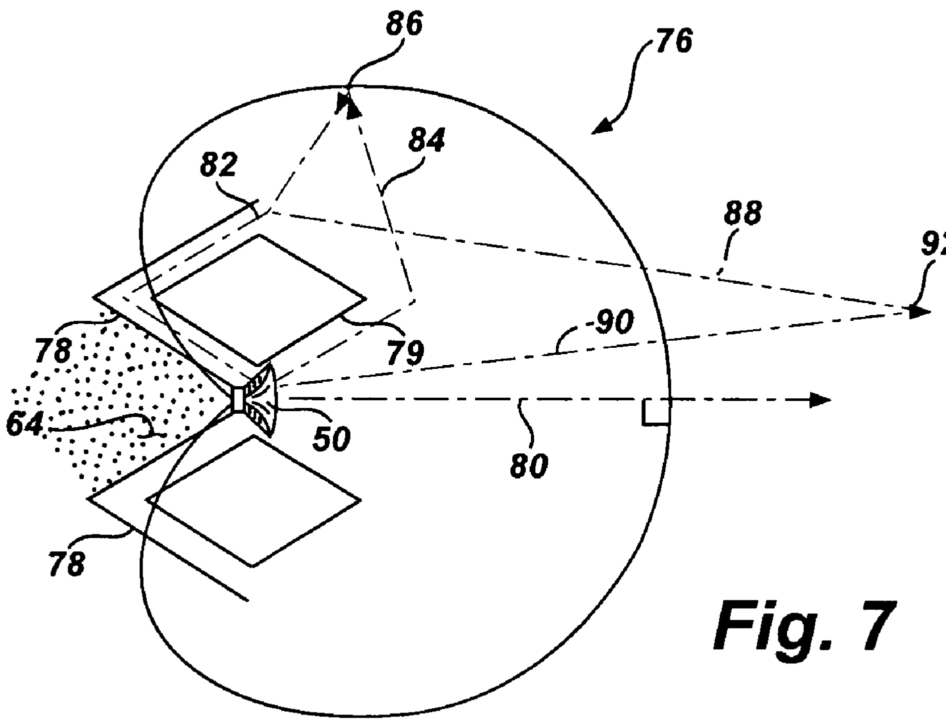
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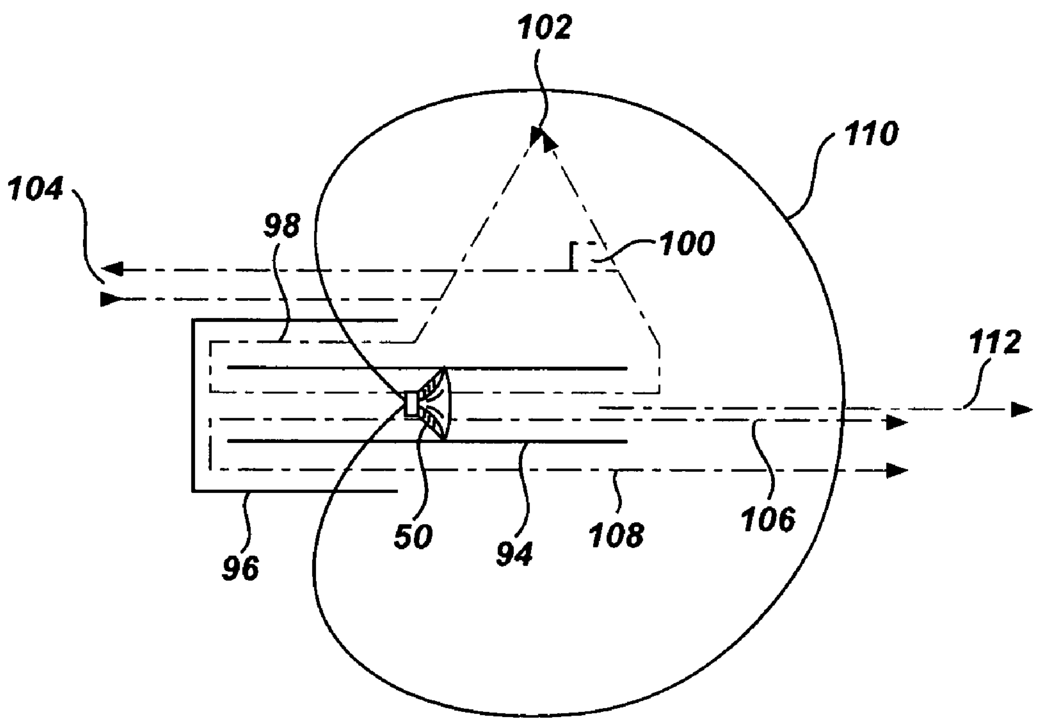
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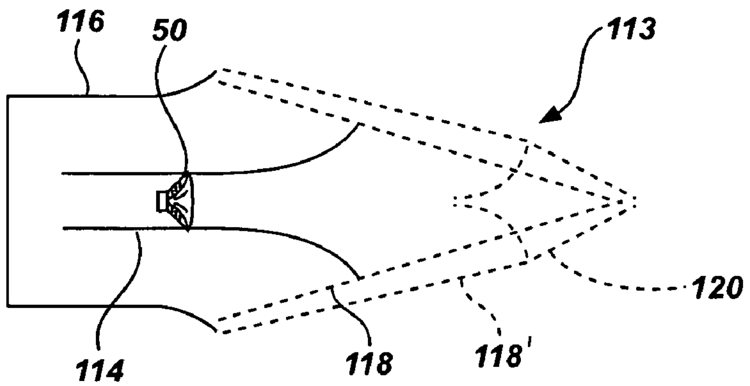

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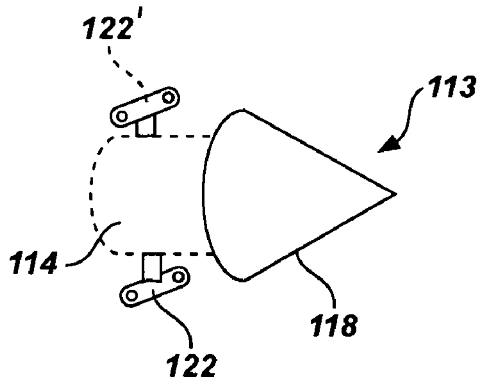

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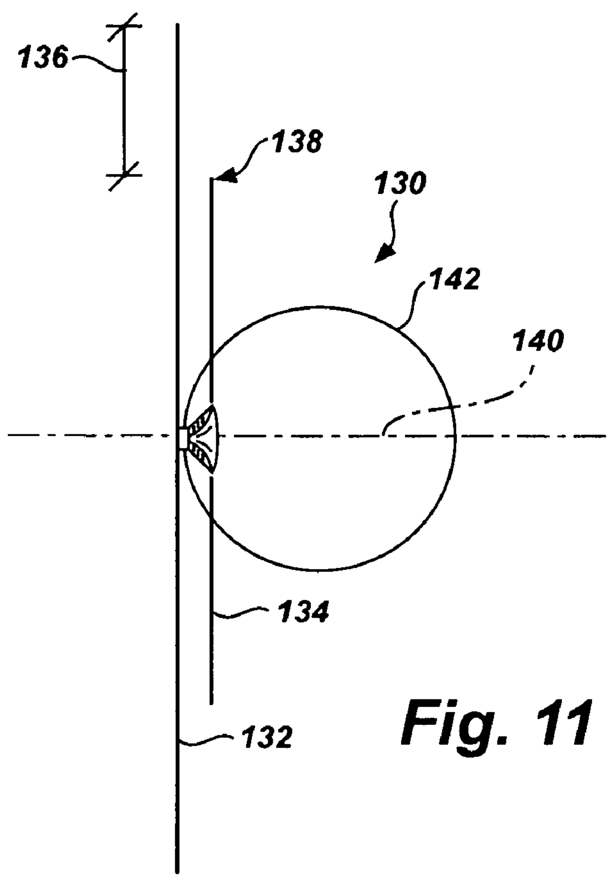

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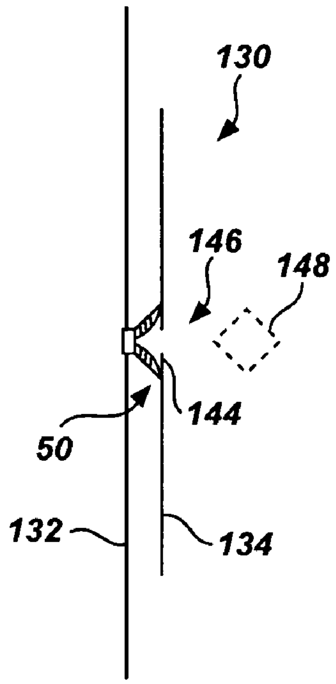

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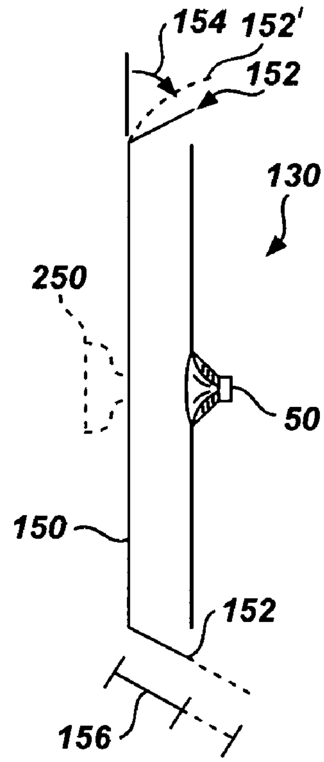

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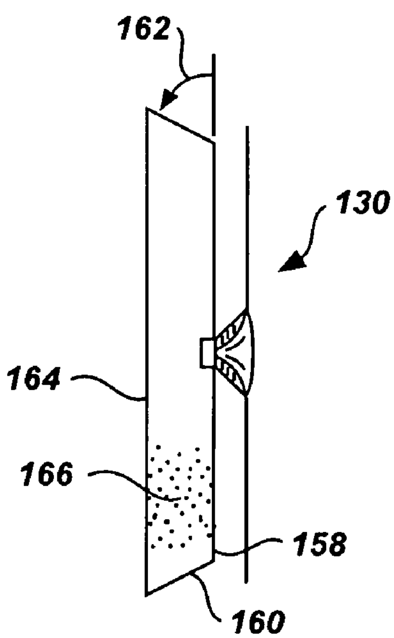

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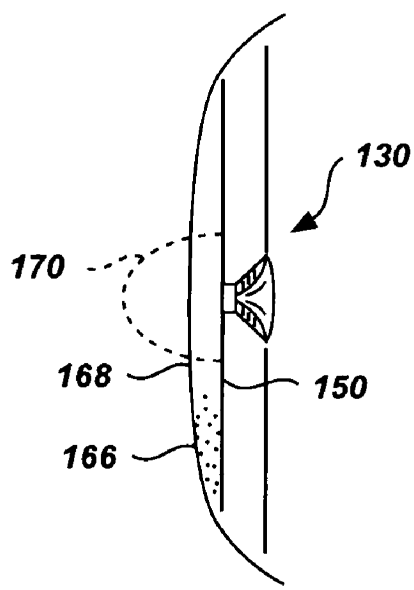

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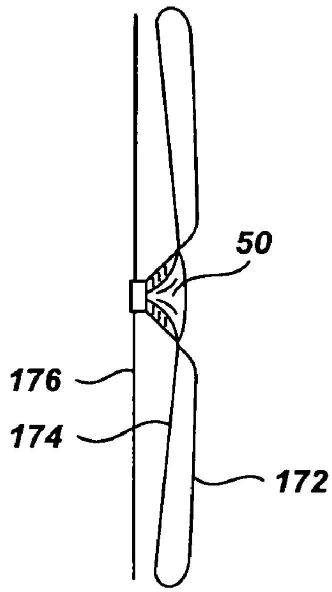

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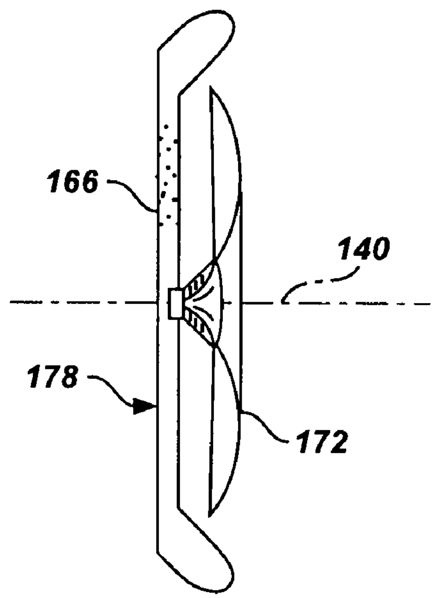

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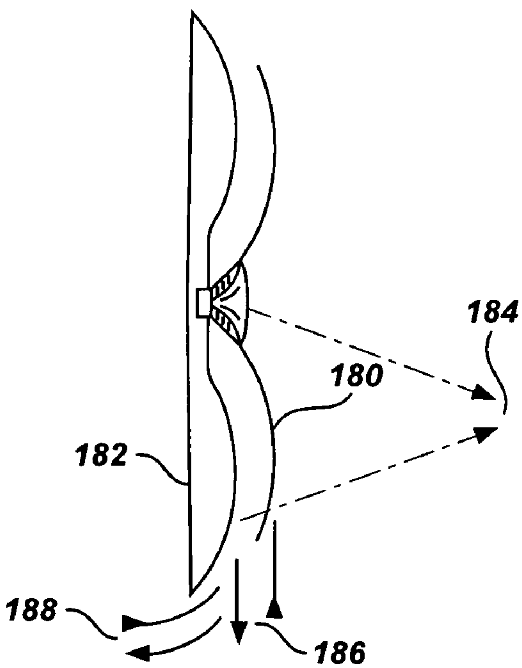

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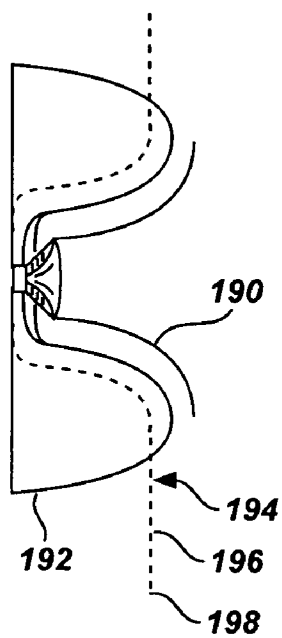

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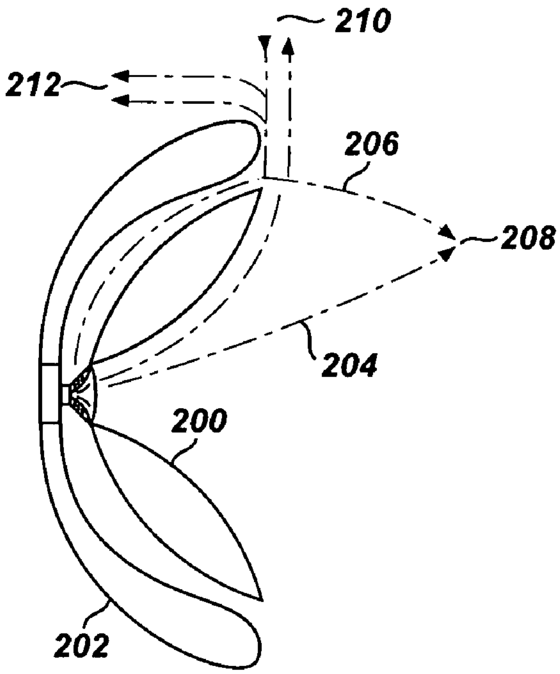

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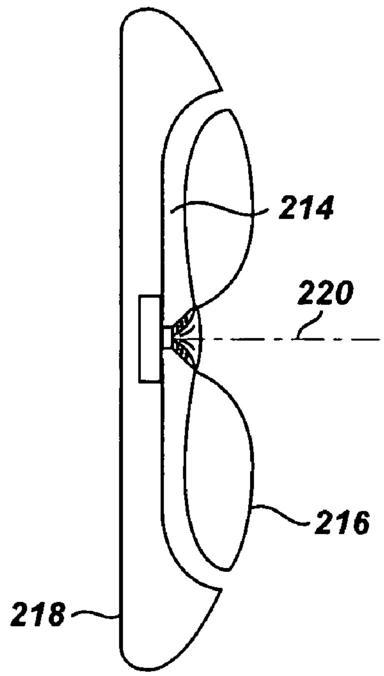

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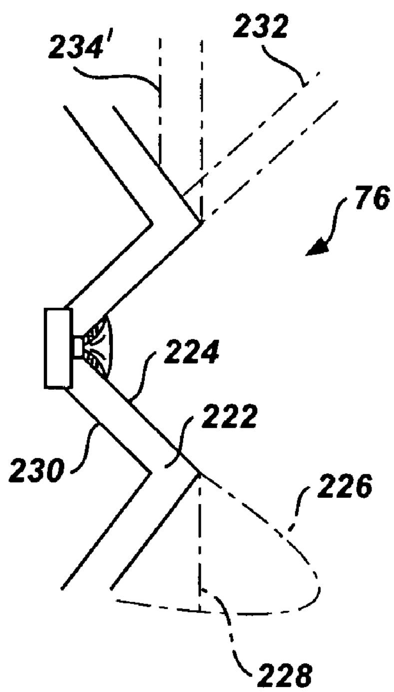

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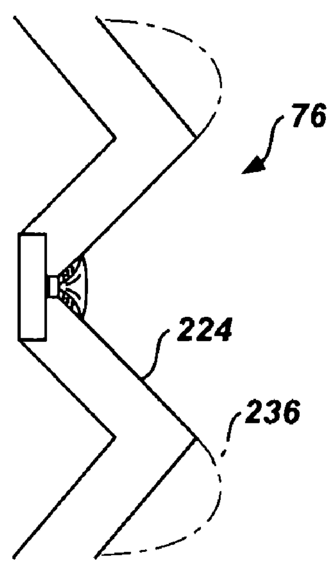

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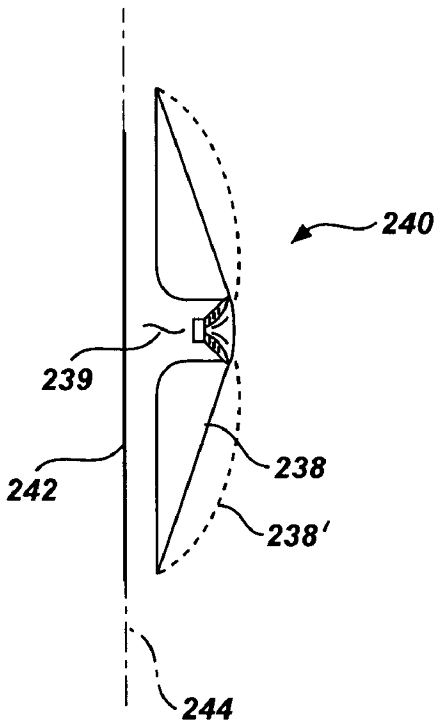

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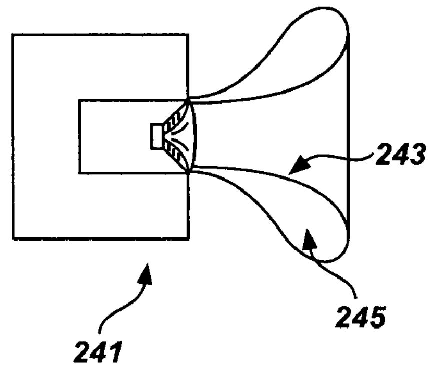

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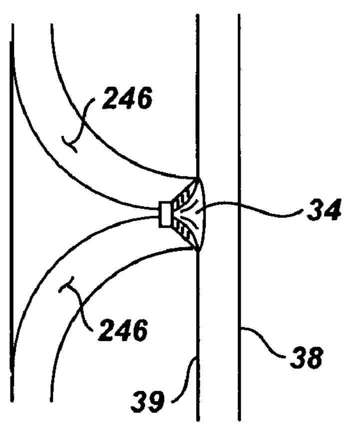

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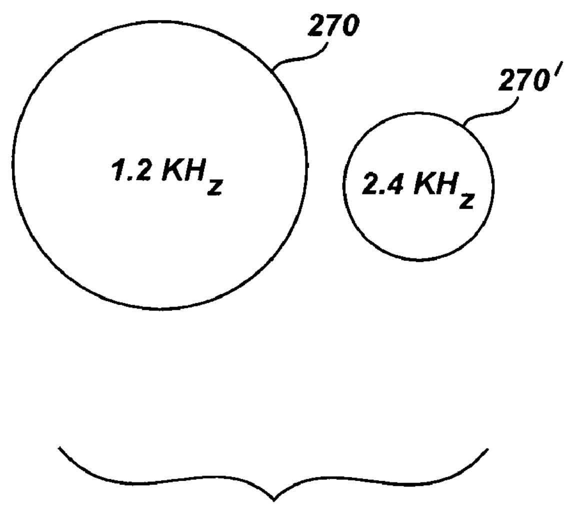

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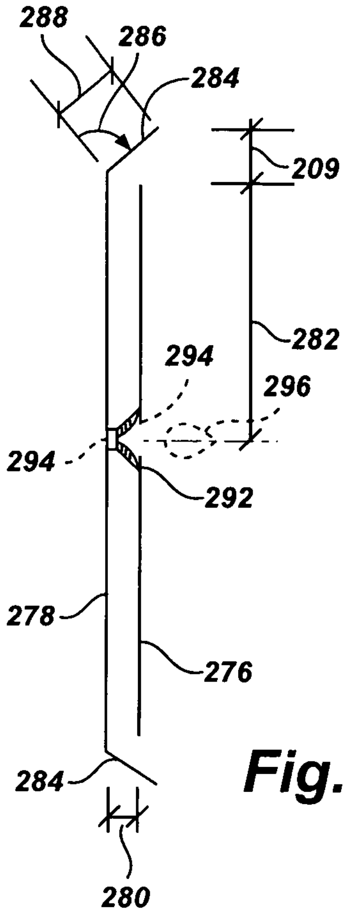

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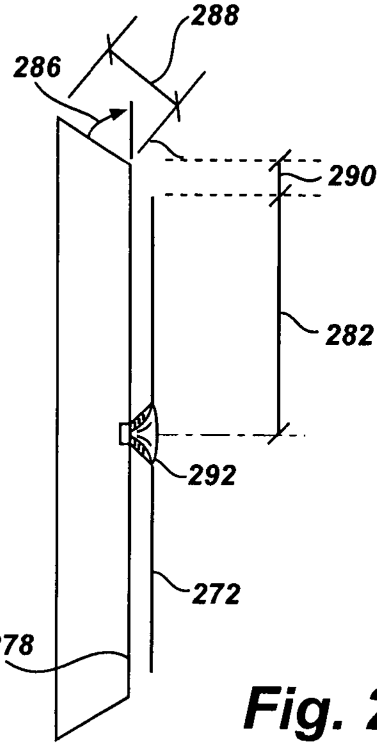

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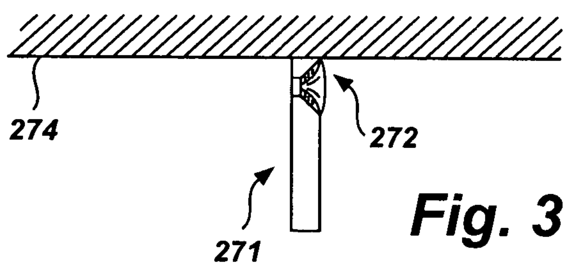

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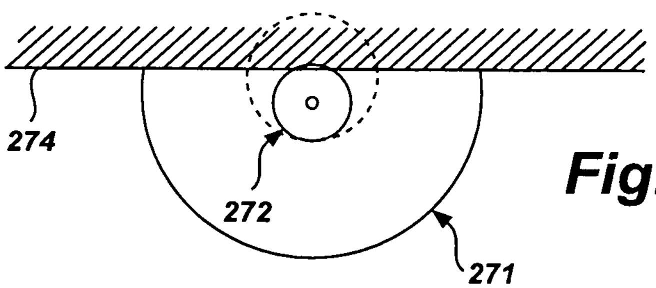

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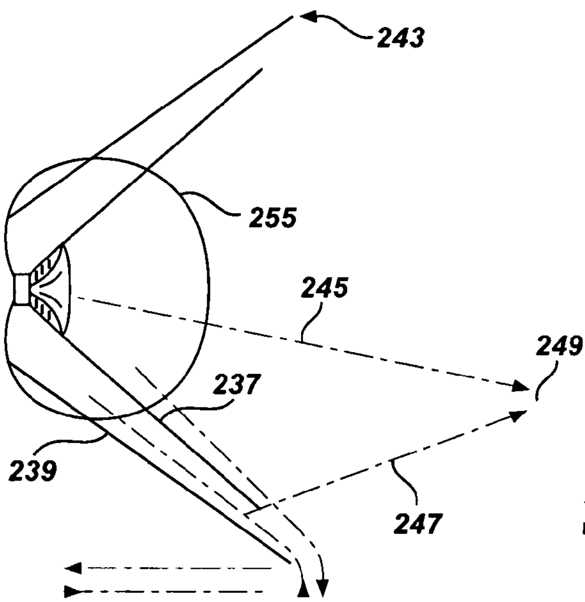

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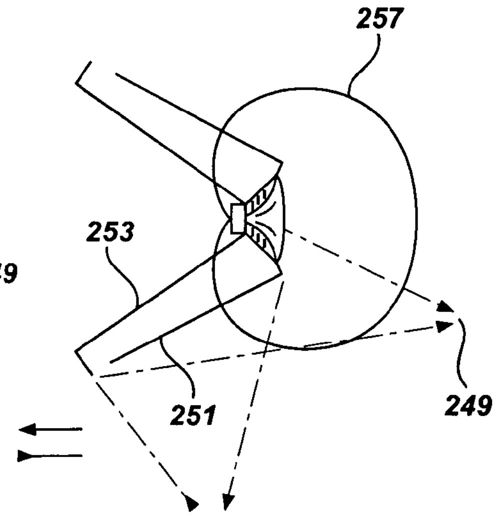

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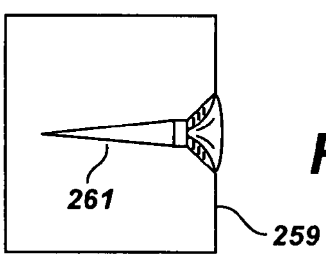

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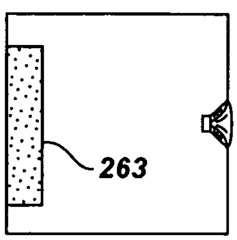

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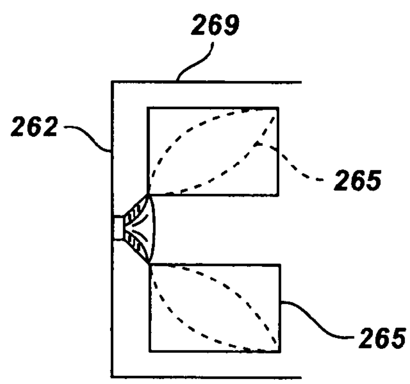

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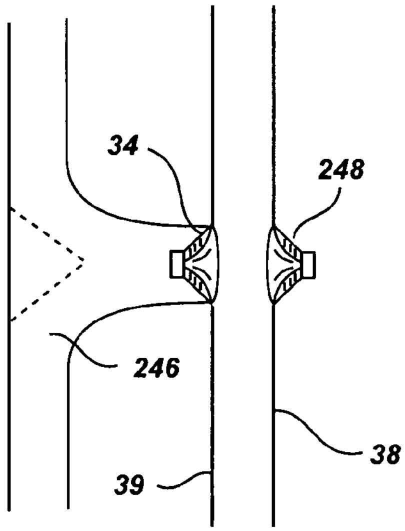

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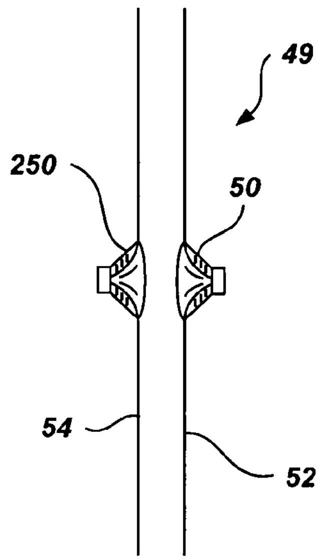

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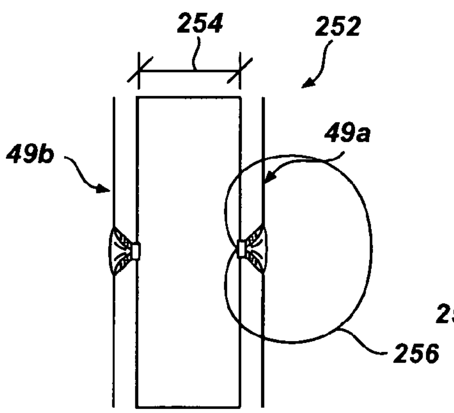

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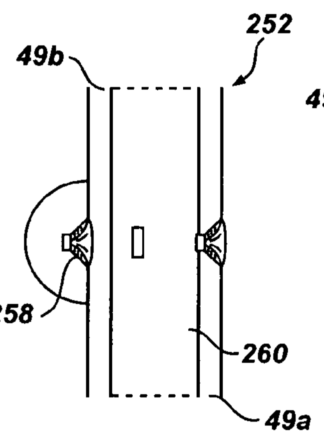

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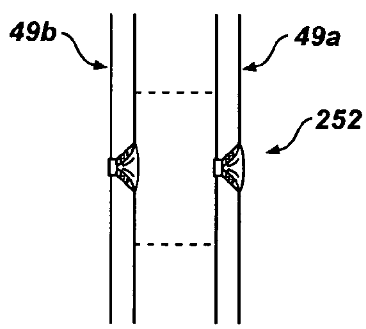

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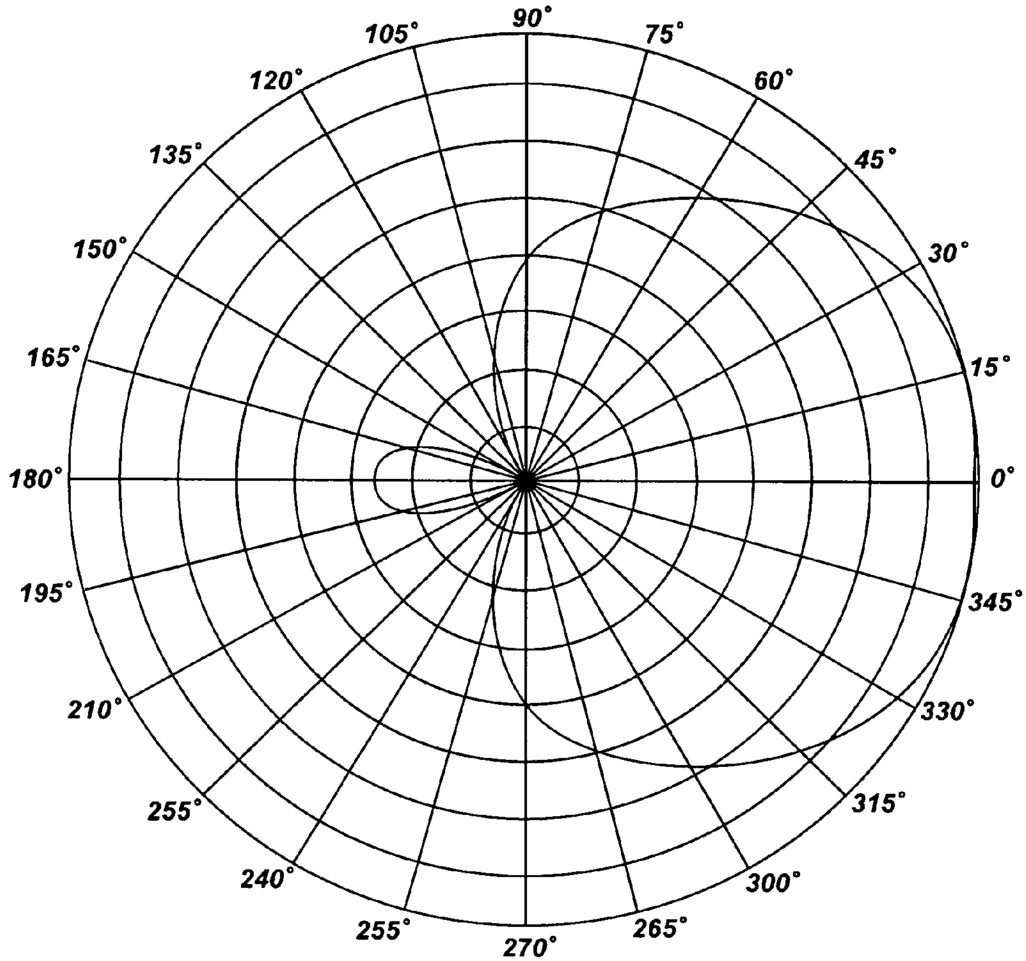

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Outer = 99.7dBs

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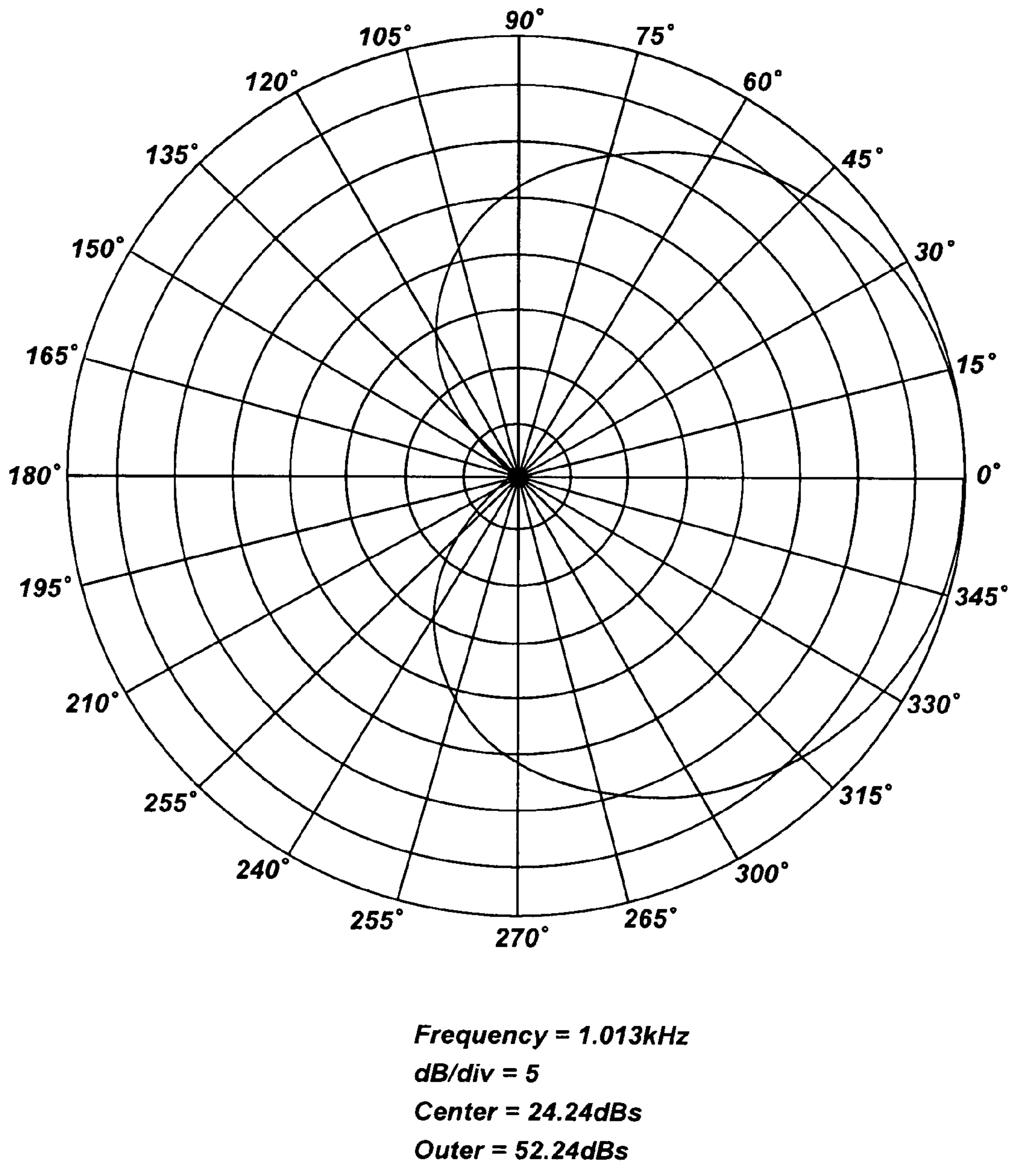
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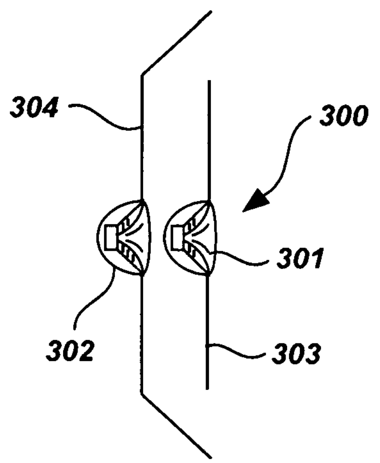
Fig. 42



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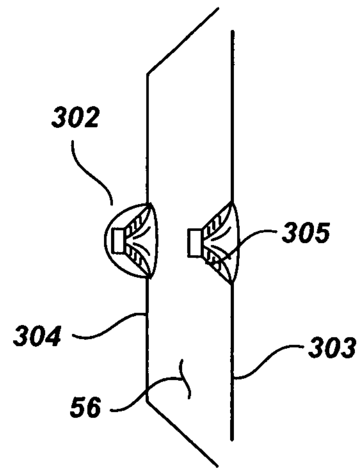

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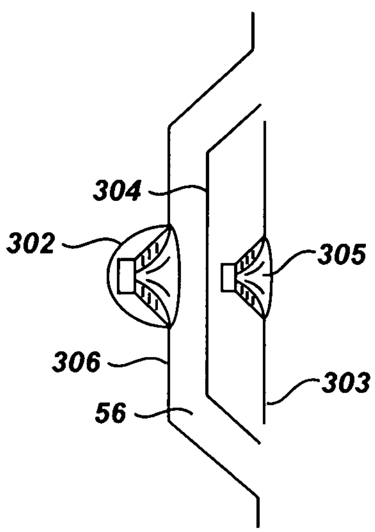

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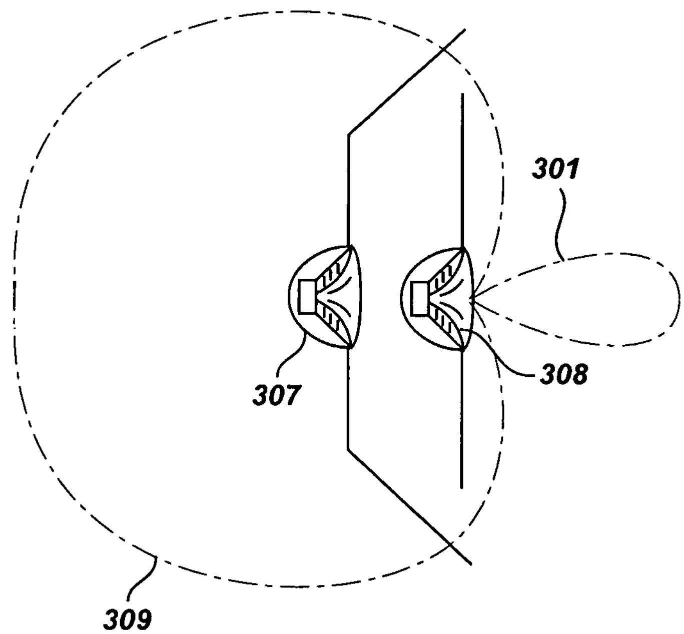

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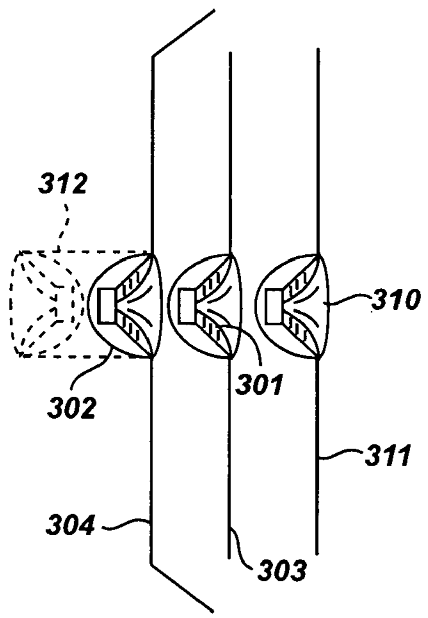

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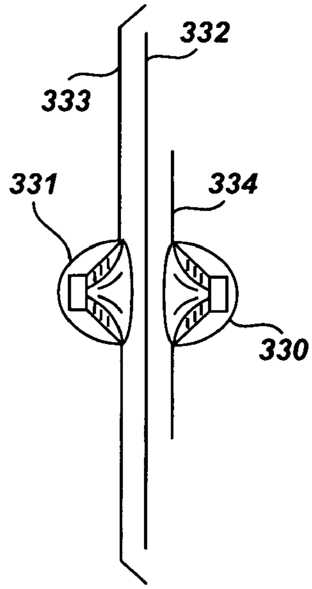

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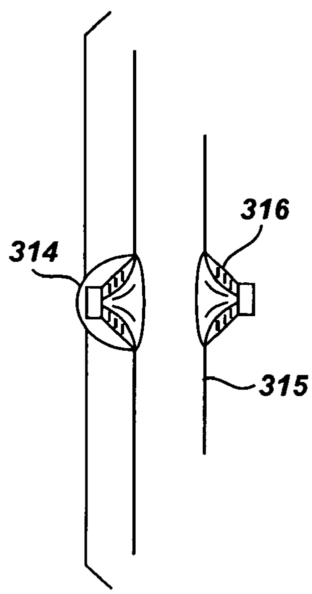

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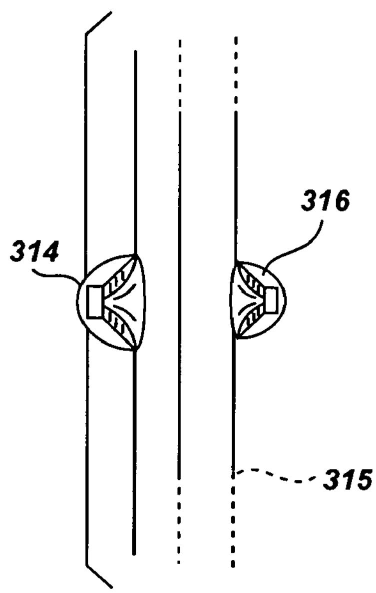

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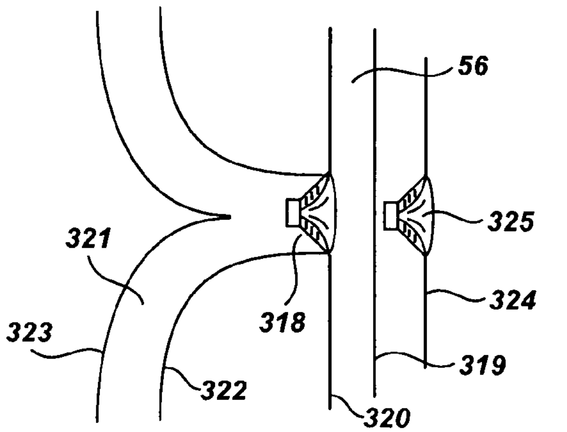

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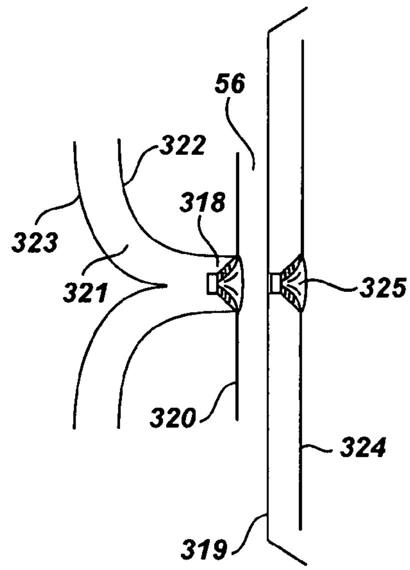

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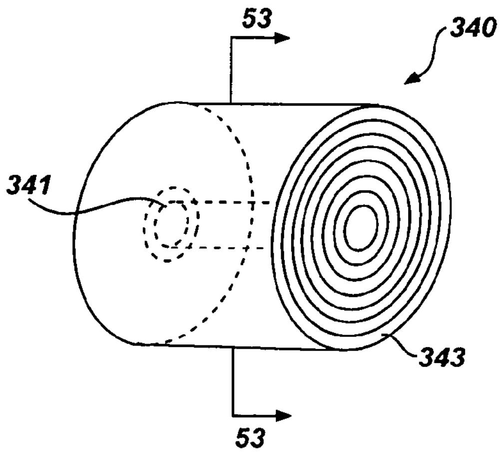

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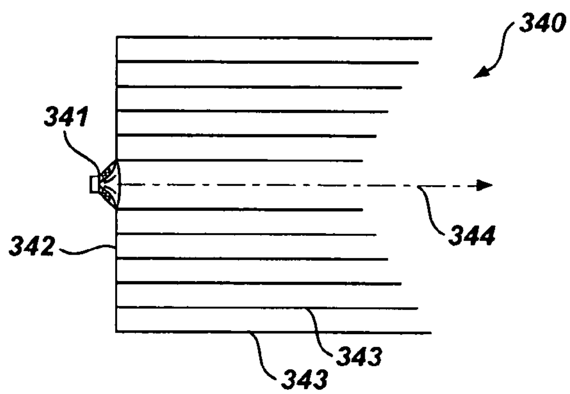

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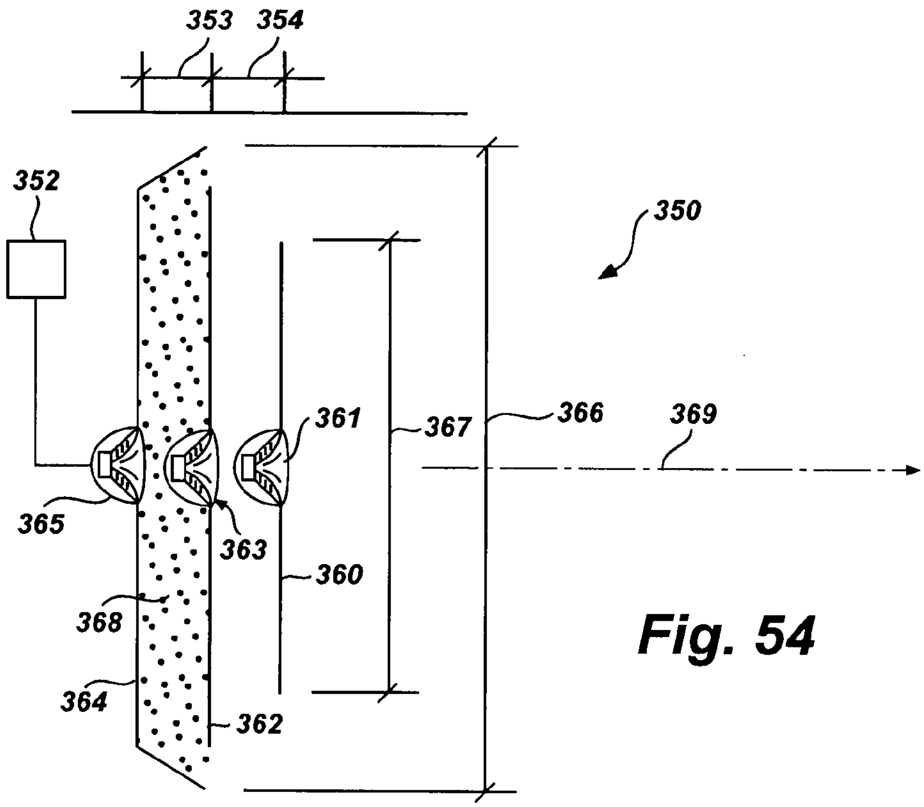
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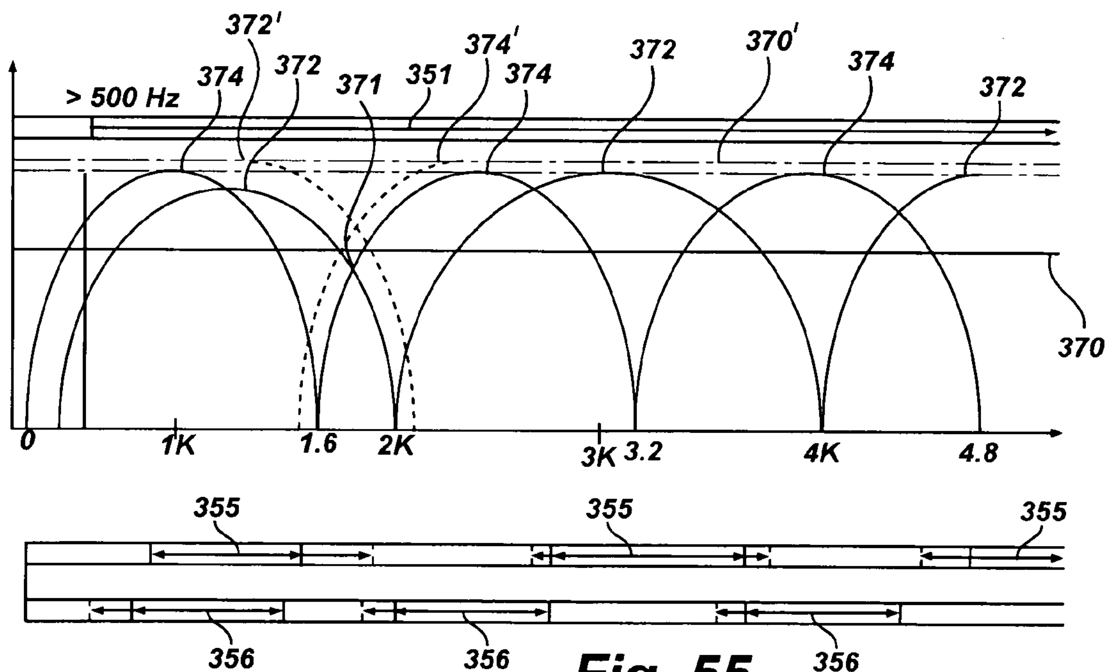
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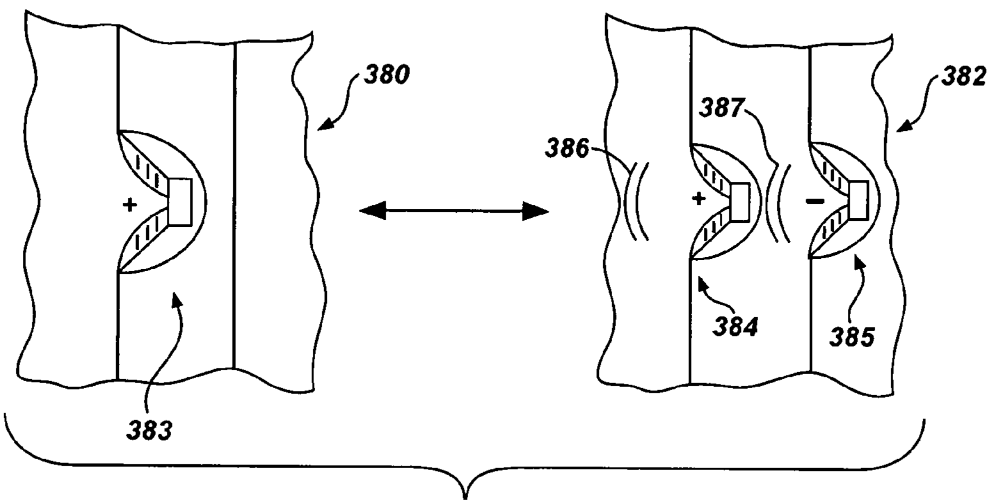
Fig. 55



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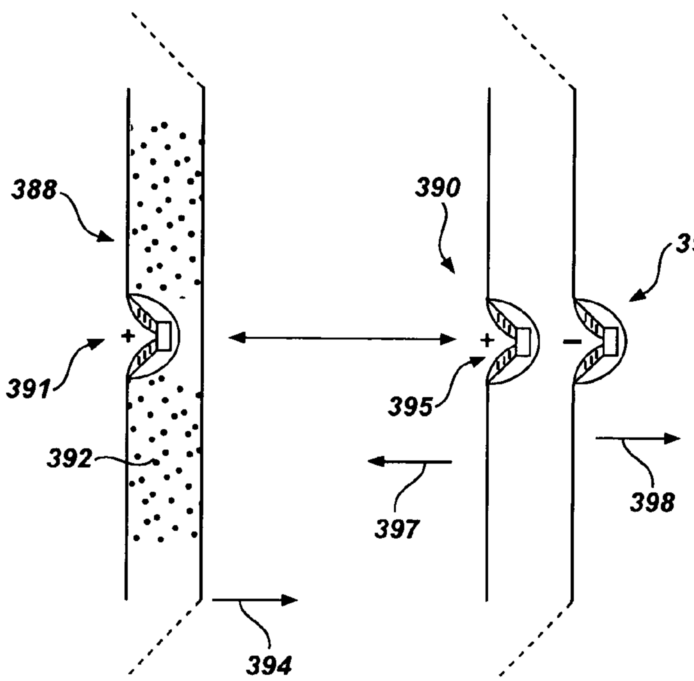

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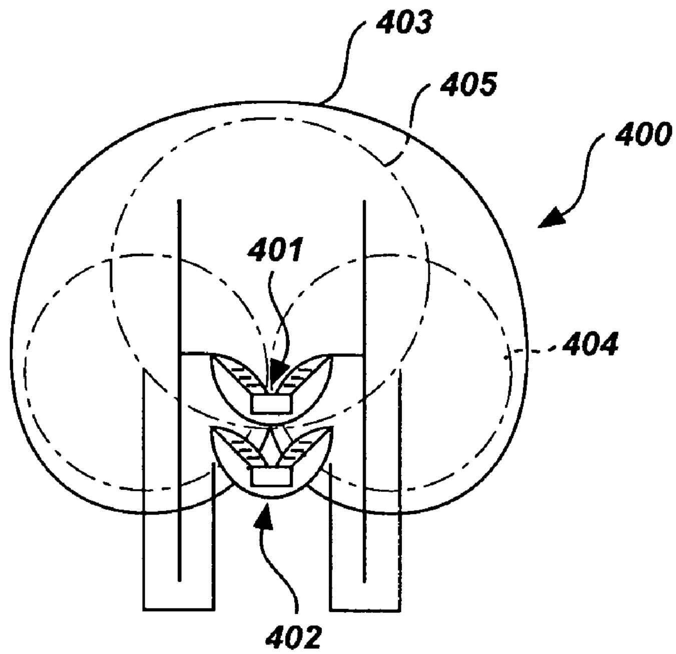

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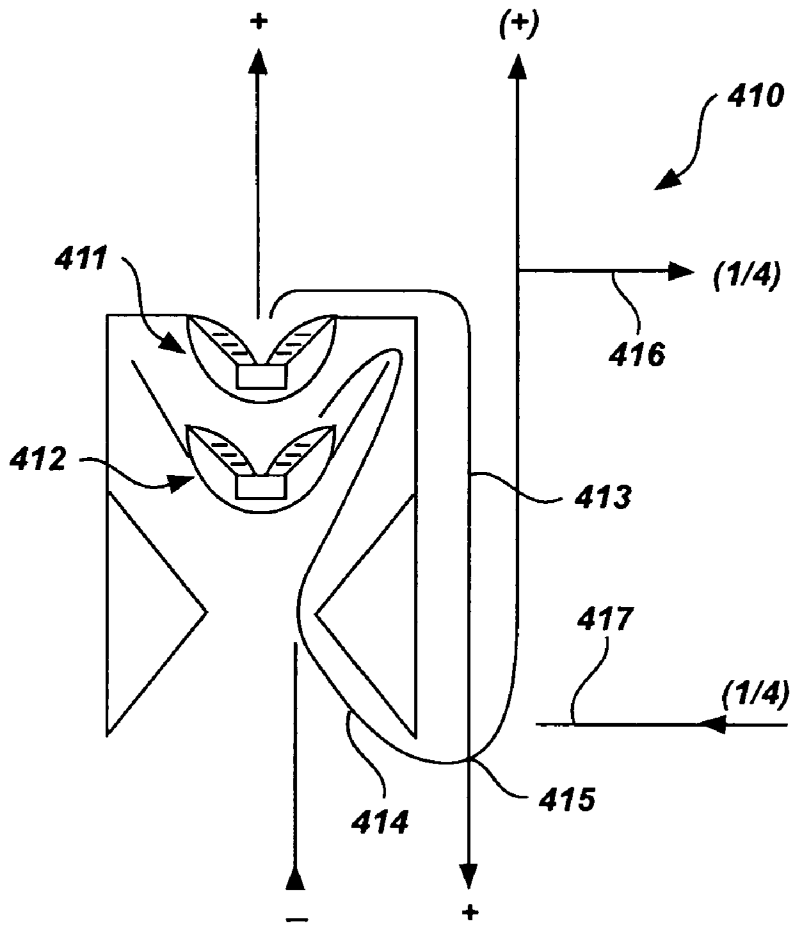

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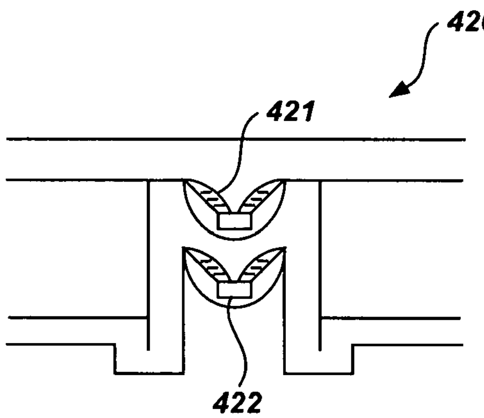

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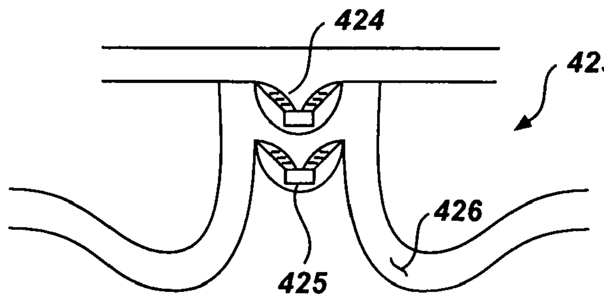


Fig. 61

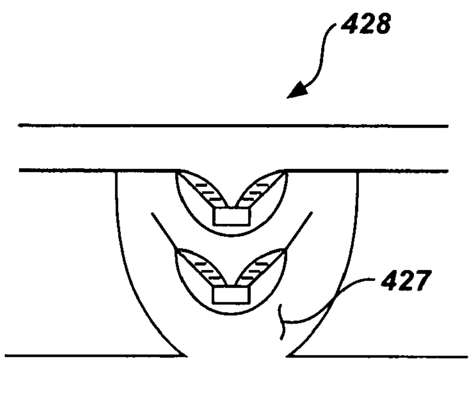


Fig. 62

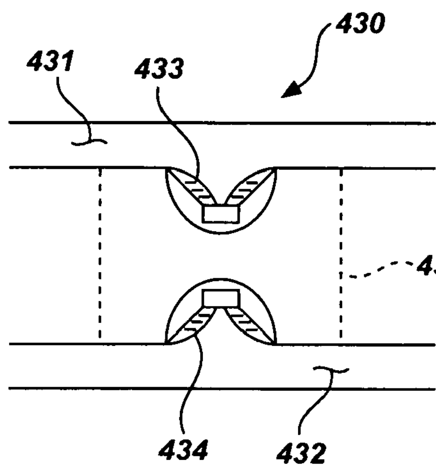


Fig. 63

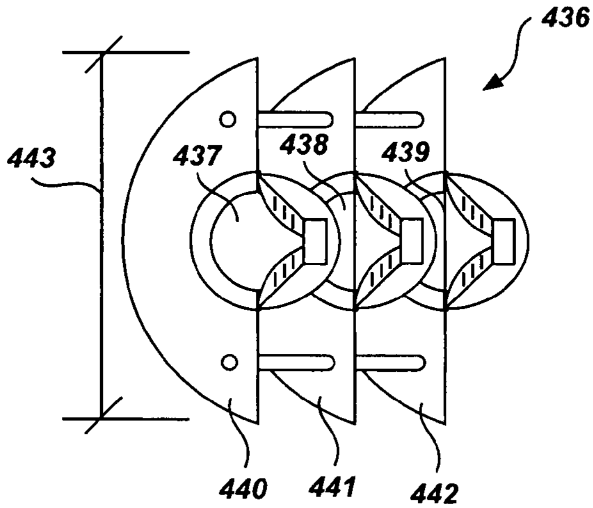


Fig. 64

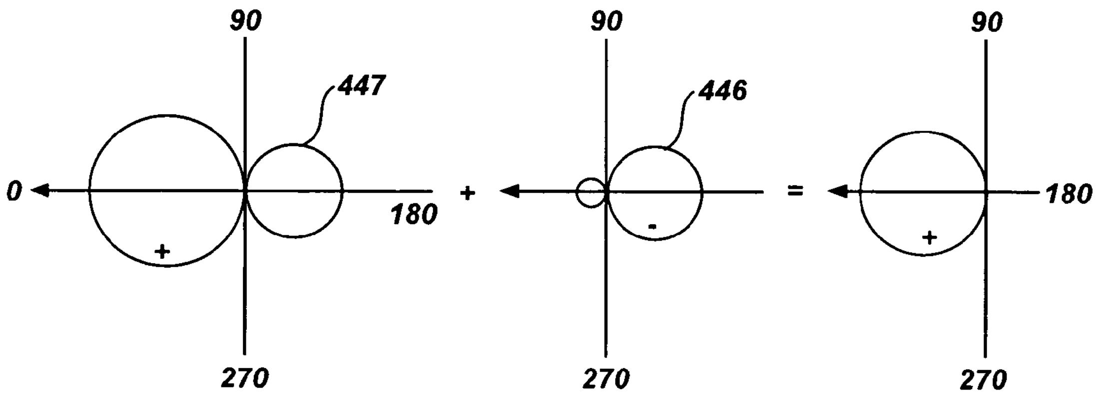


Fig. 65A Fig. 65B Fig. 65C

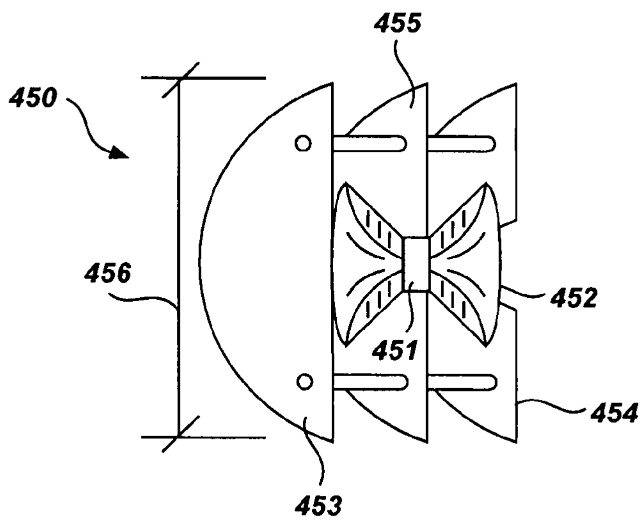


Fig. 66

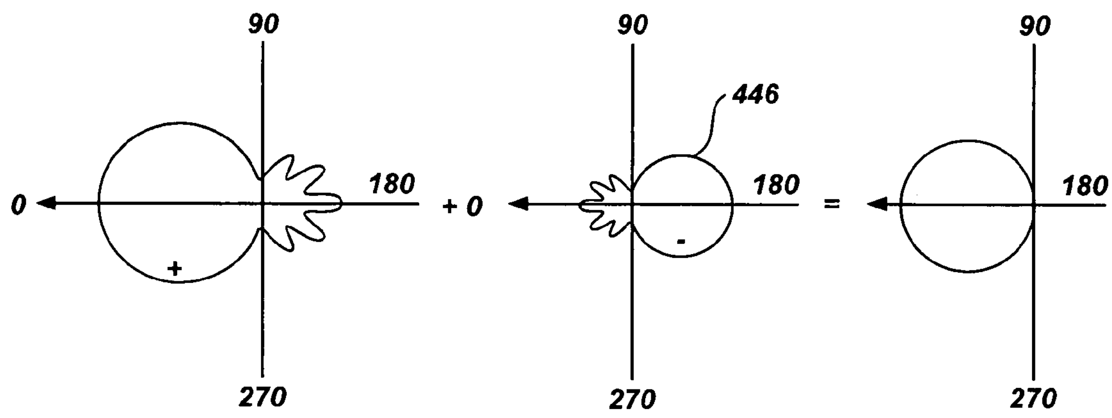


Fig. 67A Fig. 67B Fig. 67C

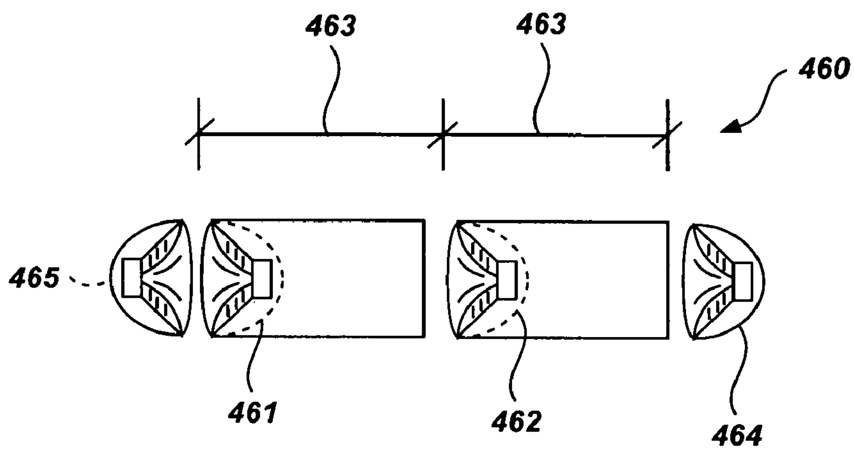


Fig. 68

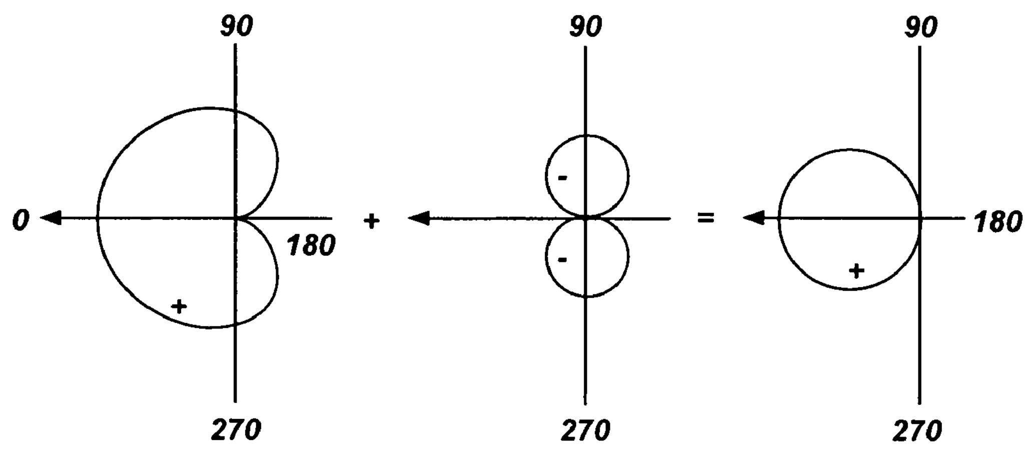


Fig. 69A Fig. 69B Fig. 69C

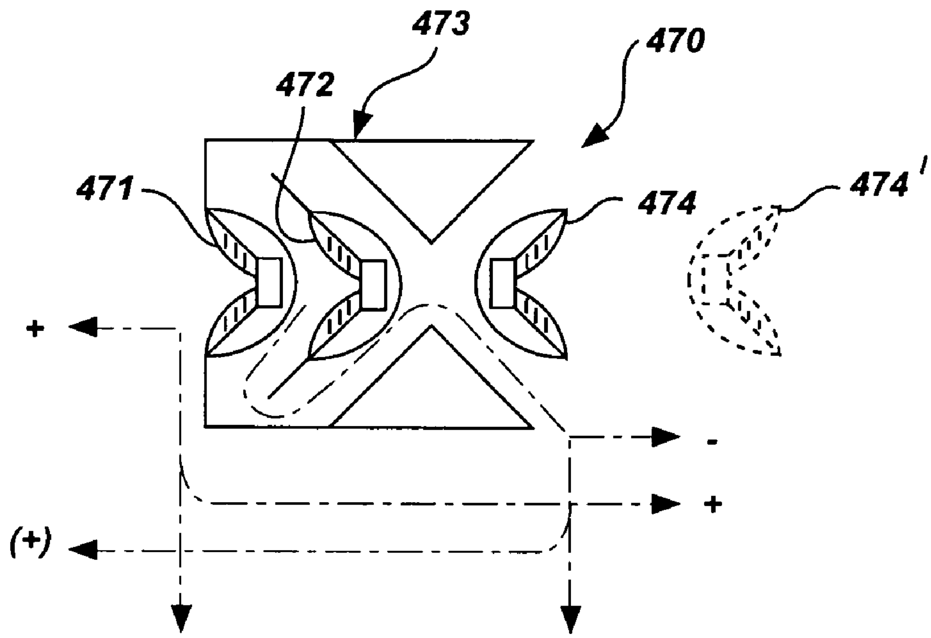


Fig. 70

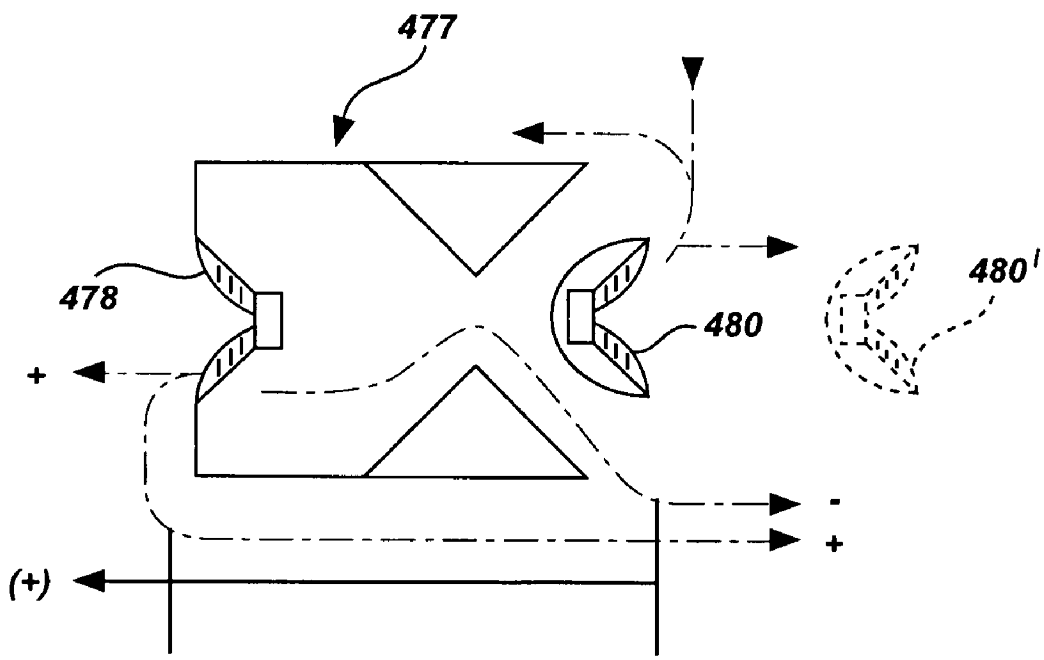


Fig. 71

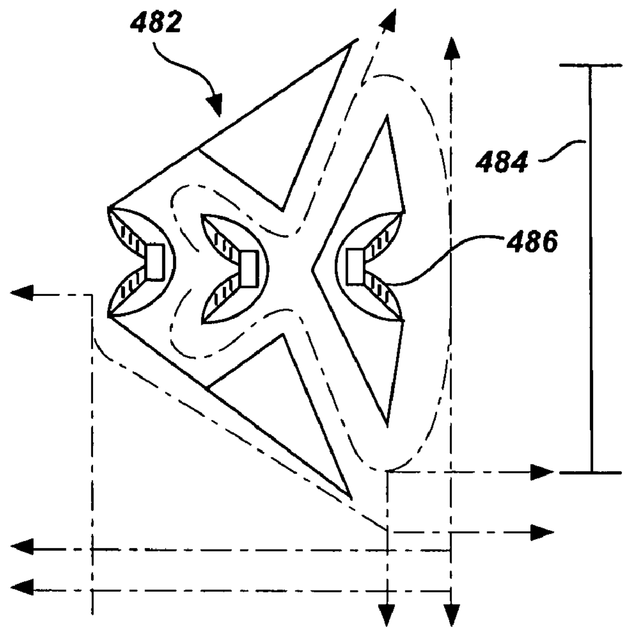


Fig. 72

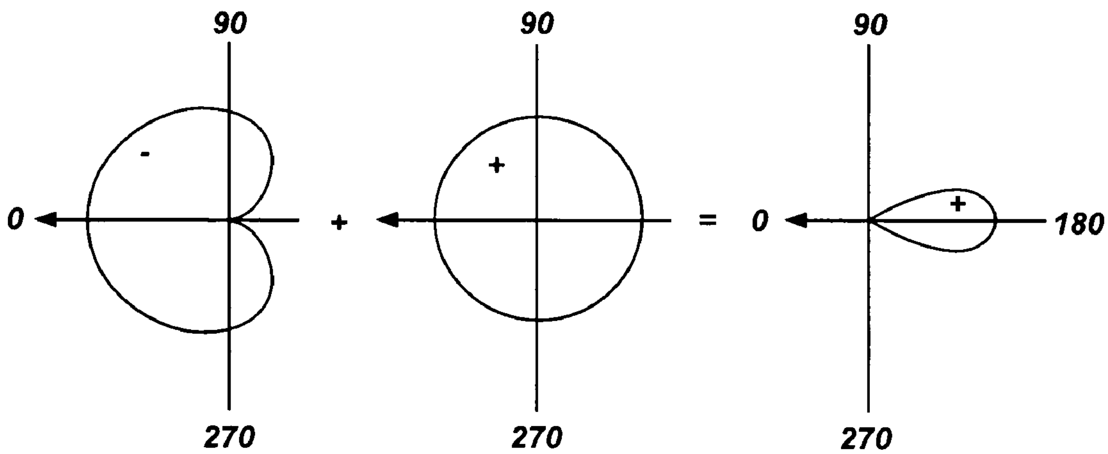


Fig. 73A Fig. 73B Fig. 73C

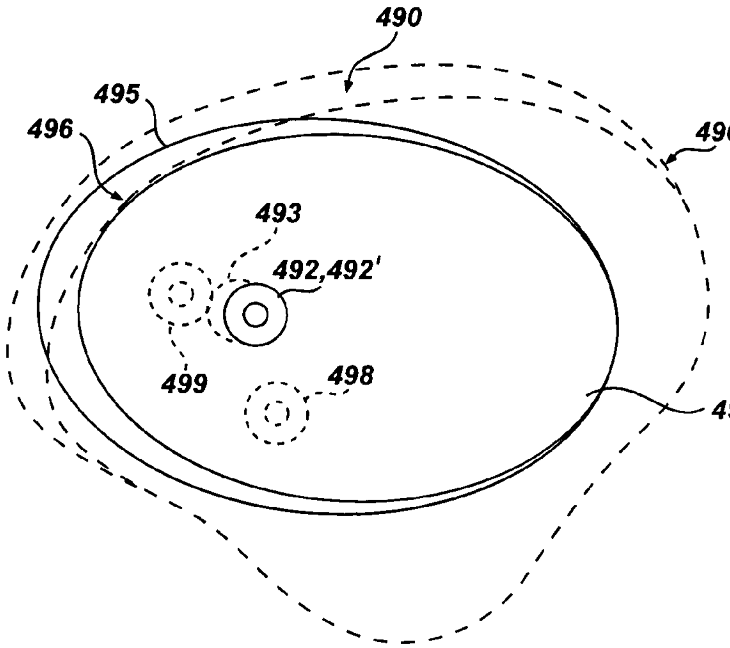


Fig. 74

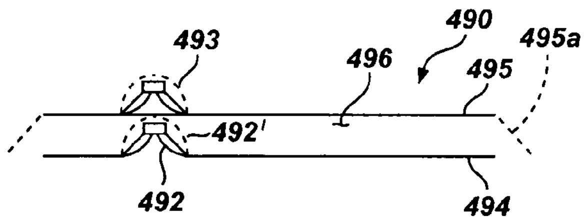


Fig. 75

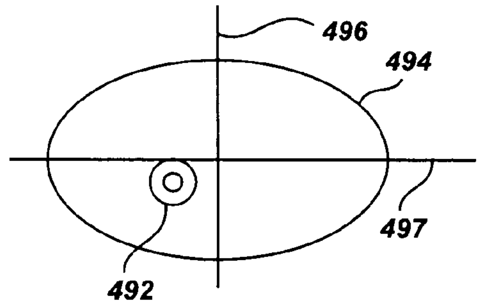


Fig. 76

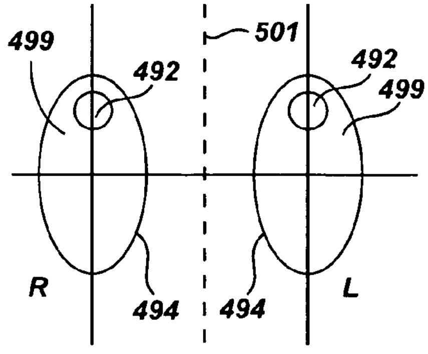


Fig. 78

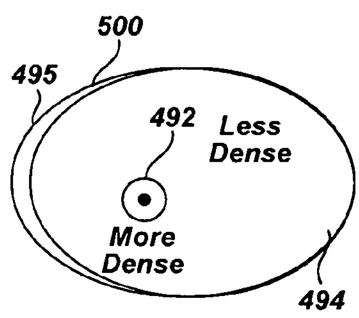
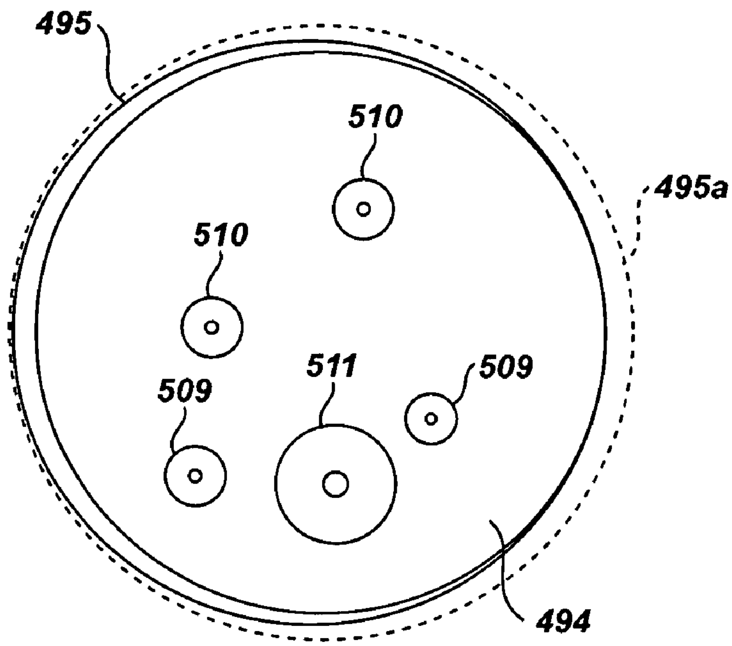


Fig. 77


495
510
495a
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511
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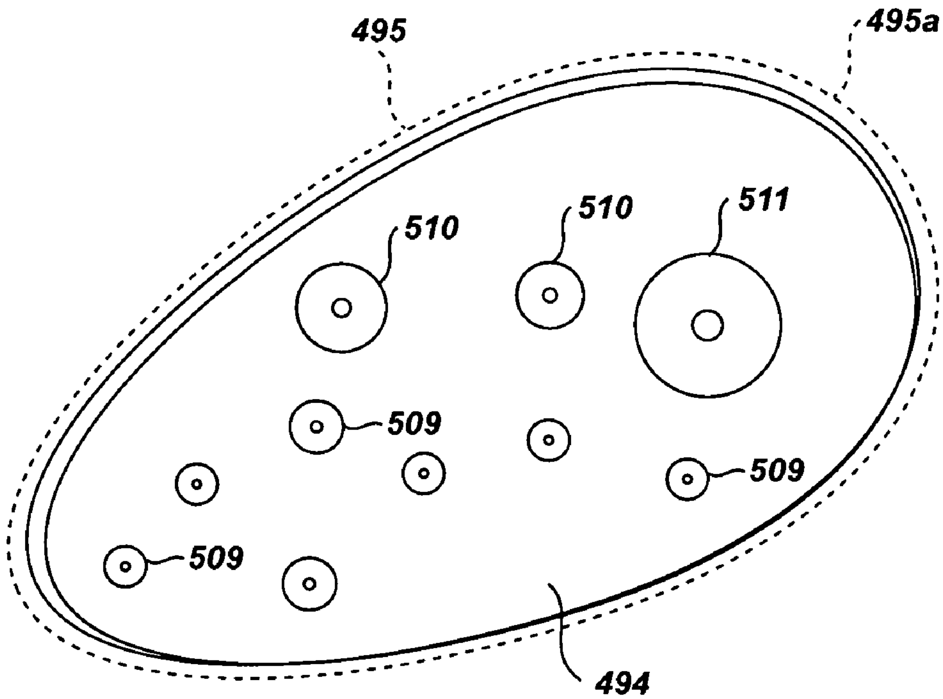
509
494

Fig. 79


495
495a
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494

Fig. 80

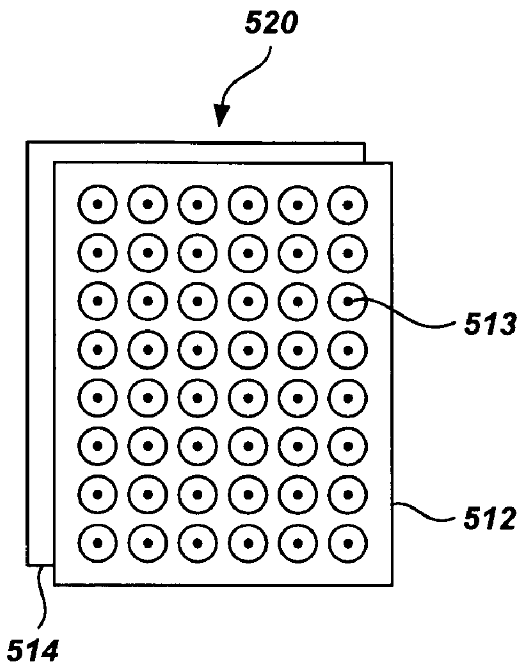

Fig. 81

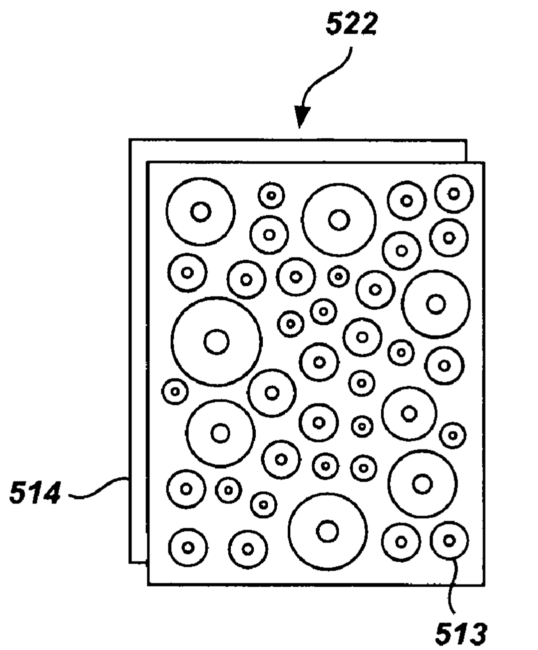

Fig. 84

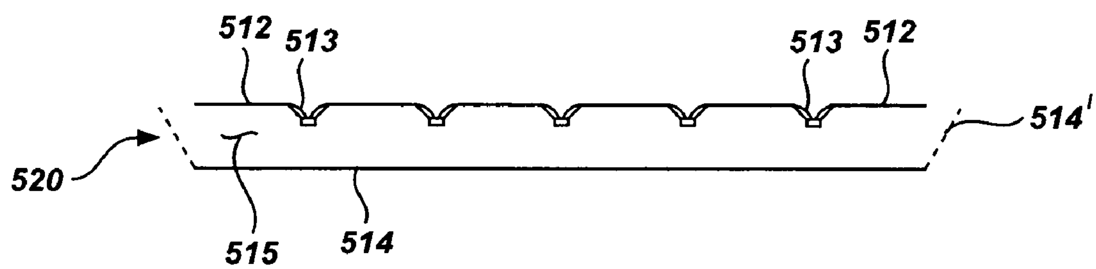

Fig. 82

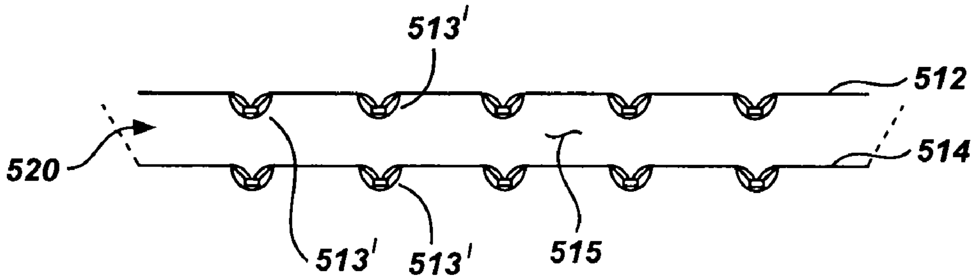

Fig. 83

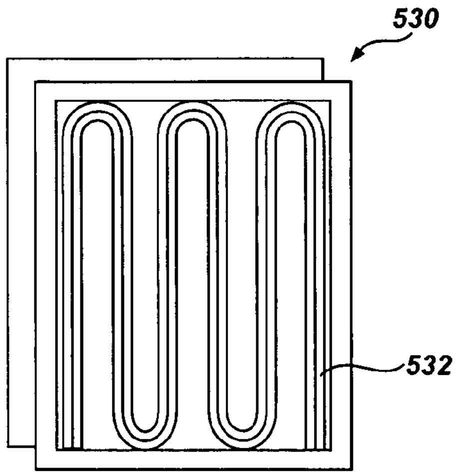

Fig. 85

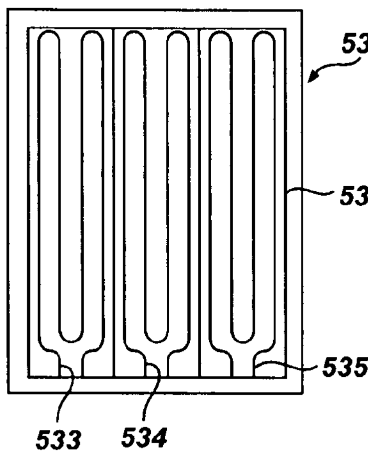

Fig. 86

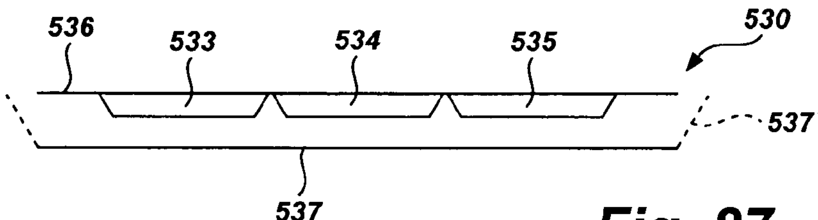

Fig. 87

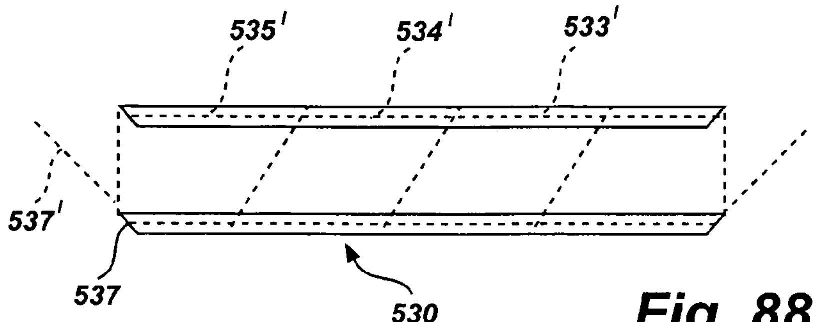

Fig. 88

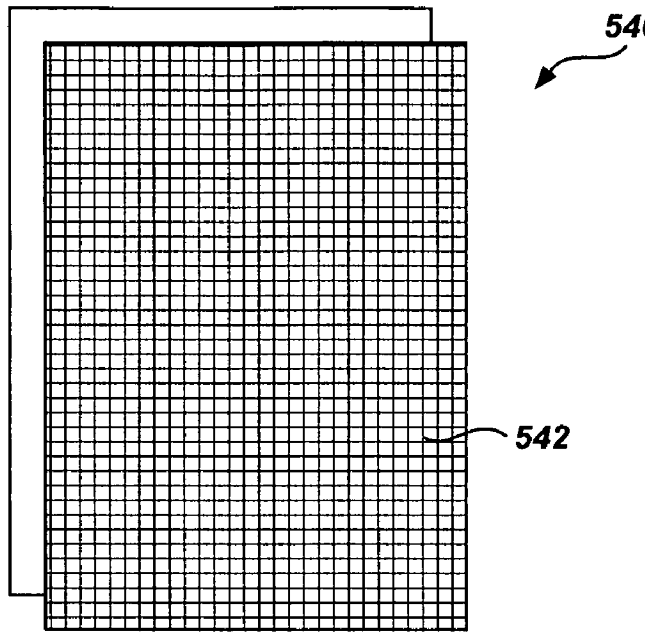

Fig. 89

Fig. 90

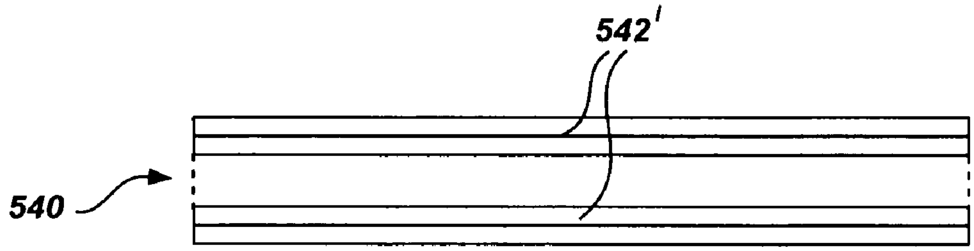

Fig. 91

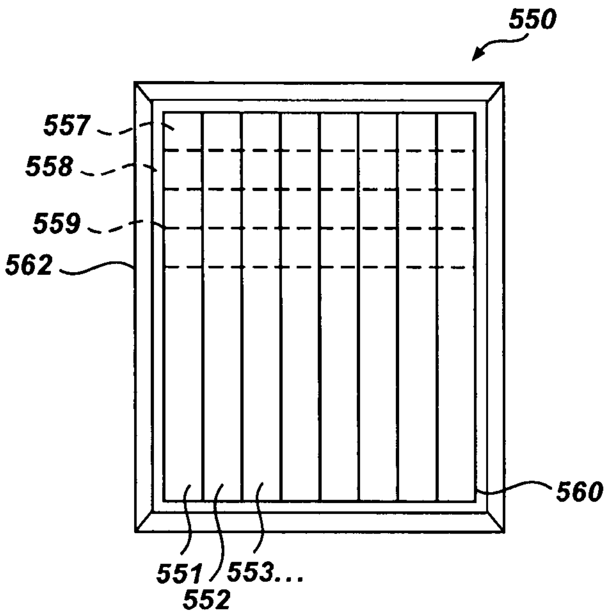

Fig. 92

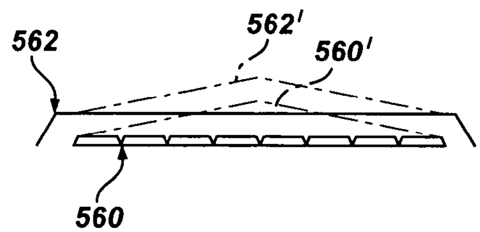

Fig. 93

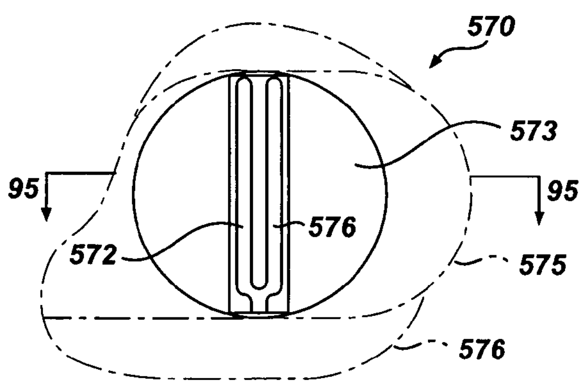

Fig. 94

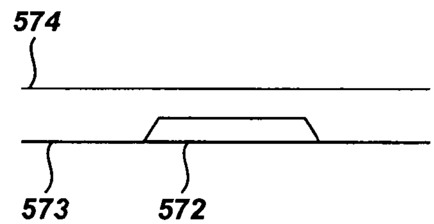

Fig. 95

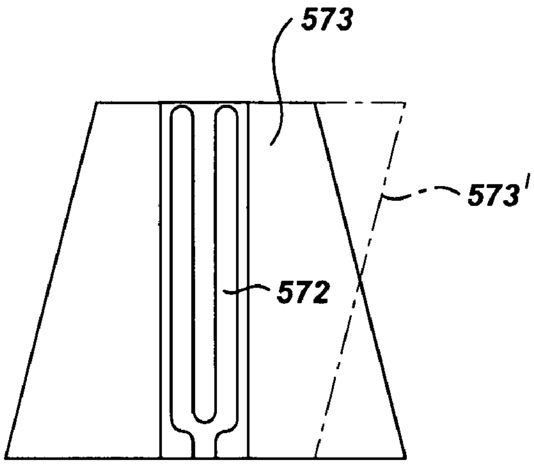

Fig. 96

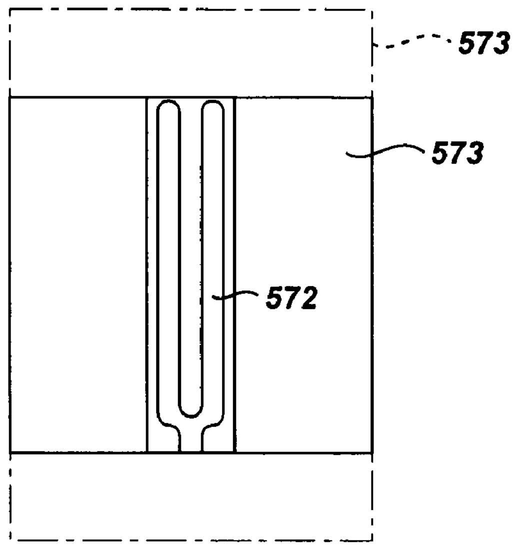

Fig. 97

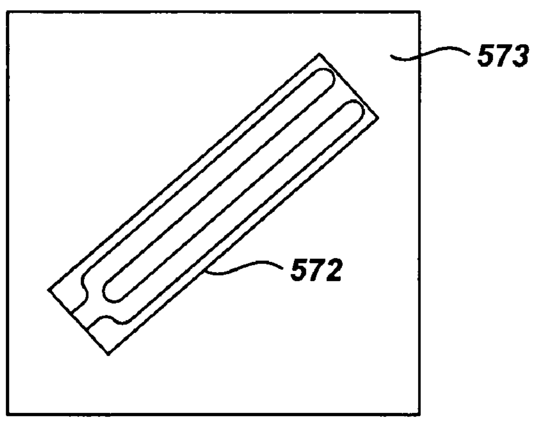

Fig. 98

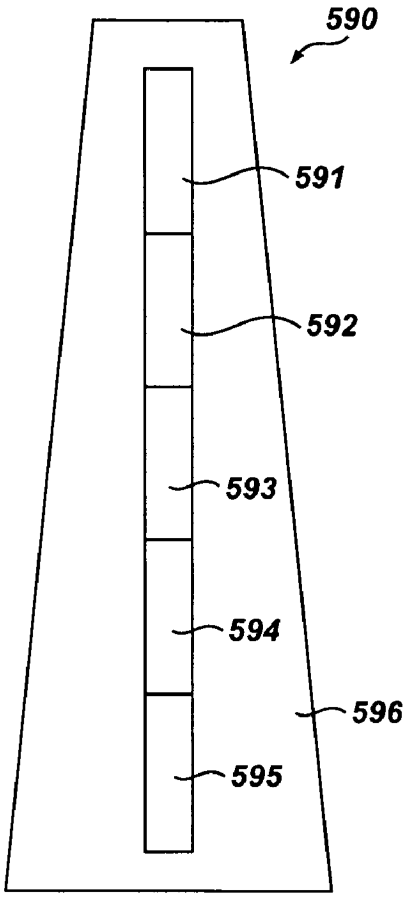

Fig. 99

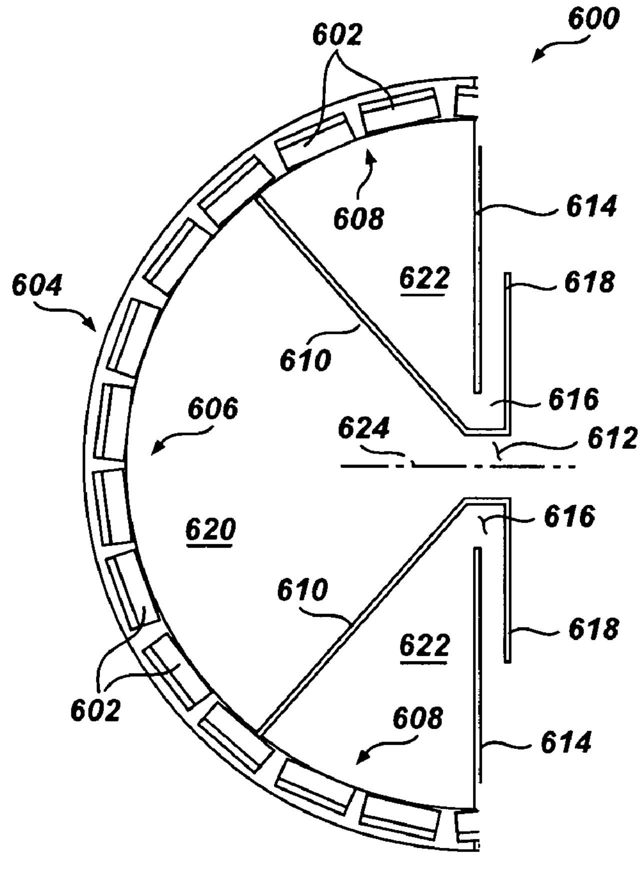

Fig. 100

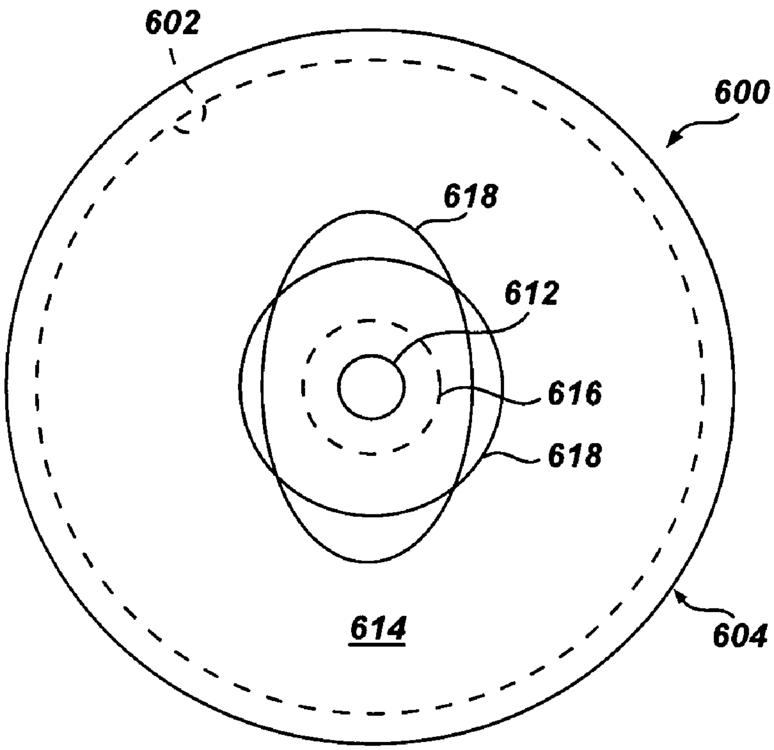

Fig. 101

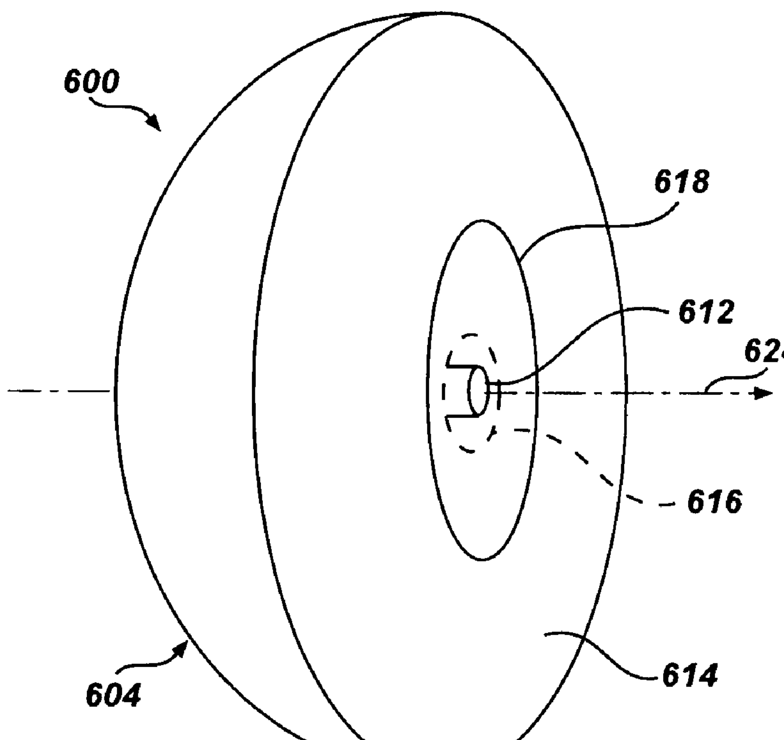

Fig. 102

DIRECTIONAL ACOUSTIC DEVICE

PRIORITY CLAIM

This is a continuation of PCT Application PCT/US06/009358 filed on Mar. 14, 2006, which claims priority to U.S. Provisional Patent Application Ser. No. 60/661,812 filed Mar. 14, 2005, and to U.S. Provisional Patent Application Ser. No. 60/672,608 filed Apr. 19, 2005, and to U.S. Provisional Patent Application Ser. No. 60/710,425 filed Aug. 22, 2005, and to U.S. Provisional Patent Application Ser. No. 60/714,646 filed Sep. 7, 2005, all of which are hereby incorporated herein by reference in their entirety.

BACKGROUND

The area of technical endeavor concerned is acoustics, and more particularly the area of directed acoustics wherein sound is controlled as to level at locations polar-plottable as distances and angles relative to a sound source and a primary acoustic axis.

It is often desirable to direct sound, so that it will be loud when perceived at locations near an acoustic axis along a direction of propagation along the axis, and attenuated at other locations. As one example of many that could be cited, in public address systems it is often desirable to project sound outward from a stage or podium, but not to overwhelm persons located there, yet have the projected sound be loud enough to be heard in a back portion of an audience (which may be quite extensive and some of which may be located far from the stage). There are other situations where directed sound would be desirable, some of which may not have been universally recognized by practitioners in the art of acoustics. As an example of this other category, it has been observed by some that back-up warning devices (sometimes called back-up beepers, because of the repeating single tone on-off nature of the output of such devices almost universally adopted) are needed but very annoying to the operators of vehicles on which they are installed. Also the output from back-up beepers can be undesirable at locations outside the area into which the vehicle is backing, for example trucks backing into loading docks at night have been known to wake persons sleeping in homes a considerable distance from the loading dock and not in line with the direction of the backing.

Moreover, numerous alarms, warning signals, and the like, are intended for persons in a specific area, and it would be desirable to direct the sound emitted to that area strongly, and have the sound projected in other directions be attenuated. Examples of this situation include but are not limited to train, truck and boat warning horns, whistles and the like, emergency vehicle sirens and the like. With respect to these it can be desirable to have an option to project an acoustic warning into an area along an axis of travel of the vehicle or craft, but to not project it rearward; and thus not so loudly disturb those behind. Those behind need not hear a loud warning, because with respect to those persons the warning is not very pertinent, as the hazard is moving away from them.

Door closing hazard warning tones and alarms, systems operators' warnings and alarms, crosswalk audio annunciator tones, and the like, directed to specific persons in specific areas are additional examples. Likewise fog horns (which need not disturb those inland) and other proximity hazard warning tones can be attenuated in directions not relevant to the purpose of the warning, resulting in less noise disruption overall.

Moreover, directivity with a narrow band acoustic signal and directivity with a wide band acoustic signal can be quite different problems. While many hailing and warning acoustic signals can be advantageously directed, these are typically narrow band signals or at least typically repeat within a defined frequency range. Returning to the auditorium venue or like example given above, wideband signals such as human voice or such as music program material, which are difficult to reproduce directionally, would be advantageously directionally reproduced if there were more cost-effective ways to do that.

SUMMARY

In one example embodiment the invention can be embodied in a directional acoustic device configured for directing an acoustic output along an acoustic axis, including: (a) at least one transducer configured for creating at least two wave trains which can be made to have a differing phase with respect to each other and which follow paths different in lengths; (b) at least one wave guide which is configured to define at least a part of said paths and to create a difference in length of said paths; and, (c) the wave trains destructively interfering in directions more than ninety degrees off the acoustic axis, the output being useful in directions close to the acoustic axis and usefully reduced in directions more than ninety degrees off the acoustic axis.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

The invention is disclosed herein, and further features and advantages can be appreciated with reference to the examples hereinafter described and which are illustrated by the drawing figures, wherein:

FIG. **1** is a schematical side view of an example acoustic emitter in one embodiment in accordance with principles of the invention;

FIG. **2** is a schematical front view of the example shown in FIG. **1**;

FIG. **3** is a schematical cross section view of an acoustic emitter in another example embodiment, a hypothetical polar plot of a given SPL of output being superimposed on the figure to illustrate its directionality;

FIG. **4** is a schematical cross section view of another example embodiment, a hypothetical polar plot of a given SPL of output being superimposed on the figure to illustrate its directionality;

FIG. **5** is a schematical cross section view of another example embodiment;

FIG. **6** is an oblique perspective view of the example emitter shown in FIG. **5**;

FIG. **7** is a schematical cross section view of another example embodiment;

FIG. **8** is a schematical cross section view of another example embodiment;

FIG. **9** is a schematical cross section view of another example embodiment; and,

FIG. **10** is an oblique perspective view of the example emitter shown in FIG. **9**;

FIG. **11** is a schematical cross section view of another example embodiment, a hypothetical polar plot of a given SPL of output being superimposed on the figure to illustrate its directionality;

FIG. **12** is a schematical cross section view of another example embodiment, additional possible features being shown in outline;

FIG. **13** is a schematical cross section view of another example embodiment, additional possible features being shown in outline;

FIG. **14** is a schematical cross section view of another example embodiment;

FIG. **15** is a schematical cross section view of another example embodiment;

FIG. **16** is a schematical cross section view of another example embodiment;

FIG. **17** is a schematical cross section view of another example embodiment;

FIG. **18** is a schematical cross section view of another example embodiment;

FIG. **19** is a schematical cross section view of another example embodiment, another example embodiment shown alternatively in outline;

FIG. **20** is a schematical cross section view of another example embodiment;

FIG. **21** is a schematical cross section view of another example embodiment;

FIG. **22** is a schematical cross section view of another example embodiment, other example embodiments shown alternatively in outline;

FIG. **23** is a schematical cross section view of another example embodiment, another example embodiment shown alternatively in outline;

FIG. **24** is a schematical cross section view of another example embodiment, other example embodiments shown alternatively in outline;

FIG. **25** is a schematical cross section view of another example embodiment;

FIG. **26** is a schematical cross section view of another example embodiment;

FIG. **27** is a schematical cross section view of another example embodiment, possible additional structural features being shown in outline;

FIG. **28** is a schematical cross section view of another example embodiment;

FIG. **29** is a schematical comparative front view of two example emitter profiles illustrating size relative to frequency of a design tone frequency;

FIG. **30** is a schematical front view of an example emitter embodiment mounting configuration;

FIG. **31** is a schematical side cross section view of the example embodiment shown in FIG. **30**;

FIG. **32** is a schematical cross section view of another example embodiment, a hypothetical polar plot of a given SPL of output being superimposed on the figure to illustrate its directionality;

FIG. **33** is a schematical cross section view of another example embodiment, a hypothetical polar plot of a given SPL of output being superimposed on the figure to illustrate its directionality;

FIG. **34** is a schematical cross section view of another example embodiment;

FIG. **34***a* is a schematical cross section view of another example embodiment;

FIG. **35** is a schematical cross section view of another example embodiment, alternative example structural configurations being shown in outline;

FIG. **36** is a schematical cross section view of another example embodiment, additional or alternative structural features being shown in outline;

FIG. **37** is a schematical cross section view of another example embodiment;

FIG. **38** is a schematical cross section view of another example embodiment, a hypothetical polar plot of a given SPL of output being superimposed on the figure to illustrate its directionality;

FIG. **39** is a schematical cross section view of another example embodiment;

FIG. **40** is a schematical cross section view of another example embodiment;

FIG. **41** is a polar plot of SPL in a horizontal plane (but which holds for all planes through the acoustic axis) for the emitter example shown in FIG. **27**; and,

FIG. **42** is a polar plot of like kind for the emitter example shown in FIG. **28**;

FIG. **43** is a schematic side crossectional illustration of an example embodiment;

FIG. **44** is a schematic side crossectional illustration of an example embodiment;

FIG. **45** is a schematic side crossectional illustration of an example embodiment;

FIG. **46** is a schematic side crossectional illustration of an example embodiment;

FIG. **47** is a schematic side crossectional illustration of an example embodiment;

FIG. **48***a* is a schematical cross section view of another example embodiment;

FIG. **48***b* is a schematical cross section view of another example embodiment;

FIG. **49** is a schematic side crossectional illustration of an example embodiment;

FIG. **50** is a schematic side crossectional illustration of an example embodiment;

FIG. **51** is a schematic side crossectional illustration of an example embodiment;

FIG. **52** is a left front perspective view of another example embodiment;

FIG. **53** is a schematic side crossectional illustration of the example embodiment shown in FIG. **52** taken along line **53-53** in FIG. **52**;

FIG. **54** is a side crossectional schematic illustration of an emitter in one example embodiment configured for wider band directional response using an electronic crossover and which may also include electronic equalization;

FIG. **55** is a diagram including an SPL vs. Frequency response plot for the respective portions of the device, the more narrow bands at which they produce directional sound and the envelope(s) in which sound can be directionally produced across a wider band of frequencies by taking advantage of overlapping of the more narrow bands by crossover, and in one example narrowing the gaps between the more narrow bands by equalization;

FIG. **56** is a schematic broken out portion illustration of two broken-out portions of emitter examples comparing dipole and two monopole implementations;

FIG. **57** is a schematic sectional illustration of two emitter examples comparing dipole and monopole implementations;

FIG. **58** is a schematic crossectional illustration of an example embodiment using folded tube waveguides and two monopole transducers;

FIG. **59** is a schematic crossectional illustration of an example using a kind of folded quarter wave pipe and two monopoles;

FIG. **60** is a schematic crossectional illustration of an example using two spaced circular waveguides and a connecting pipe with two monopoles;

FIG. **61** is a variation on the example of FIG. **60**;

FIG. **62** is a further variation on the example of FIG. **61**;

FIG. **63** is a crossectional example of an example where two circular waveguides are separated and independently activated by two monopoles;

FIG. **64** is a schematical crossectional perspective view of an example embodiment in a narrow band device of smaller size using three monopole transducers;

FIG. **65** is a series of three polar plots of two overlapping acoustic signal regimes and the resulting overall regime;

FIG. **66** is a schematical crossectional perspective view of an example embodiment in a narrow band device of smaller size using two dipole transducers;

FIG. **67** is a series of three polar plots of two overlapping acoustic signal regimes and the resulting overall regime;

FIG. **68** is a schematical crossectional view of an example narrow band device of small size having a long narrow form factor;

FIG. **69** is a is a series of three polar plots of two overlapping acoustic signal regimes and the resulting overall regime;

FIG. **70** is a schematical crossectional view of an example narrow band device of small size having a compact form factor;

FIG. **71** is a schematical crossectional view of an example narrow band device of small size having a compact form factor;

FIG. **72** is a schematical crossectional view of an example narrow band device of small size having a narrow beam output;

FIG. **73** is a series of three polar plots of two overlapping acoustic signal regimes and the resulting overall regime;

FIG. **74** is a schematical perspective view of a wide band device example, variations in shape of baffles are shown in outline;

FIG. **75** is a crossectional schematical view of the example shown in FIG. **74**;

FIG. **76** is a schematical front view of a variation of the device shown in FIG. **74** illustrating transducer placement with respect to symmetry of the device;

FIG. **77** is an other example embodiment which is a variation of that shown in FIG. **74**;

FIG. **78** is a front schematical view of a stereo pair of emitters such as that shown in FIG. **74**;

FIG. **79** is a schematical perspective view of another embodiment in a wide band device using a plurality of transducers, a forward extension of the rear baffle which can be used in one variation (as shown by element **62** in FIG. **4** for example) is shown in outline;

FIG. **80** is a variation on the example shown in FIG. **79**;

FIG. **81** is a schematical perspective view of another example wide-band device where transducers cover a forward baffle of two baffles forming a waveguide for a rear wave;

FIG. **82** is a schematical crossectional view of the example of FIG. **81** in an embodiment using dipole transducers;

FIG. **83** is a schematical crossectional view of the example of FIG. **81** in an embodiment using monopole transducers;

FIG. **84** is a schematical perspective view of another example wide-band device where transducers cover a forward baffle of two baffles forming a waveguide for a rear wave, being a variation on the example of FIG. **81** and replacing ordered rows and columns of similar transducers with a non-symmetrical pattern of transducers of different sizes and/or types;

FIG. **85** is a schematical perspective view of another example wide-band device where a transducer covers a forward baffle of two baffles forming a waveguide for a rear wave, the example using a planar magnetic transducer;

FIG. **86** is a schematical perspective view of a variation where three planar transducers are used;

FIG. **87** is a schematical crossectional view of the device of FIG. **86** using dipole transducers;

FIG. **88** is a schematical crossectional view of the device of FIG. **86** using monopole transducers;

FIG. **89** is a schematical perspective view of another example wide-band device where a transducer covers a forward baffle of two baffles forming a waveguide for a rear wave, the example using an electrostatic transducer;

FIG. **90** is a schematical crossectional view of the device of FIG. **89** using a dipole transducer;

FIG. **91** is a schematical crossectional view of the device of FIG. **889** using two monopole transducers;

FIG. **92** is a schematical perspective view of another example wide-band device where a transducer covers a forward baffle of two baffles forming a waveguide for a rear wave, the example using a number of planar form transducers;

FIG. **93** is a crossectional schematical view of the example shown in FIG. **92**, a virtual position of the elements being shown in outline;

FIG. **94** is a schematical front view of an example embodiment of a wide band device using a planar-form transducer in a double baffle arrangement, a planar magnetic transducer being shown as an example planar form transducer, but other types being substitutable;

FIG. **95** is a schematical crossectional view taken along line **95-95** in FIG. **94**;

FIG. **96** is a variation of the example shown in FIG. **94**;

FIG. **97** is a variation of the example shown in FIG. **94**;

FIG. **98** is a variation of the example shown in FIG. **94**;

FIG. **99** is a variation of the example shown in FIG. **94** using a plurality of transducers;

FIG. **100** is a schematical crossectional side view of an example embodiment in a device which can be narrow or wide band wherein a plurality of transducers are arranged in a hemisphere and higher SPL in the directional output is facilitated;

FIG. **101** is a schematical front view of the example shown in FIG. **100**; and,

FIG. **102** is a side-front schematical perspective view of the example shown in FIGS. **100** and **101**.

DETAILED DISCLOSURE OF EXAMPLE EMBODIMENTS OF THE INVENTION

With reference to FIG. **1** and FIG. **2**, a directional audio emitter **10** comprises an array of transducers **12**, which can be conventional, such as small speakers of one of the many types known. A central transducer **14** is surrounded by a ring of transducers equidistant from the central transducer. An audio output, which consists essentially of a single tone (being a single frequency or more than one frequency, each bounded within a narrow band of frequencies), can be directionally shaped in a plane by making the sound source two point sources, e.g. **16**, **18** located in the plane and separated by one half wavelength. In the example embodiment, the distance between the central transducer and the other transducers forming the ring is one-half wavelength of a tone to be produced by the emitter. In one example, the transducers are carried on a baffle plate **20** so that a radius distance **22** is one-half wavelength of a tone to be projected and a diameter distance **24** is then a full wavelength. It has been found that such an emitter can project a tone, of a single frequency or narrow band of frequencies that corresponds (at least essentially) to a wavelength matching the diameter distance, with high directionality. The output level of the center transducer **14** is made essentially equal to that of all the outer ring of transducers taken together. The transducers are in phase, and selective cancellation and reinforcement, depending on direction of propagation, occurs. If the baffle plate is configured so as to attenuate audio emissions in a negative direction along the acoustic axis **25**, the audio output can be directional in a single (positive) direction **30**. In one embodiment, the baffle plate extends outward beyond the outer ring of transducers to a periphery **21** which causes output from all the transducers to be subjected to similar conditions very close to the transducers and at the periphery, which can give improved matching of the outputs in a rear direction **28**.

As will be appreciated, the one-half wavelength dimension (radius **22**) mentioned assumes essentially a single line (circle) source with essentially no thickness, whereas in fact the transducers **14**, **16** have physical extent. Other realities different from the theoretical assumptions, such as the need for the central transducer to have much more power than the peripheral ones, and thus perhaps of a different type, as well as manufacturing variations in all aspects of the device (not just the transducers), and the like, can make the actual performance vary from the predicted performance, as is well known and appreciated by practitioners in the art. Nevertheless, the basic assumptions have been found to hold, and can be verified empirically.

Moreover, returning to discussion of the illustrated embodiments, additional configuration aspects can be varied to enhance directionality or to enhance output SPL. In one embodiment, a gradient scheme can be used. When a second emitter array **26** is used (which second array is configured similarly to the first and positioned one-quarter wavelength behind the first emitter **10**) and phase-leads the forward emitter, a baffle effect is created when the emitters are run one-quarter wavelength out of phase. As is known in the art gradient systems can create the effect without using or depending upon a physical baffle. This is because in the negative direction **28** the output directly cancels, while in the positive direction **30** the output from the two emitter transducer arrays is in phase and thus is additive. In another embodiment, a physical baffle can be used and the two emitters are run at different levels (the back emitter having less SPL) so that the rear emitter just cancels residual audio output from the front emitter that circumvents the physical baffle. An improvement over such a gradient system is obtained in the present example is obtained however, because transverse cancellation (e.g. ninety degrees off axis) is improved. Most gradient systems are not sufficiently out of phase side-to-side to produce good cancellation in that directions, being about one quarter wavelength offset only. The example arrays each inherently cancel side-to-side, and thus obtain an improved result in a gradient configuration. This allows power to be close to doubled, quadrupled, etc. by staking up the arrays along the acoustic axis. The reason a full doubling etc. is not obtained is that this arrangement does not allow the path distance from the central transducer **14** and the outer transducers **12** to a point in the far field to be equal, and thus a phase shift occurs. This latter point will be better understood with discussion of the following further examples. Moreover, after one becomes familiar with the next example it will be apparent that the forgoing example can be modified to eliminate the central transducer by changing the size (diameter) of the outer ring of transducers **12**, without total loss of the side cancellation effect.

With reference now to FIG. **3**, it will be appreciated that a similar effect can be obtained in another example emitter **32** using a single transducer **34**. The transducer is positioned in a forward end of a quarter-wave pipe **36**. Circular disks **38**, **39**, **40**, **41** closely spaced and positioned at the front and rear of the quarter-wave pipe are between one-half and one full wavelength in diameter (e.g. 0.765 wL), and form circular line sources around their peripheries. As will be appreciated by those skilled in the art the pipe is referred to as a quarter-wave pipe, but can actually have a different length (depending on the spacing between disks, for example, and other real-world factors such as reflectivity of materials, etc.) Sound **42** from the front disk pair is reinforced by sound **44** from the back pair in the forward direction, and is cancelled in the rearward direction, giving a polar plot such as the example hypothetical cardioid-shaped plot **46** shown superimposed over the device with respect to the acoustic axis **48**. Since the emitter is symmetrical around the acoustic axis, the directionality holds in all planes through the acoustic axis. As will be appreciated, this symmetry of device and acoustic effect holds for all the symmetrical examples shown in the figures (including that of FIGS. **1** and **2** when a sufficiently high number of transducers are used so as to simulate a circular sound source).

With reference now to FIG. **4**, in another example emitter **49** a transducer **50** is surrounded by two circular plates **52**, **54** which are each about one wavelength in diameter. This creates a circular sound source at the periphery **56** that is spaced one-half wavelength **57** from the (central) transducer. It will be appreciated that the transducer is operating in a dipole mode and that the sound emanating from the circular sound source at the periphery of the forward circular plate **52** will be in-phase with that emitted directly by the centrally located transducer at far-field locations forward of the emitter along the acoustic axis **58**. Thus, the emitter is analogous to the example of FIGS. **1** and **2**, and the output cancels at 90 degrees from the acoustic axis. However, this example is simpler in construction, and uses a single transducer instead of many transducers. The sound output will likewise be directional for the reasons explained above, and symmetric about the acoustic axis (as shown by a hypothetical polar plot **60** superimposed on the figure). In one embodiment the rear disk is extended around and brought forward at an outer edge portion **62** around the periphery **21** so that the opening between the plates faces forward, and in another embodiment a sound-attenuating material **64** can be used to increase the baffle effectiveness of the rear plate. The forwardly extending portion can terminate even with the front plate, or can turn back outward and extend as a baffle further outward to the peripheral edge, **21** as shown in outline.

With reference to FIGS. **5** and **6**, the example just discussed can be further modified in another example emitter **65** by modifying one or both of the front and rear disks, **66**, **68**, respectively, to provide a flare, such as an exponential flare, or other flare configuration, different from that flare (e.g. that of the example of FIG. **4**) which would result from keeping the distance between the disks constant. Furthermore, a screen **70**, or other acoustically transparent cover, can be provided to protect the transducer **50** from the environment, and/or from washing sprays, flying objects, etc. which may be inherent in the environment of the application to which the emitter is directed, for example a back-up warning beeper for semi-tractor-trailer trucks, dump trucks and other heavy equipment (including construction equipment of various kinds), garbage collection vehicles, and fork lifts, to name a few examples.

In one example, a central protective cone **72** and louvers **74** can be provided. This cone particularly shields the location of the transducer **50**. This is in addition to the protection the screen **70** affords. In one embodiment this cone can be given a phase-plug shape, and can act cooperatively with the other structure to mitigate some of the interference with the sound pathways that its own presence creates.

Turning now to FIG. **7**, in another embodiment which is a modification of the configuration discussed above in connection with FIG. **4**, the emitter **76** can be modified so as to have a smaller diameter overall, while still providing one-half wavelength difference sound pathways for the functionality described above. By "folding" the rear plate **78** and modifying the front plate to be a rotated polygon **79** (rotated about the acoustic axis **80**) the sound waves follow pathways **82**, **84** of equal length to a point **86** which is 90 degrees off axis in the far field so that they cancel (at least in part), and of lengths **88**, **90** differing by one-half wavelength to a point **92** on axis in the far field, so that sound from the dipole transducer is in-phase there. Pathways to the rear far field ideally will be of equal length so as to provide good cancellation, thereby quieting the emissions to the rearward. In one example, sound absorbing material **64** can be used as discussed above in this configuration as well.

With reference to FIG. **8**, in another example embodiment of the invention the folding is taken to a point where the forward and rearward plates discussed above become instead inner and outer concentric pipes **94**, **96**, respectively. The outer pipe is closed at a back end to create a folded pathway **98** for the rear wave from the dipole transducer **50**. At 90 degrees off-axis, this pathway is matched in length by the pathway **100** of the front wave to a point **102** in the far field in that direction, where they cancel at least in part. The same situation obtains behind the emitter **104** of this example, the matching path length giving a null by cancellation of the front wave by the back wave. In the forward direction sound pathways **106** and **108** of the front and back waves, respectively, differ by one-half wavelength and so the sound is in-phase. This gives the hypothetical pattern **110** around the acoustic axis **112** as shown.

Turning to FIGS. **9** and **10**, in another example emitter **113**, which is a variation of that, just discussed, the pipes **114**, **116** can be configured to provide a flair for improved efficiency, and/or to alter directivity parameters influenced by flair (wider or narrower dispersion and sound pressure level due to flair geometry). A screen **118** or **118'** can be provided to protect the transducer **50** as discussed above, as can a cone **120** (or "plug") as discussed above. A mounting bracket **122** or **122'** can be included so that the emitter can be mounted to a surface (not shown).

With reference to FIG. **11**, in another example embodiment an emitter **130** is mounted so that the back plate **132** comprises a baffle that extends well beyond the outward circular extent of the front plate **134**. The baffle in one example can be a large surface on which the emitter is mounted. For example if the emitter is mounted on a wall, for example a back side wall of a truck trailer, the baffle will be provided by the surface on which it is mounted. In another embodiment the back plate simply extends outward some distance **136** which is at least a substantial fraction of the frequency of the tone to be emitted, from the outer periphery **138** of the front plate. This controls the pathways of the front and back waves so that they are more equal in length into the far field in the negative direction along the acoustic axis **140**, and also helps equalize the levels of the front and back waves at that location, to improve cancellation and obtain an improved null in the rear direction. This results in an improved directionality as illustrated by a superimposed hypothetical polar plot **142** of a sound level value which can be obtained using the configuration.

In obtaining improved directionality, and specifically in improving the cancellation to the sides and rearward (i.e. at 90, 180, and 270 degrees and azimuths therebetween, taken from the acoustic axis) it has been found that managing the difference in level between the front and back waves as well as configuring for phase difference effects is important. To illustrate—it has been found in some examples of the configuration shown in FIG. **4**, without the extending portions of the back plate (e.g. obliquely angled forward extensions **62** and/or outwardly extending baffle portions terminating at the outer periphery **21**), a rear wave portion of the sound (which is emanating from between the plates **52**, **54**) measured in the far field rearward (e.g. 180 degrees off the forward acoustic axis) can be about 6 to 10 dB higher in level than that of the front wave, as determined by empirical measurement. This difference in level can give rise to a rear lobe of emitted sound plot (albeit considerably smaller than the front lobe), even though the waves may be essentially completely cancelled.

Likewise it will be appreciated that if the front and backwave path lengths are not matched, the match in level not be availing in producing a null either. It has been found that some configurations which improve the match in path length degrade the match in level, and vice versa. A desirable end is to find configurations where cancellation is optimized for the application, given the limitations of the geometry. The examples discussed herein are directed to this end. It will be appreciated that depending on whether cancellation to the sides (90 and 20 degrees) or the rear (180 degrees) is preferred, different approaches can be taken.

Returning to discussion of the illustrated examples, providing the baffle, as illustrated by the example of FIG. **11**, or by adding the extensions **62** extending the rear plate forward as shown as an alternative in FIG. **4** (with or without further baffle extensions to the periphery **21**), provides improved cancellation as just discussed. This is accomplished by one or both of better equalizing the level of the front and back waves, and also by (at least incrementally) improving the matching relationship in the path lengths of the front and back waves of the dipole for better cancellation rearward.

In other examples, e.g. as shown in FIG. **12** (some as possible added features), other variations for wave pathway modification are illustrated. In one example embodiment the front plate (or structure carried by the front plate) extends inward forming an inwardly overhanging portion **144** over the front of the transducer **50**. This results in forming a smaller opening **146** for the front wave. In another example, a structure **148** is positioned over the transducer, which can be configured to act like a phase plug, again to control path length.

With reference now to FIG. **13**, in an example akin to alternatives of FIG. **4** discussed above, the rear plate **150** is integral with forwardly folded extension portions **152**, which are disposed at an oblique angle **154** to the front and back plates. For example the angle can be in the range of 20 to 80 degrees. An angle of 45 degrees has been used with success, for example. A length **156** of the extension portions can be chosen to provide the match in level of the front and back waves and control path length as discussed. In one embodiment the extension portion **152'** can be given a curved shape, rather than the straight section (frustoconical) configuration **152** before described. For example the extension portion can be made parabolic in shape with a focus at the transducer **50**. In this illustrated embodiment, the transducer **50** is flipped 180 degrees, which better accommodates providing a second transducer **250** in one example discussed more particularly below. A forward facing configuration for the transducer, such as that shown in FIG. **27**, can be used.

With reference to FIG. **14**, in another example the back plate **158** is provided with backward extending portions **160**.

These can be disposed at an oblique angle **162** (e.g. 60 degrees) and are configured to provide the control of front and back wave comparative phase and level, as discussed above, to give improved cancellation rearward. In one example the back of the emitter **130** can be closed by a closure plate **164**. In one example sound absorbing material **166** can be included, for example placed intermediate the back plate **158** and the closure plate in that example. With reference to FIGS. **27** and **28**, variations of the example configurations just discussed are illustrated in greater detail; and further information regarding these examples will be set out below.

With reference to FIG. **15**, in another example an emitter **130** (similar to the example shown in FIG. **13**) is modified to include a back closure plate **150** and a space between the back plate and the closure plate. Sound absorbing material **166** can be provided between the back plate **150** and the closure plate. In another embodiment (not shown) the closure plate is omitted and the sound absorbent material is carried by the back plate. In another example embodiment, rather than a cover plate a cover **170** can be placed over the back plate in the area of the transducer only. These measures can be effective in reducing direct radiation of sound by the back plate (or any part of the transducer which is intimately adjacent the back plate, or which extends through it).

Turning to FIG. **16**, in another embodiment a front portion **172** is less plate-like, and can have a rounded configuration to guide sound waves from the transducer **50**. It can, for example control the flair of the rear wave guide space **174** between the front portion and a back plate **176**, can provide a flair for the front wave, and can control relative path lengths for the front and rear waves to front, side and rear locations far field. Further variations can be seen with reference to the example of FIG. **17**, wherein a rear portion **178** (which also can be filled with a sound deadening material **166**) can likewise be shaped to control the path of the front and rear waves, particularly to the far field rearward. As with all the examples discussed, the emitter and these front and back portions are symmetric about the acoustic axis **140** in the illustrated examples.

Another variation is shown in the example illustrated in FIG. **18**, wherein a front plate **180** is configured with a flair and rounded shape, and cooperates with a rear portion **182** to provide front wave and back wave pathways of desired lengths and configurations. This is so that the front and back wave are in-phase at a forward location **184**, and out of phase at side and rear locations **186**, **188**, respectively. This provides the phase relationships for improved directionality, as is the case with the previous examples of FIGS. **11-17** discussed above, and will be the case with the following examples illustrated in FIGS. **19-21**.

With reference now to FIG. **19**, the flair and shaping provided are more pronounced, with the front plate **190** flaring more, and the back portion **192** having more depth. It will be appreciated with increased flare forward the level can be unbalanced forward, but since the front and rear waves are in-phase and additive, this is not objectionable. Since to the rear of the emitter the front wave is usually down in level with respect to the back wave, an increase in the level of the front wave can improve level match in one embodiment. In another example, shown in outline as alternative in the figure, a back portion **194** having baffle-like extensions **196** and outer terminations **198**, is provided rather than the more bulbous configuration. The back portion **194** in the later case is more plate-like and provides a baffle, rather than having the deep thickness but less outward plate-like projection distance just discussed.

In the example shown in FIG. **20**, both the front portion **200** and rear portion **202** have thickness and curved configurations. A direct path **204** forward and a longer pathway **206** for the rear wave differ by one half of a wavelength to give an in-phase condition at a forward location **208**. Whereas, path lengths to a side location **210** and rear location **212** are approximately equal. Another variation on this theme is shown in the example of FIG. **21**. This later example embodiment comprises a configuration which is between that of FIG. **17** and that of FIG. **20**. However, it retains a more orthogonal relationship of the rear wave pathway in the back wave guide space **214** between a front portion **216** and rear portion **218** with respect to the acoustic axis **220**. This can simplify design which is (in this connection) based on providing a difference in pathway lengths of a desired magnitude with respect to a wavelength of the narrow frequency band or single frequency to be directionally emitted.

With reference now to FIG. **22**, a variation on the example embodiment of FIG. **7** is illustrated. The folded configuration of the back wave guide space **222** results in a more compact configuration in that the emitter does not have to be a full wavelength in diameter. Variations include having the front plate **224** continue to extend forward by forward extensions **226**, or to the side to form baffle portions **228**. These can form a separation between the front wave and back wave at the side of the device, or, as shown alternatively at the top of the figure the back plate **230** can have corresponding extension portions **232**, **234** which follow the configuration of the front plate. The configuration chosen will depend on which of side or rear cancellation is more of a priority, for example. A further variation is shown in the example of FIG. **23**, where the front plate **224** can be altered to have a curved configuration and thickness, for example a curved front surface **236** and unaltered rear surface.

Additional variations on this theme will be appreciated with reference to FIGS. **32-35**. The example shown in FIG. **32** is similar to one of the variations shown in FIG. **22**. The front plate **237** is angled forward, as is the rear plate **239**. The rear plate extends beyond the front plate however, and at a periphery **243** both the rear wave path and the front wave path have to turn the corner at the same location to reach the rearward far field. The configuration thus accommodates forward addition of the front and back waves by making the respective pathways **245**, **247** to a front location **249** differ in length by one-half wavelength. The pathways to the sides and rear are essentially equal in length for the front and rear wave, and thus cancellation can occur. The extension of the rear plate helps equalize the level in the rearward direction far field as well. A superimposed hypothetical level plot **255** illustrates the effect.

Another variation is illustrated by the example shown in FIG. **33**. This time the front and rear plates **251**, **253**, respectively, angle backward. In this embodiment the front and back wave are made in phase at a forward location **249** by difference in path length of one half wavelength as discussed above, and cancel rearward, and partially cancel to the side. A hypothetical level plot **257** illustrates the effect. With reference to FIG. **34**, by wrapping the front plate **259** completely around rearward and collapsing the back plate on itself to form a cone **261** a roughly equivalent system can be made. Carrying the concept further, with reference to FIG. **34***a* the cone can be eliminated, and some sound absorbent material **263** can be used to balance the level of the back wave to the front wave to get improved cancellation rearward.

With reference now to FIG. **35**, a system roughly equivalent to the example of FIG. **32** can be made by turning the front plate into a doughnut-shaped cylindrical front element

265 and wrapping the rear plate **267** forward to form cylindrical forward extension **269**, a forward extent of which comes even with the front element. In another example embodiment (**265'**) the front element can be given curved surfaces to provide a smoother transition and a flair for the front wave. In this embodiment the path lengths for the front and rear waves can be made essentially the same to the rear and to the sides for cancellation, but different by one-half wavelength forward for a cumulative (reinforcing) effect there.

Referring now to FIG. **24**, in another embodiment a front portion **238** is configured to provide a rear wave guide space **239** that extends rearward then curves outward. The back plate **242** can be made to extend outward by baffle portions **244**, or can be eliminated altogether by mounting the emitter on a large relatively flat surface as discussed above. A curved configuration **238'** for the front portion is also illustrated to modify path length. As will be appreciated this configuration also decreases the diameter of the emitter **240**.

With reference to FIG. **25**, in another example embodiment comprising a variation on the examples shown in FIGS. **8** and **9** an emitter **241** can include a flared pipe portion **243** and lobed configuration providing thickness **245** to the front wave pipe. This alters levels and path distances as discussed above to alter the cancellations to optimize for side or rear cancellation, or some combination thereof, as desired.

Turning to FIG. **26**, a variation on the example embodiment shown in FIG. **3** is illustrated. Here the path length distances can be adjusted to provide the differences desired, but the rear wave guide space **246** is given a curved configuration (and thus a more gradual flair) rather than a quarter wave pipe and then orthogonal expansion (extreme flair) outward. As will be appreciated, reflections can further complicate the problem (not just in this embodiment, but in all embodiments), but overall the device example of these figures can be made to give a cardioidal level plot such as that shown in FIG. **8**, or another shape plot by adjusting the configuration dimensions.

Turning now to FIG. **36**, in another example embodiment a further transducer **248** can be added to the front plate **38** of the example embodiment illustrated in FIG. **26**. This further transducer is operated in phase with the first transducer **34** so that the output in the forward direction (to the right in the figure) is enhanced. In another example embodiment the relative phases between the transducers can be adjusted to improve side cancellation (albeit at the expense of level forward in one example).

With reference to FIG. **37**, in another embodiment a variation of the example illustrated in FIG. **4** includes a primary transducer **50** carried by the front plate **52**, which primary transducer can be flipped 180 degrees from that discussed above and shown in FIG. **4** (and is so illustrated flipped in FIG. **37**) and a secondary transducer **250** mounted in the back plate **54**. The purpose of the secondary transducer is to provide an ability to adjust the nulls to the side and rear of the emitter **49**. In one embodiment it is essentially identical to the primary transducer. In another embodiment the secondary transducer can be smaller than the primary transducer, since in that case it can be used primarily to provide a fine adjustment on the system primarily defined by the primary transducer and geometry as discussed above.

Moreover in one embodiment the secondary transducer **250** is run in-phase with the primary transducer and adjusted as to level to null the sound in the rearward (left in the figure) direction. It also increases or decreases the level of the sound coming from the back wave guide space between the plates, but provides a canceling wave as well so does not appreciably affect the side null. In another embodiment it is adjusted out of phase to adjust the amplitude of sound emitted from the back wave guide space between the plates, enabling adjustment of the side and rear nulls if desired. In another embodiment it is adjustable as to both level and phase relationship with the primary transducer for purposes of adjustment of the nulls. As will be appreciated, in most applications the settings will be predetermined, or will be "factory-set" for each emitter. It will be further appreciated that addition of a secondary transducer is possible on many of the other example embodiments set forth herein. The use of the secondary transducer with the other example embodiments is to the same purpose, and to achieve essentially the same effect accomplished in one of the ways just discussed. By way of one example of many that could be given, a secondary transducer can be added to the configuration of FIG. **13** (as shown in that figure) . This can be used to improve the rearward null for example as will be made more appreciable from the discussion below of FIG. **27**.

With reference to FIG. **38**, gradient schemes can also be used, as illustrated by the example of that figure. The gradient emitter **252** can comprise two emitters **49***a,b* such as discussed above in connection with FIG. **1** for example; and these are separated by a distance **254**. As is known in the operation of gradient systems and as discussed above, the distance in one example can be one quarter wavelength, and the two emitters can be operated at a quarter wave phase difference so that the outputs are additive in the forward direction and cancel in a rearward direction. This gives rise to the sound pattern illustrated by the superimposed hypothetical cardioid sound pressure level plot **256** shown in the figure. The side and rear nulls are usually mutually exclusive as is known in such a system, but can be relatively adjusted by manipulation of relative level of the two emitters **49***a*, **49***b*.

With reference to FIG. **39** in a variant of the gradient emitter **252** just discussed, the side levels can be better nulled by providing only a "front wave" of limited power on the rear emitter **49***b*, thus enabling by delay additional nulling adjustment in the rearward direction, a small increase in the forward direction level and some adjustment capability overall. The transducer **258** of the rear emitter can be enclosed and the two emitters separately mounted, or in another example the emitters can be connected to form an inner chamber **260** and the rear transducer **258** can be mounted within that chamber.

With reference to FIG. **40**, in another gradient example the two emitters **49** can be mounted separated from each other and facing the same way to form a gradient emitter **252**. Again the level, or phase, or both, of one with respect to the other can be adjusted as needed to improve the cancellation to the rear or side or both as desired to correct for imbalances in level and phase. In one embodiment the rear emitter can be of much lower power and can act essentially as a vernier to optimize performance of the front emitter analogous to the auxiliary and primary emitter combinations discussed above.

With reference to FIG. **29**, as to all the embodiments, the size of the device **270**, **270'** overall is dependant on the frequency of the narrow band or single frequency to be emitted. For example, as to the embodiment shown in FIG. **27**, viewed from the front or back, would resemble that shown in FIG. **29** and would decrease in diameter by one half by doubling the frequency, for example from 1.2 kilohertz to 2.4 kilohertz. While this may seem obvious, it is important to remember in applications where the profile of the device is a consideration. For example if the emitter **270** is to be mounted on a vehicle and in a slipstream (not shown) wind resistance can be decreased (for example) by selecting a higher frequency (or frequencies) for the tone or narrow band of frequencies to be used. Moreover, because the device in the examples is symmetrical about the acoustic axis, it can be configured and mounted so that only one half the device as discussed in each case is presented to the slipstream. For example, as illustrated in FIGS. **30** and **31** the emitter **271** can be mounted so that the transducer **272** is mounted in or just below a surface **274**, for example a bottom of a truck trailer, to present less wind resistance.

With reference now to FIG. **27**, in this example the emitter is configured for a frequency range of about 1.2 to 1.4 kilohertz. The diameter of the front plate **276** is one half the wavelength at the 1.2 kHz frequency. The front plate is spaced from the rear plate **278** by a distance **280** of about one tenth to one fifth the radius **282** of the front plate. The forwardly extending portion **284** of the rear plate is disposed at an angle **286** of 45 degrees. The distance **288** that the portion extends at that oblique angle can bring it a up even with the front plate, or beyond, and in one example is such as to bring it even therewith. The width **290** of the opening can be approximately equal to the distance **280** between the plates. The transducer **292** can be about four to six centimeters in diameter. Inwardly extending portions **294** as discussed above can be provided, and/or a phase-plug or the like **296**, but such were not used in the example now discussed. This example emitter was tested and the results are shown in the polar plot and parameter listing shown in FIG. **41**.

With reference to FIG. **28** a similar device but configured with the rear plate extending backward at angle of about 60 degrees a distance **288** of about 5 centimeters was also tested and the results are shown in FIG. **42**. It is interesting to note that the embodiment of FIG. **27** appears to be unbalanced slightly in the rearward axial direction and be more directional forward while the embodiment of FIG. **28** appears to have a more ideal null rearward, but has a higher SPL in the sideways directions.

With reference to FIG. **43**, in another example embodiment the emitter **300** is configured with two transducers **301**, **302** operating in monopole mode; i.e. they are closed-back units radiating in one direction. The forward baffle plate **303** is one wavelength in diameter, the wavelength of a first tone. In the illustrated example the rear baffle plate **304** extends around the forward plate as before described, but other configurations described above can be used. This example allows the levels of the first and second transducers to be individually adjusted for better cancellation. Also, the two transducers can project distinct tones, for example a first tone frequency plus 15 Hz and a first tone minus 15 Hz, for a difference tone (beats) of 30 Hz. Another difference in frequency can be chosen. In one embodiment the back transducer can emit two tones, one tone being the first tone, and a second tone being one with a wavelength which when multiplied by about 0.765 gives the diameter of the emitter baffle plate. In this way the device can emit two tones simultaneously, each of which is directional. This allows a dual tone acoustic signal to be emitted directionally. With reference to FIG. **44**, in another embodiment a forward transducer **305** is a dipole, and so works as before described in connection with FIGS. **4**, **13**, and the like. The second transducer **302**, can be operated to increase or decrease the level of the back wave in the waveguide space **56** between the baffles **303**, **304**. This by operating it in phase or 180 degrees out of phase with the first transducer and adjusting its level. In another embodiment the second transducer **302** can produce a second tone, again to create beats if the frequency difference is small, or a dual tone effect if the tone is the inverse of 0.765 times the wavelength of the tone of the first transducer, which in turn is the frequency corresponding to the diameter of the forward baffle in wavelength. Turning to FIG. **45**, in another example embodiment a separate waveguide **56** is provided by a third baffle **306** for the output from the rear transducer **302**. Producing a second tone, also with directionality gives the advantage of making the source of the audio signal more locatable for the human listener, therefore enabling better perception of the direction to the emitter from the listener. This is useful in warning devices, annunciators, etc. where the recipient of the audio signal is to be made aware of something and its location. Also a dual tone capability enables a richer, more engaging audio signal to be produced, as will be recognized by one skilled in the art.

With reference now to FIG. **46**, in one example embodiment the configuration is similar to that shown in FIG. **43** discussed above, but the “rear” transducer **307** is sent a signal delayed one quarter wave from that of the “front” transducer **301**. This means the rear transducer **307'** and waveguide **56'** are virtually at the position shown in outline in the figure. With this configuration, the waves cancel “forward” producing a null zone **308** in “front” of the emitter. The sound does not cancel to the sides and “rearwardly” as it is out of phase by one quarter turn. Thus if the device is “flipped around” it functions to produce a level polar plot **309** shown in the overlaid hypothetical plot **309**. Thus the device has the advantage of tuning by changing the level and frequency of one transducer with respect to the other to obtain a better null zone.

With reference to FIG. **47**, in another example embodiment three closed monopole transducers **301**, **302**, **310** and three baffles **303**, **304**, **311** are used. This again enables a dual tone directional device. The diameter of the most forward baffle **311** is about 0.765 of the wavelength of the tone produced by the middle transducer **301**, while the diameter of the middle baffle **303** is about 0.765 of the wavelength of the tone produced by the rearmost transducer **302** in this example. The forward transducer allows adjustment of a trim audio signal than can include one or both tones at levels as needed to improve rearward/sideward cancellation. It adds to forward level as well. Moreover, the phase of the signal from the forward transducer can be adjusted as well to improve rearward/sideward cancellation. In another embodiment a forth transducer **312** can be used for further trim; again separately adjustable for level and phase of one or both tones to improve rearward/sideward cancellation. As will be appreciated, the transducers can be of lower cost and power handling because there are more of them in this example. Many separately adjustable transducers gives more flexibility in customizing the tonal quality of the audio signals emitted, as well as improving directionality by better matching of canceling signals to signals to be suppressed.

In another example embodiment using the same physical configuration, two tones are produced by the middle transducer **301**, one corresponding to a wavelength which multiplied by 0.765 gives the diameter of the forward most baffle **311**, and the other which has a wavelength that equals the diameter of the forward most baffle. In this case the forward most transducer **310** can produce this same tone and be phased with the middle transducer second tone to provide directionality in a manner described above with respect to FIGS. **1-3**, a central source surrounded by a circular line source, the radius being one half wave length, while the other tone produced by the middle transducer is directional by the method discussed above.

As will be appreciated, more than one of the methodologies for directionality can be applied in this example. Because separate transducers are used, both in-phase (with different path lengths) and pseudo-gradient (out of phase, but similar path lengths) means discussed above, or combinations thereof, can be used in canceling "forward" or "rearward" to create null zones where cancellation occurs to bring the level down there as discussed above.

With reference to FIG. **48***a* in another example embodiment a dipole transducer **314** in a baffle arrangement such as discussed above in connection with FIG. **4** for example, is combined with a forward baffle **315** of smaller size and a second dipole transducer **316**. This gives a two tone capability, also with directionality. As will be appreciated the forward baffle plate **315** and forward transducer **316** can be moved outward and another baffle plate **317** added, as shown in FIG. **48***b*. This increases efficiency as the front wave does not need to divert as far to get around the forward baffle **315**.

With reference to FIG. **49**, in another example embodiment a forward closed monopole transducer **330** cooperates with a rear monopole transducer **331** and a front baffle **332** and rear baffle **333** to provide a directional emitter similar to that described in connection with FIG. **43**. Except however that the center transducer is not mounted in the front baffle, but in front of it in a small forward baffle **334**. The forward transducer can also produce a second tone, which has a wavelength that is 1/0.765 of the diameter of the small forward baffle. This is also directional due to the smaller circular source being close to a much larger baffle **332**. The second tone is cancelled side and rearwardly, and projects forwardly.

With reference to FIG. **50**, in another example, a gradient scheme such as discussed above in connection with FIG. **3** is given a two tone capability. A first dipole transducer **318** is positioned adjacent a first waveguide **56** defined by a forward baffle **319** and a second baffle **320**. A second waveguide **321** for the rear wave is given a flared shape, and eliminates the quarter-wave pipe of the example shown in FIG. **3**. This is defined by an outer bell-shaped baffle **322** and an inner corresponding baffle **323**. A smaller forward baffle **324** and second dipole transducer **325** provide a directional second tone. The diameter of the larger forward baffle is 0.765 times the wavelength of the first tone produced by the first transducer. The diameter of the smaller forward baffle is equal to the second (higher frequency) tone. A similar arrangement but with different frequencies is shown in FIG. **51**.

With reference to FIGS. **52** and **53**, in another example embodiment a directional emitter **340** includes closed monopole transducers **341** mounted in baffle plates **342** which in turn supports a number of concentric sheets or layers of sound absorbent material **343**. As will be appreciated, sound propagating in a forward direction **344** which does not encounter the sound absorbent material will be projected forward. Whereas sound propagating through the sound absorbent material will be attenuated. This quiets the sides and rear of the device **340**, and the device is simple, though somewhat larger than can be made using other methods described above.

The sound absorbent material **343** is layered or disposed in sheets separated by air gaps or alternating layers of more and less dense material, because sound attenuation is increased by proving density boundaries the waves must cross. Thus layers of material, which can be of alternating different densities, or the same density but separated by air gaps, for example, in the illustrated embodiment, are used. The material can be a foamed polymeric material, spun glass, or another spun resin, the latter two having confining support into layers as shown, or another sound absorbent material. While this embodiment works to provide directionality by absorption rather than cancellation of wave energy, it too can be effective in providing directed audio signals.

With reference to all the drawing figures, heretofore, the discussion has been directed to essentially single tone, or two, or three tone devices (some of which can produce another tone from the difference between two tones, i.e. a difference tone, or at least beats. Nevertheless, with the examples disclosed it will be appreciated that not just a single tone, or a single group of different single tones, can be produced. There is some room to vary the frequency and still have directionality, at least within certain bands around the design frequencies. Device examples where two or more such bands around different tones are used in overlapping fashion to provide a wider band response will now be discussed.

With reference to FIGS. **54** and **55** In another example embodiment rather than one, two, or a few distinct tones, an emitter **350** can be made to have a capability of reproduction of sound over a band **351** of frequencies. The emitter, along with associated electronics **352**, as will be apparent from the following, is configured so as to enable reproduction across a range of frequencies enabling a wider band output, while retaining some or all of the directionality of the narrow-band examples discussed above. In general terms, this is done by means of providing a plurality of emitter portions **353**, **354**, each having (in the illustrated embodiment a plurality of bands **355**, **356** of frequencies where sound can be emitted with directionality by the emitter portions, respectively. A crossover can be conventionally provided electronically to direct the appropriate frequency portions of the acoustic signal to be reproduced to the appropriate portion(s) of the emitter. Equalization can be applied as well to smooth response and close gaps in bands as will be discussed in more detail below.

Specifically with reference to FIG. **54**, in one example embodiment the emitter **350** is configured similarly to the examples shown in previous figures, with round disks forming baffles **360**, **362**, **364** and transducers **361**, **363**, **365**. In this example the transducers are monopole types. A rear portion **353** of the emitter portions has a disk diameter **366** of about one foot in the example. The forward portion **354** has an associated disk diameter **367** of about eight and one half inches in the example. The baffle **362** intermediate the front and rear emitter portions serves both, as does the transducer **363** mounted therein. That is to say, this middle transducer **363** serves as a forward transducer for the rear portion and a back transducer for the forward portion. Audio signals for both portions are sent to the same transducer in this embodiment. Moreover, a low pass functionality can be provided in the larger diameter portion by providing higher frequency absorbing material **368** in one embodiment. The function of the low pass functionality will be described below.

Specifically with reference to FIG. **55**, because of the different diameters of the portions **353**, **354** of the emitter, and the crossover provided in the electronics **352** in this example, an overlapping of frequency bands gives the wider band **351** over which an acceptable response envelope **370**, **370'** (**370** prime) exists. Equalization of the response curves **372**, **374** can extend the bands, as shown in outline, and raise the envelope height in which the response will be essentially linearly correspondent with the incoming audio signal in the forward axis (**369** in FIG. **54**). This is shown by the larger area under the curve(s) which corresponds to the **370'** envelope shown in the figure. The intersection point **371** is controlling the un-equalized essentially linear response envelope of the device. In the frequency range around the intersection point **371** at higher SPL levels partial cancellation occurs forward to an extent introducing distortion, and the crossover is not availing at this frequency as both curves are down at this point, which will be appreciated with reference to the un-equalized response curves **374**, **372**. Equalizing these curves using electronics (**352** in FIG. **54**) conventionally can close the gaps between response curves, as illustrated by the outline curve portions **372'** and **374'** and thereby expand the envelope **370** to that shown at **370'**.

Other emitter configurations having plural tone capability discussed above could be adapted to wider band devices using this approach. The response curves will be different depending on configuration, but the general idea can be implemented across a plurality of emitter examples disclosed herein by changing the other parameters accordingly.

With reference now to FIG. **56**, it should be remembered that equivalent systems **380**, **382** can be constructed with dipole transducers (e.g. **383**) or with two monopole speakers **384**, **385** driven 180 degrees out of phase. The two-monopole approach allows independent adjustment of the level and phase of the "front wave" **386** and "back wave" **387** which can be useful in configuring and tuning the system **382**. Moreover, real-world systems creatable rarely exactly conform to the ideal conceptions, and this independent adjustability can help obviate that difference by facilitating said separate adjustment of two independently creatable wave trains. As to each of the above-discussed embodiments in the various figures of this disclosure, it will be appreciated that by manipulation of the configurations of the emitter involved two monopoles can be substituted for a single dipole, for example as shown in FIG. **57**.

With reference to FIG. **57** it will be appreciated that two substantially equivalent systems **388**, **390** are presented. A first system **388** using a dipole transducer **391** has absorbent material **392** in a wave guide space **393** as needed to match the amplitude of the front and back wave from the dipole transducer in a rear direction **394** for improved cancellation. A second system **390** using two monopole transducers **395**, **396** allows this same matching to be effected electronically; and has the further capability of relative phase adjustment.

Moreover, separate signal processing can allow distinct signals different in other ways to be sent to the front and back transducers **395**, **396**. This can facilitate two or more separate acoustic signals being reproduced by the same emitter at the same time. For example, a first signal can be a directionally produced narrow band signal as described above. A separate second narrow band signal can be omni-directionally produced by phase rotation of a part of the second signal sent to one of the transducers to counteract the directional nature of the emitter. The two signals are essentially overlaid and the result is essentially the same as if it could be produced by separate emitters placed in the same point in space at the same time. The possibilities of this overlay approach will be further appreciated with additional examples.

In another example a first signal can be directionally projected in a first direction **397**, while a second signal is directionally projected in at least one other direction (e.g. in an opposite direction **398**). In an implementation in a back-up beeper, a warning tone can be sent outward from the vehicle while a much quieter masking signal can be sent towards the operator for example (not shown). In this latter embodiment not only is the level of the alarm brought down for the operator, but a further enhancement in the comfort of the operator is possible by creating a more pleasant and less jarring tone by introduction of the masking tone of, say, additional harmonics, etc. In one example of this implementation the transducers **395**, **396** are operated 180 degrees out of phase to produce the first signal, and are operated in-phase and at an integer multiple of the frequency of the first signal to produce the second signal. In other examples a third, a forth, and so on, additional signals can also be simultaneously sent to the emitter. Again, each such signal can have a distinct and different polar plot pattern of dispersion, as will be appreciated by those skilled in the art. In one embodiment, the first and second signals can be at the same frequency, and the second signal can be used to alter the shape of the polar plot of the first signal; for example widening or narrowing the zone where the first signal is sent strongly. Vice-versa the same can be done for widening or narrowing the null zone where the waves emitted sum to zero.

Some additional examples of configurations where two monopole transducers are used (instead of one dipole) will now be discussed. With reference to FIG. **58**, in another embodiment similar to that of FIG. **8** discussed above, an emitter **400** having two transducers **401**, **402** provides the same overall functionality as discussed above, but allows the adjustments and further functionality just discussed in connection with providing two monopoles instead of one dipole. For example, in one embodiment the first signal has the cartioid dispersion pattern shown in the hypothetical overlay curve **403**, which is similar to that for the dipole version discussed above. The second signal is at the same frequency but phase-rotated and relatively adjusted front to back between the two transducers so that it has a second plot **404** shown. This second signal is out of phase with the first signal so that the two signals additively produce a third plot **405** which has a directionality different from that of the first signal (**403**). This can, in some circumstances, substantially decrease overall efficiency, but the trade-off for this loss can be a different and more desirable dispersion pattern. For example, in the example just discussed, the resulting pattern is more directional. Since higher directionality is conventionally harder to achieve than higher efficiency in this context, this trade-off may afford advantages. This is true even if increased cost of the system required to give the SPL needed to achieve the result is considered.

With reference to FIG. **59**, another example embodiment in an emitter **410** (this time similar to those of FIGS. **34**, **34*a*** discussed above), is realized using two monopole transducers **411**, **412**. As will be appreciated path lengths **413**, **414** from the transducers to a point **415** are equalized using a folded configuration within the emitter for the output of a rear one of the pair of transducers. Again, separate adjustment for tuning of the system is enabled, as well as super-imposition of separate signals for additional effects as just discussed is enabled. For example as shown the sideways emissions are out of phase by ¼ wavelength. A separate set of signals that are out of phase front to back so that they cancel in both directions, but which are but out of phase by one quarter wavelength can be configured to just cancel the sideways emissions of the first signal. The result is essentially the same as that illustrated by the example shown in FIG. **58**, the two separate signals combine to form a new pattern different from that of either the first or second signals.

With reference to FIG. **60**, an example embodiment emitter **420** similar to that of FIG. **3** is realized using two transducers **421**, **422**. The example can otherwise function as described above in connection with FIG. **3**. Again, in this embodiment of FIG. **60** however, tuning and alteration of the dispersion pattern is enabled by allowing distinct signals two be sent to the two transducers. Note that this embodiment is also similar to that of FIGS. **50** and **51** discussed above, and a variation is shown in FIG. **61** (emitter **423**) where a wave guide **426** for the "rear wave" output of a monopole transducer **425** is likewise smoothed in configuration. Additional variation is illustrated by FIG. **62**, which employs a folded configuration for such a wave guide **427** of the emitter **428** shown. Another variation is shown in FIG. **63**. This latter version of an emitter **430** eliminates the folded configuration, and indeed the connection between the two round wave guides **431**, **432** and simply involves a different electronic delay between the transducers **433**, **434**. The quarter wave pipe (**36** in FIG. **3**) is eliminated. Other physical structure **435** holds the wave guides in fixed relationship to each other. Again, superimposition of one or more additional acoustic signals can alter the dispersion pattern as just mentioned with the other embodiments just discussed. It will be appreciated that the principles of these latter few examples can be generalized an applied to many if not all the examples disclosed herein.

With reference now to FIG. **64**, a narrow band device **436** can be realized in a relatively small physical space by providing three monopole transducers **437**, **438**, **439** in three circular baffle plates **440**, **441**, **442** of a diameter **443** of convenient size. For example the diameter can be about one-half wavelength in one example. Here wavelength being a representative value from the narrow frequency band to be reproduced by the device. Taking a single frequency tone as an example, a front wave signal is sent to a first transducer **437**, and a backwave (phase angle 180 degrees) signal is sent to the middle transducer **438**. By adjustment of one or more of the frequency (holding the baffle diameter fixed, relative amplitude of the front and back wave signals, and relative phase angle of the front and backwave signals, a polar plot approaching that shown in FIG. **65** (plot **65**A) can be achieved. A second set of acoustic signals is sent to The middle **438** and rear **439** transducers, likewise 180 degrees out of phase with each other (more or less), and adjusted as to amplitude and phase angle to achieve a polar plot as shown in FIG. **65** (plot **65***b*) which is a mirror image of the prior-mentioned polar plot but reduced in amplitude so that the back lobe **446** matches, essentially, the back lobe **447** produced by the other pair (**437**, **438**) of transducers, but 180 degrees out of phase therewith so as to cancel it. The resulting overall output of the device **436** is illustrated by the third plot (**65***c*) of FIG. **65**. It will be appreciated that by overlapping two directional signals in the device an improvement in directionality is achieved in a device of overall smaller dimensions compared with those discussed above having baffles of approximately one wavelength diameter. This can be significant in applications where the overall size of the device is important, and smaller is better.

Other ways of implementing the overlapping concept are possible. With reference to FIG. **66**, a dipole device **450** employing two dipole transducers **451**, **452** in baffles **453**, **454** separated by a middle baffle **455** is configured for directional projection of an audio signal of narrow band character. Here again the diameter **456** of the device is considerably smaller than those described above having a full wavelength diameter (approximately). By adjustment of the frequency of the output of the first transducer **451** a first output of non-ideal directional nature is obtained. This is shown in FIG. **67** (plot **67***a*). A second, mirror image (but down in amplitude) audio signal that is reverse in phase and direction is sent to the back transducer **452** and gives the plot shown in FIG. **67** (plot **67***b*). The resulting overall output is the sum of the two outputs, shown in FIG. **67** (plot **67***c*). As with the prior example, the undesirable parts of the directional acoustic outputs of two overlapping signal regimes cancel out when the signal regimes are coordinated with the device configuration.

Another example of this concept is realized in a gradient embodiment having an entirely different form factor. With reference to FIG. **68**, a narrow band emitter **460** of elongated small diameter form includes a gradient scheme comprising two transducers **461**, **462** separated by one quarter wavelength **463**. The audio signal is fed to these transducers, and that to one transducer is delayed by 90 degrees phase shift, to give a first audio signal regime, illustrated by the output plot **69***a* shown in FIG. **69**. The signals sent to these transducers to give the first signal regime are combined and rotated 180 degrees and simultaneously fed to the first transducer **461** and a third transducer **464** located one half wavelength from the first transducer. This second signal regime creates an audio output as shown in plot **69***b* of FIG. **69**. The two signal regimes together create the more directional output shown in plot **69***c* of FIG. **69**. As will be appreciated, a fourth transducer **465** could be added, and the second signal regime could be sent to that forth transducer and the third transducer **464**. However, the example works with just three transducers.

A further reduction in size can be realized at the cost of additional complexity in signal processing is provided (as well as some additional complexity in handling the acoustic path lengths in air in the device as discussed above in connection with the example shown in FIG. **59**). With reference to FIG. **70**, in one example embodiment an emitter **470** similar to that discussed above and shown in FIG. **59** includes two transducers **471**, **472** in a wave guide housing **473** configured to produce a gradient effect as discussed above. A further transducer **474** is included, and is positioned as shown. A delay is used to create a virtual position for the further transducer, shown as **474'** at the virtual position. Looking front to back, and vice versa, the virtual position is one half wavelength from the first or front transducer **471** or the second or rear transducer **472**. A cancellation scheme such as that shown in FIG. **69** is effected by introducing a delay into the signal paths to the front transducers **471**, **472**—this allows a phase shifted signal to be sent to the further transducer **474** in the rear. This phase shifted signal is paired with a signal sent to one of the other transducers to produce the canceling signal (**69***b* plot in FIG. **69**). As will be appreciated, the delay to the primary signal (**69***a* in FIG. **69** sent to the front transducers mentioned above is so that a delay to create the virtual position **474'** can be accommodated. Also, depending on which of the front transducers is used to form the canceling pair, the delays can be further adjusted as needed. For example, if the rear transducer **472** is used, the delays must be further adjusted so that the signals match as the pathway from the rear transducer **472** to the far field at 90 degrees (and 270 degrees) is longer by a quarter wavelength than that from the front transducer **471** to the same location(s). In any event it will be apparent that overlapping systems can be created in this way to produce a more directional output.

With reference to FIG. **71** it will be appreciated that a similar configuration, but for replacement of two monopole transducers with a single dipole transducer **478**, can achieve a similar result in an emitter example **477** illustrated. Here the signal sent to a rear transducer **480** is likewise paired with one of the front wave or the back wave of the forward dipole, and is delayed and phase rotated to give an independent radiation pattern similar to that shown in plot **69***b* of FIG. **69**. Again, the whole signal sent to the transducers is delayed so that the relative delays can be effected, as the signal (**69***a* in FIG. **69**) to the front transducer is "advanced" compared to portions of the cancellation signal, and time is needed to create the phase rotations and delays needed for the signals that implement the scheme. In other words the program material as a whole can be delayed, as some signal paths require more delay and some less and processing can introduce delays that need to be mitigated. Moreover, it will be appreciated that in the dipole example the cancellation signal is limited to one half the output of the dipole, so the cancellation to the sides will be less effective by half, and the resulting pattern will be something in between plot **69***a* and plot **69***c*.

With reference to FIG. **72** in another embodiment an emitter **482** is constructed so that a distance **484** of about a quarter wavelength is created across the "back" of the emitter. This causes a more narrow null zone in the "rear" direction, as shown by plot **73***a* in FIG. **73**. A "cancellation" signal (plot **73***b* in FIG. **73**) is sent to the rear transducer **486** which radiates omni directionally and is out of phase. As will be appreciated the overlapping of these audio signals results in a narrow beam in the "rear" direction (as defined in the previous examples) shown by plot **73***c* in FIG. **73**. As will be appreciated, efficiency is traded for directionality in this example.

With reference now to FIGS. **74** and **75**, an example of a wide-band directional emitter **490** includes a dipole transducer **492**, or two monopoles **493**, **492'** disposed in a baffle and waveguide arrangement as discussed above. Two baffle plates **494**, **495** are closely spaced to create a waveguide **496** for a "rear" wave as discussed above. The rear baffle **495** can fold around and provide forwardly extending portions **495***a* around the periphery as discussed above. The baffles in one example are circular and the transducers are off center in at least one of two axes of symmetry **496**, **497** as shown in FIG. **76**. The baffles in another example are elongated in one or more axes (e.g. **497** in FIG. **76**). The transducer(s) can be in other locations **498**, **499** in other examples. The salient principle is that the distance from the transducer(s) to the outer periphery of the waveguide varies. As will be appreciated there is then no one distance corresponding to a frequency which will cancel the forward wave as in the examples shown in FIGS. **54** and **55**. Accordingly, wide band response is possible without the need for overlapping systems described above. Moreover, the response of the emitter can be adjusted to some extent by adjusting the path lengths; that is to say by providing a different shape of the emitter **490'** waveguide, kind of equalization is possible, by emphasizing certain path lengths and minimizing others, relatively speaking. A further adjustment can be made by providing attenuating material **500** of variable density in the waveguide space **496**. As shown in FIG. **77** the shorter distances can have more dense material in the pathways, while the longer distances have less dense material in the pathways. Since the devices are asymmetrical, in a stereo implementation the asymmetry can be mirror reflected to provide overall symmetry left to right across an axis of symmetry **501** as illustrated in FIG. **78**.

As illustrated in FIGS. **79** and **80** in other examples various shapes can be combined with multiple transducers **509**, **510**, **511** at multiple locations. These transducers can be of various sizes and/or various types, and crossovers (not shown—conventional) provided to direct various frequency spectrum portions to various speakers positioned with respect to the baffle **494**, **495** shape and edges to give the response desired.

As will be appreciated with reference to FIG. **81**, in another example the entire face of a forward baffle **512** can be covered with transducers **513**. Again, these can be dipoles as shown in FIG. **82**, or monopole pairs **513'** as shown in FIG. **83**. Again the waveguide **515** is defined by baffles **514**, **512** as previously described. The rear baffle can have forwardly inclined portions **515'** as previously described. This configuration also provides a wide band directional emitter **520**. Moreover, as will be appreciated, this configuration can be beam-steered by providing delays in the signal pathways to individual rows and columns of transducers. This also allows the sound emitted to be focused, by providing delays from the outer rows and columns to the innermost rows and columns (or a single central transducer—not shown) or vice versa. With reference to FIG. **84**, in another embodiment the face of the emitter **522** can be likewise covered by transducers **513**, but these can be randomly placed, and/or can be of various sizes/types. Again, in one example a crossover network can be provided to direct different frequency spectrum portions to different transducers.

With the examples shown in FIGS. **81** and **82** it will be appreciated that the audio signal pathways in air are equal to the side and rearward for each dipole or monopole pair **513**, **513'**, and that the distance to the edges of the baffles **512**, **514** is different for each transducer (but symmetry can result in several sets of transducers each having the same sets of uneven distances to the edges). Therefore the forward wave cancellation effects are again masked by redundancy, and a wideband response is enabled.

With reference to FIG. **85** in another embodiment the numerous conventional transducers are replaced by a planar magnetic transducer (PMT) **532** in an emitter **530** otherwise configured as before described. As illustrated by FIG. **86** in another example several rows **533**, **534**, **535** of PMT transducers can be used. As with the previously described embodiments monopole and dipole transducers can be used. With reference to FIG. **87** dipole PMTs **533**, **534**, **535** are mounted in a front baffle **536**. In FIG. **88** another example is shown incorporating dipole pairs of PMTs **533'**,**534'**, **535'** mounted in the front baffle and rear baffle **537** (which, again, can have forwardly extending portions **537'** at the edges).

With reference to FIG. **89** in another example an electrostatic transducer **542** covers most of the front of an emitter **540** otherwise configured as before described. Again, as shown in FIGS. **90** and **91** monopole and dipole devices can be used. The emitter otherwise can be as before described.

With reference to FIG. **92**, in another example the face of an emitter **550** using PMT or electrostatic type transducers is divided into transducer columns **551**, **552**, **553**, etc. and can be divided into rows **557**, **558**, **559**, etc. as well if multiple transducers are provided in each column. Using dipole devices as an example, as illustrated in FIG. **93** the front baffle **560** carrying the transducers (or defined by them) is backed by a rear baffle **562** as before described. Delays can be used to focus and/or beam steer the output, for example moving and shaping the front baffle's effective position (and also the rear baffle). In one example the delay is between the inner and outer columns and the virtual position of the emitter elements is shown designated by primed reference numbers **560'**, **562'** to give a focusing result.

Other examples of wide band devices using plane form transducers (PMTs will be shown and described as examples only) can include embodiments where less than all the front baffle is covered. For example with reference to FIGS. **94**, **95**, a dipole PMT transducer **572** is mounted in a circular emitter **570** of two baffle plates **573**, **574** as before described. These baffle plates can be other shapes e.g. **575**, **576** as will be appreciated. Again distances from the transducer to the edges of the baffles vary, so the front wave cancellation is smoothed and wide band response results. Other shapes are illustrated by FIGS. **96**, **97** and **98**, with variations.

A further variation is illustrated by FIG. **99**, wherein an emitter **590** various transducers, **591**, **592**, **593**, **594**, **595**, are arranged to have various non-canceling ranges of distances to the baffle **596** edges corresponding to various frequencies. These can be connected via a crossover network (not shown—conventional) to a signal source (not shown) so that the portions of the signal to be optimally reproduced directionally are sent to the corresponding transducer for that frequency range from among the set of transducers of the device.

With reference to FIGS. **100**, **101** and **102**, an example embodiment in a device **600** which facilitates much more intense outputs, employs a number of transducers **602** arranged in a hemispherical support **604**. These transducers can be of one of a number of types, for example conventional loudspeakers using magnetic voice coil motor technologies, piezo-electric types, or other types. In order to increase output, increasing the power density of acoustic motors in the hemisphere is desirable. Accordingly, transducer types which give high power output in small physical sizes are desirable. In one embodiment, instead of a hemisphere, a cylindrical section can be used, for example having the a cross-section such as that shown in FIG. **100**. In such an example, elongated transducers such as ribbons, elongated planar magnetic transducers, and the like, can be used. In other words, the transducers **602** shown schematically can be a wide variety of types.

With reference to FIGS. **100-102**, it will be appreciated that the transducers are divided into at least two groups **606**, **608** divided from each other by at least one wave guide **610**, in the illustrated example being configured as a frustum of a cone and opening into a central opening **612** comprising an outlet for the output of one group (**606**) of transducers. It will be appreciated that this takes the place of the central transducer discussed in the previous examples. The frustoconical wave guide and a front baffle plate **614** direct the output from the second group of transducers (**608**) to a concentric opening **616** just outside the central opening. The two groups of transducers are phase-flipped so as to be 180 degrees out of phase with respect to each other. They can be independently adjusted in SPL for matching for improved cancellation as in the embodiments discussed previously. A front baffle plate **618** wave guide is provided to separate two wave trains from the two respective groups of transducers which exit the concentric openings **612**, **616** about one hundred eighty degrees out of phase, as discussed with reference to the previously presented examples. The forward baffle wave guide can be elliptical, or other shape to prevent forward cancellation at certain frequencies, as discussed above, or for a narrow band device can be round as shown alternatively (**618** alt.).

As will be appreciated it is the openings **612**, **616**, and the forward baffle wave guide **618** which give rise to directionality in the ways discussed above. In this example the hemisphere **604** containing the transducers **602** can be of essentially any convenient practicable size for the number and type of transducers used, as directional functionality does not depend on the size of the hemisphere. In one embodiment the size of the hemisphere is chosen to create a Heimholtz resonance in at least one of at least two chambers **620**, **622** into which the two groups of transducers **606**, **608** (respectively) direct their output. This can be done to increase the output from at least one group of transducers. Moreover, as will be appreciated the wave guides **610**, **618**, and openings, **612**, **616**, can be modified, smooth transitions supplied, and shaping provided, to maximize output and minimize sonic artifacts arising from geometry, edges, and transitions, as is well known in the art.

Using efficient, small, transducers **602** a relatively large SPL output can be directionally created using a device **600** such as illustrated in the example which is not unduly large. As will be appreciated across a narrow frequency band, coinciding with a resonant frequency of the transducers and coordinated with the structure to be directional along an acoustic axis **624**, a very high SPL output signal can be directionally generated. Likewise, across a wider band voice or other acoustic signal can be directionally generated, at less intensity than a narrow band signal, but still with very high power.

With reference to all the drawing figures, it will be appreciated that directionality in emitted sound of a single frequency or narrow band of frequencies can be obtained using low cost means which can be both simple and robust (to survive in various service environments). While specific examples have been disclosed, it will be appreciated that modifications and variations can be made without exercise of inventive facility, and the scope of the invention is not intended to be limited to the disclosed examples.

What is claimed is:

1. A directional acoustic emitter having an acoustic axis, including:

at least one transducer configured to impart at least two acoustic wave trains into a fluid media along at least two pathways;

at least one wave guide, configured for separating the wave trains along at least a portion of their pathways;

the wave guide configured so that over at least one narrow frequency range the wave trains do not destructively interfere along the acoustic axis in a positive direction so as to eliminate useful output, and which do destructively interfere along the acoustic axis in a negative direction, and which at least partially destructively interfere in a direction transverse to the acoustic axis.

2. The emitter of claim **1**, wherein the narrow frequency range is restricted to substantially a single frequency.

3. The emitter of claim **2**, wherein the single frequency is between about 1.2 kilohertz to about 1.4 kilohertz.

4. The emitter of claim **2**, wherein the waveguide includes an emitter face having a diameter of about one wavelength of the single frequency.

5. The emitter of claim **2**, wherein the waveguide includes a substantially circular emitter face.

6. The emitter of claim **5**, wherein the pathways radiate outwardly from a single, central transducer through at least one circularly expanding waveguide.

7. The emitter of claim **5**, wherein the waveguide includes a diameter of between about 0.6 and about 0.8 times the wavelength of the frequency.

8. The emitter of claim **7**, wherein the waveguide includes a diameter of about 0.765 times the wavelength of the frequency.

9. The emitter of claim **1**, wherein the waveguide includes an emitter face that is symmetrical about the acoustic axis.

10. The emitter of claim **1**, wherein a single transducer imparts the at least two wave trains.

11. The emitter of claim **1**, further comprising at least two transducers, each imparting one of the at least two acoustic wave trains into the fluid media.

12. The emitter of claim **11**, wherein the output of one of the transducers is electrically reduced to enhance destructive interference in the negative or transverse directions.

13. The emitter of claim **11**, wherein the output of one of the transducers is electrically phase shifted to enhance destructive interference in the negative or transverse directions.

14. The emitter of claim **11**, wherein the output of one of the transducers is electrically phase shifted to reinforce output in the positive direction.

15. The emitter of claim **2**, where the two pathways impart at least two acoustical wavetrains into the media at locations separated by about ½ a wavelength of the single frequency.

16. The emitter of claim **2**, wherein the narrow frequency range is substantially one dominant frequency.

17. The emitter of claim **2**, further comprising a plurality of transducers combined to achieve a wideband system.

18. The emitter of claim **17**, wherein each of the plurality of transducers operates at a different, substantially single frequency.

19. The emitter of claim **17**, wherein at least one of the plurality of transducers produces a dominant frequency that is spaced one octave above a frequency of another of the plurality of transducers.

20. The emitter of claim **17**, wherein at least one of the plurality of transducers produces a dominant frequency of about 2 kHz, and wherein another of the plurality of transducers produces a dominant frequency of about 1 kHz.

21. The emitter of claim **17**, wherein at least one of the plurality of transducers produces a dominant frequency and one or more odd multiples thereof.

22. The emitter of claim **17**, wherein at least one of the plurality of transducers produces a dominant null frequency at even multiples of a dominant frequency.

23. The emitter of claim **21**, wherein the at least one of the plurality of transducers produces a dominant frequency at about 1 kHz, about 3 kHz and about 5 kHz.

24. The emitter of claim **1**, wherein the output of at least one of the pathways is acoustically reduced with acoustically absorbent material to further enhance destructive interference.

25. A directional acoustic emitter having an acoustic axis, including:

at least one transducer configured to impart at least two acoustic wave trains having a common frequency into a fluid media; and

at least a pair of wave guides, defining a first pathway and a second pathway, the second pathway having a length that differs from a length of the first pathway by about ½ wavelength of the common frequency such that: over a selected frequency range, the wave trains do not destructively interfere along the acoustic axis in a positive direction so as to eliminate useful output, and which do destructively interfere along the acoustic axis in a negative direction, and which at least partially destructively interfere in a direction transverse to the acoustic axis.

26. The emitter of claim **25**, wherein the first and second wave guides include substantially cylindrical pipes.

27. The emitter of claim **26**, wherein the first and second wave guides are concentric pipes.

28. The emitter of claim **27**, wherein at least one of the waveguides is folded, such that a greatest overall dimension of the directional acoustic emitter is less than a sum of the lengths of the first and second pathways.

29. The emitter of claim **25**, wherein one of the waveguides is about a ¼ wavelength pipe and wherein another of the waveguides is a folded pipe of about ½ wavelength.

30. The emitter of claim **25**, wherein a single transducer imparts the at least two wave trains.

31. The emitter of claim **25**, further comprising at least two transducers, each imparting one of the at least two acoustic wave trains into the fluid media.

32. A craft operable to directionally emit an acoustic warning signal, comprising:

a vehicle; and

an emitter, coupled to the vehicle, the emitter including:

at least one transducer configured to impart at least one acoustic wave train into a fluid media along at least two pathways;

at least one wave guide, configured for separating the wave trains along at least a portion of their pathways;

the wave guide configured so that over a narrow frequency range the wave trains do not destructively interfere along an acoustic axis of the emitter in a positive direction so as to eliminate useful output, and which do destructively interfere along the acoustic axis in a negative direction, and which at least partially destructively interfere in a direction transverse to the acoustic axis.

33. The craft of claim **32**, wherein at least two acoustic wave trains are imparted into the fluid media.

34. The craft of claim **32**, wherein the emitter is aligned relative to the craft such that the acoustic axis of the emitter is aligned with a direction of travel of the craft.

35. The craft of claim **34**, wherein the emitter is aligned relative to the craft such that the positive direction of the emitter is oriented toward a reverse direction of travel of the vehicle.

36. The craft of claim **32**, wherein the narrow frequency range is restricted to substantially a single frequency.

37. The craft of claim **36**, wherein the two acoustic wave trains are imparted into the fluid media from locations separated by about ½ a wavelength of the single frequency.

38. The craft of claim **33**, wherein a single transducer imparts the at least two wave trains into the fluid media.

39. The craft of claim **33**, further comprising at least two transducers, each imparting one of the at least two acoustic wave trains into the fluid media.

40. The craft of claim **32**, wherein the pathways radiate outwardly from a single, central transducer through at least one circularly expanding waveguide.

41. The craft of claim **40**, wherein the single, central transducer imparts a single acoustic wave train that is directed into the at least two pathways.

42. A directional acoustic device configured for directing an acoustic output along an acoustic axis, including:

at least one transducer configured for creating at least two wave trains which can be made to have a differing phase with respect to each other and which follow wave paths different in length;

at least one wave guide which is configured to define at least a part of the paths and to create a difference in length of the paths;

the wave trains destructively interfering in directions more than ninety degrees off the acoustic axis and reinforcing each other in directions less than ninety degrees off the acoustic axis.

43. The device of claim **42**, further comprising at least two transducers, each creating one of the wave trains.

44. The device of claim **43**, wherein one of the wave paths is a folded wave path and has a greater length than another of the wave paths.

45. The device of claim **43**, wherein at least one of the wave paths comprises a substantially cylindrical wave pipe.

46. The device of claim **45**, wherein at least one of the wave pipes comprises a quarter-wave pipe.

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