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(72) Inventor: **Andrews, Anthony John**
Dorking, Surrey RH5 4PS (GB)

(74) Representative: **Robinson, John Stuart**
Marks & Clerk
Nash Court
Oxford Business Park South
Oxford OX4 2RU (GB)

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(71) Applicant: **Andrews, Anthony John**
Dorking, Surrey RH5 4PS (GB)

(54) **LOW FREQUENCY LOUDSPEAKER**

(57) A low frequency loudspeaker for reproducing the lowest frequency range in a multi-band sound reinforcement system comprises an enclosure (8 to 13) with a front port (14). Drive units (1, 2) are mounted on baffles (3, 4) which divide the enclosure (8-13) into sealed chambers (5, 7) behind the drive units (1, 2) and a cham-

ber (6) which vents through the port (14) but is otherwise sealed. The drive units (1, 2) point generally away from the port (14). The chamber (6) extends smoothly backwards from the port (14) and the cross-sectional area of the chamber (6) perpendicular to the direction (17) of sound emission from the port (14) increases continuously with distance from the port (14).

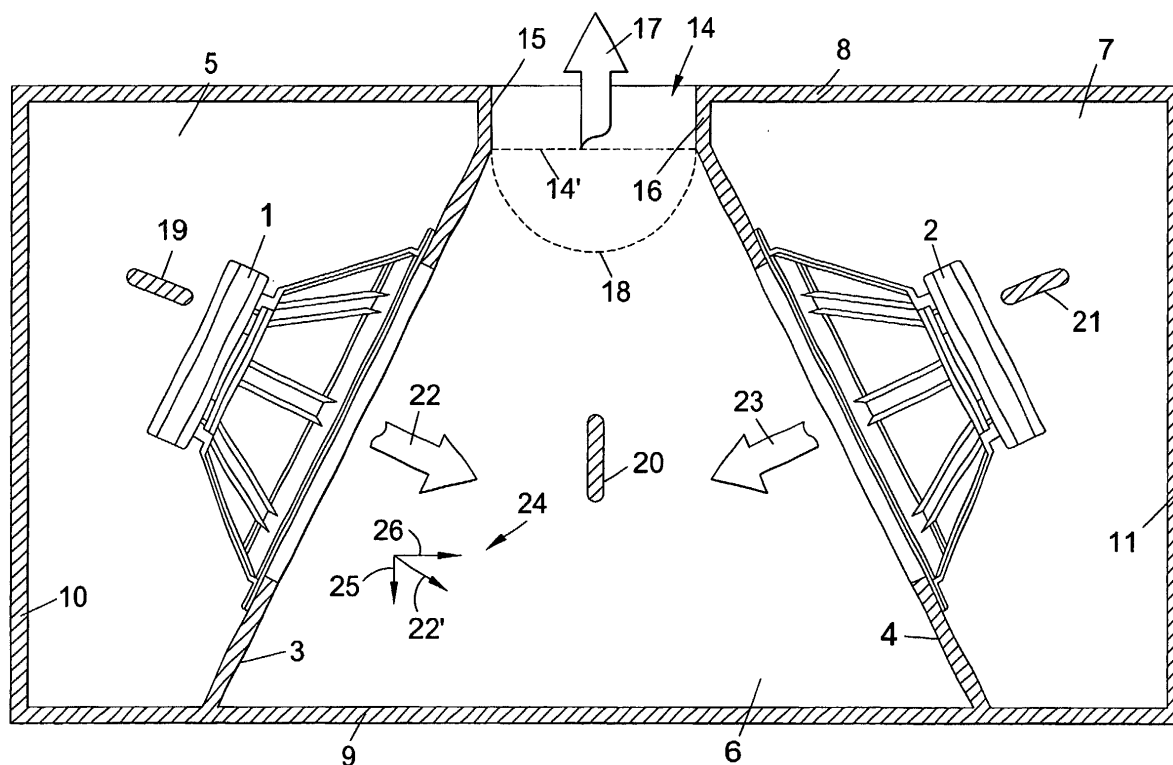


Fig. 1

Description

[0001] The present invention relates to a low frequency loudspeaker. Such a loudspeaker may be used as part of a full range system for reproducing the whole audible frequency spectrum, for example in a sound reinforcement system.

[0002] In known sound reinforcement or "public address" systems, it is usual for the audible frequency spectrum to be divided into several different frequency bands, each of which is reproduced by a loudspeaker specifically designed for that frequency band. This allows high quality sound reproduction to be achieved at very high sound levels in a large auditorium or other venue. An advantage of this arrangement is that each loudspeaker handles a limited frequency range and can be designed for and, in some sense, optimised for reproducing the frequency band supplied to it.

[0003] As is known, it is difficult to reproduce the lowest audible frequency band below about 60Hz by means of acceptably compact loudspeakers. Conventionally baffled loudspeakers for reproducing this part of the sound spectrum would require baffles of unacceptably large dimensions because the wavelength of sound below 100Hz is greater than 3 metres. For example, the wavelength at 20Hz is approximately 15 metres and conventionally baffled loudspeakers would require baffles of this order of size.

[0004] So-called "infinite baffle" enclosures can be made much more compact because the sound produced from the rear of a conventional cone diaphragm loudspeaker driver is effectively prevented from being radiated by mounting the transducer in the panel of a sealed chamber or enclosure. However, the acoustic loading of such a transducer results in very low efficiency of converting electrical power to acoustic power.

[0005] In high power high quality sound reinforcement systems, it is acceptable to divide the sound spectrum into four or more frequency bands. It is then acceptable for the loudspeaker reproducing the lowest frequency band to operate over a relatively narrow frequency band, for example of the order of one octave. This allows relatively compact enclosures to be used with good electro-acoustic conversion efficiency being achieved while providing sufficiently high sound levels for sound reinforcement in relatively large venues. However, known techniques suffer from producing sound in the lowest frequency range with relatively uneven frequency response and with relatively large levels of distortion.

[0006] US 4 215 761 discloses a low frequency loudspeaker in which an electromagnetic drive unit has a rear chamber and a front sound channel. The sound then diverges such that the tapering throat is followed by a horn. There is no port in this loudspeaker.

[0007] EP 0 692 922 discloses a low frequency loudspeaker in which two drive units are provided with rear chambers, front chambers and outlets of different sizes. One of the front chambers is slightly tapered towards its

outlet, which appears to be acting as a port.

[0008] According to a first aspect of the invention, there is provided a low frequency loudspeaker as defined in the appended claim 1.

[0009] According to a second aspect of the invention, there is provided a sound reinforcement system as defined in the appended claim 18.

[0010] Preferred embodiments of the invention are defined in the other appended claims.

[0011] Such a loudspeaker is capable of reproducing the lowest frequency range at high sound pressure levels while being relatively compact. In addition, such a loudspeaker provides a relatively "smooth" sound over a frequency range typically of the order of at least one octave. The smoothness of reproduction is believed to result from a smooth frequency response within the frequency range for which the loudspeaker is designed and relatively low distortion. Such a loudspeaker represents a substantial improvement in sound quality over known types of loudspeakers for reproducing a similar frequency range without having any other significant penalty in terms of its performance.

[0012] The invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view on line I-I of Figure 2 of a low frequency loudspeaker constituting an embodiment of the invention;

Figure 2 is a perspective front view showing the external appearance of the loudspeaker of Figure 1;

Figure 3 is a perspective rear view with top and rear walls and drive units removed;

Figures 4 and 5 are graphs illustrating second and third harmonic distortion against frequency of an example of the invention and a comparison example; and

Figure 6 is a graph illustrating the frequency responses of the example of the invention and the comparison example.

[0013] The loudspeaker is intended for use as part of a high quality high power sound reinforcement system. In particular, the loudspeaker is intended to be used for reproducing the lowest frequency band in a multi-band system, typically with a frequency range of 25 to 60Hz. The loudspeaker comprises a pair of substantially identical drive units 1 and 2, each of which comprises an electromagnetic driver having a frusto-conical diaphragm with a largest diameter of nominally 18 inches (approximately 45 centimetres). The drive units 1 and 2 are mounted on baffles 3 and 4 forming internal parts of an enclosure, for example made of wood or any other suitable material. The baffles 3 and 4 divide the enclosure

sure into a first chamber 5, a second chamber 6, and a third chamber 7. The drive units 1 and 2 are shown as physically projecting into the chambers 5 and 7 in Figure 1. However, the drive units may alternatively be mounted so as to project into the chamber 6 so as to improve cooling and the volumes of the chambers 5 and 7 may be adjusted accordingly.

[0014] Each of the first and third chambers 5 and 7 is disposed behind its respective drive unit 1 and 2 and is acoustically sealed so as to prevent or greatly reduce the emission from the loudspeaker of sound from the rear of the drive unit diaphragm. The chambers 5 and 7 may be provided with a small aperture (not shown) to permit pressure equalisation of air in the chambers with ambient atmospheric pressure so as to prevent changes in atmospheric pressure from offsetting the drive unit diaphragms from their normal rest positions.

[0015] The enclosure comprises a front wall 8, a rear wall 9, sidewalls 10 and 11, a top wall 12 and a bottom wall 13. The enclosure is thus cuboidal in shape with a largest (width) dimension of approximately 1.4 metre. The front wall 8 has formed therein a port 14 defined by an aperture in the front wall 8 and a re-entrant "tunnel" comprising side walls 15 and 16 and the adjacent portions of the top and bottom walls 12 and 13 inner or input with an end 14' of the port being illustrated by broken lines. The port has a sound transmission direction illustrated by an arrow 17. The cross-sectional area and shape of the port 14 are constant throughout the length of the port. A part cylindrical acoustically transparent grill 18 is provided so as to prevent the ingress of material which might be damaging to the drive units 1 and 2.

[0016] The top and bottom walls 12 and 13 are braced by the baffles 3 and 4, the walls 15 and 16, and struts 19 to 21, all of which extend between and are rigidly fixed to the top and bottom walls. The baffles 3 and 4 are rigidly fixed and sealed to the inner end of the port walls 15 and 16 at the input end 14' of the port, from which they extend at an obtuse angle. The baffles 3 and 4 are likewise fixed and sealed to the rear wall 9. The baffles 3 and 4 and the relevant portion of the rear wall 9 define the second chamber 6, which tapers in cross-sectional area (perpendicular to the sound emission direction 17 of the port 14) from the rear wall 9 to the port 14. Thus, the cross-sectional area increases with distance from the port towards the rear wall 9. In this respect, the height of the second chamber 6 remains constant but the width increases continuously and monotonically from the inner end of the port 14' to the rear wall 9.

[0017] The drive units 1 and 2 have sound emission directions indicated by arrows 22 and 23, respectively. The drive units are oriented so that the sound emission directions 22 and 23 point generally away from the port 14 and towards the rear wall 9. This may be expressed vectorally as illustrated at 24 in that the vector 22' corresponding to the direction 22 can be resolved into a component 25 parallel to the sound emission direction

17 of the port 14 and a component 26 perpendicular to the component 25, the component 25 pointing in the opposite direction to the sound emission direction 17.

[0018] The second chamber 6 and the port 14 are substantially symmetrical about a plane parallel to the sound emission direction 17 and perpendicular to a plane which is parallel to both the sound emission direction 17 of the port 14 and the drive unit sound emission directions 22 and 23 and parallel to the top and bottom walls 12 and 13. Indeed, the whole loudspeaker is symmetrical about this plane.

[0019] The orientations of the baffles 3 and 4 so as to be non-parallel to each other and to the side walls 10 and 11 reduce the effects of standing waves within each of the chambers 5 to 7. The inclined baffles 3 and 4 also define the tapering cross-sectional area of the second chamber 6.

[0020] As mentioned hereinbefore, in an actual example of the loudspeaker shown in Figures 1 and 2, the drive units 1 and 2 are of "18 inch diameter" types with 4 inch (10 centimetre) voice coils driving the inner ends of the frusto-conical diaphragms. Such an example is capable of reproducing the frequency band from about 25 to about 60Hz and would generally be connected to a power amplifier, for example capable of about 450 watts continuous power and 3 kilowatts of peak power, supplied via a cross-over filter arrangement for restricting the frequency range supplied to the power amplifier substantially to that of the operating frequency range of the loudspeaker. Such an arrangement is capable of an electro-acoustic efficiency of 102dB at 1 metre away from the front wall 8 on the axis of the port 14 for one watt of electrical input power at 35Hz. The loudspeaker therefore has high electro-acoustic efficiency and is capable of generating very high sound pressure levels suitable for use in a sound reinforcement system for relatively large venues. The frequency response within the frequency range is very smooth with very small "peaks" and "dips" between 25 and 60Hz. The distortion performance is excellent with very low levels of distortion being produced within the frequency range at very high sound pressure levels.

[0021] Although the port 14 has been referred to as the region of space between the walls 15 and 16, this is for the sake of convenience because there may not be an abrupt cut-off between the volume functioning as the port and the volume constituting the second chamber 6, at the input end 14' and between the volume functioning as the port and the exterior of the loudspeaker.

[0022] Although the mechanism by which the loudspeaker achieves improved sound reproduction is not fully understood, it is presently believed that the reducing cross-sectional area of the chamber 6 to the input end (14') of the port 14 contributes to the improvements which have been achieved. It is also believed that the orienting of the drive units 1 and 2 so as to point generally away from the port 14 may contribute significantly to the improvement. In order to test this belief, an exam-

ple of the loudspeaker as described hereinbefore was compared with a comparison example. The comparison example differed only from the example of the invention in that the port 14 was formed in the middle of the wall 9 instead of in the wall 8, which was therefore sealed.

[0023] Figures 4 and 5 illustrate the second and third harmonic distortion performances of the example of the invention and the comparison example. Figure 6 compares the frequency responses of the example of the invention and the comparison example. In each of Figures 4 to 6, the performance of the example of the invention is illustrated by the unbroken curve whereas the performance of the comparison example is illustrated by the broken curve.

[0024] The example of the invention is intended for use between about 25 and 60Hz and this is the only region in Figures 4 to 6 which is of relevance to its performance. Thus, throughout the whole of this region, the second harmonic distortion performance of the example of the invention is improved compared with the comparison example with the average improvement being 2dB. The third harmonic distortion performance of the example of the invention is improved throughout nearly all of this range with the average improvement being 3dB. The third harmonic distortion is particularly important because odd order harmonics tend to be more noticeable and less pleasant than even order harmonics. In this respect, a very large improvement in performance is achieved between about 40 and 55Hz as compared with the comparison example.

[0025] In the frequency range of interest, the output falls less rapidly with decreasing frequency for the example of the invention as compared with the comparison example. For a given electrical input power, the example of the invention produces 2dB more acoustic output at 30Hz and an average of 1dB more acoustic output over the frequency range of 20 to 60Hz. All of the improvements are very significant for a loudspeaker of this type. The phase response is also linear over a wider bandwidth.

[0026] It should be emphasised that the comparison example does not represent any previously known loudspeaker but was provided merely to attempt to ascertain the significance of the features of the invention which are believed to contribute to the improvement in performance.

Claims

1. A low frequency loudspeaker comprising a first electro-acoustic transducer (1) and an enclosure (8-13), the transducer (1) being disposed on a first baffle (3) which divides the enclosure (8-13) into an acoustically substantially sealed first chamber (5) behind the first transducer (1) and a second chamber (6) in front of the transducer (1) having a port (14) for emission of sound from the enclosure, **characterised in that** the port (14) has an input end (14')

forming an output end of the second chamber (6), and the second chamber (6) has a cross-sectional area, perpendicular to a sound emission direction (17) of the port (14), which increases substantially continuously with distance from the port, and the port (14) has a substantially constant cross-sectional area perpendicular to the sound emission direction (17) of the port (14).

2. A loudspeaker as claimed in claim 1, **characterised in that** the second chamber (6) is substantially acoustically sealed apart from the port (4).

3. A loudspeaker as claimed in claim 1 or 2, **characterised in that** the port (14) has a substantially constant cross-sectional shape perpendicular to the sound emission direction (17) of the port (14).

4. A loudspeaker as claimed in any one of the preceding claims, **characterised in that** the port (14) is re-entrant in the enclosure (8-13).

5. A loudspeaker as claimed in any one of the preceding claims, **characterised in that** the port (14) is disposed in a front wall (8) of the enclosure (8-13) and the first baffle (3) extends from the input end (14') of the port (14) to a rear wall (9) of the enclosure (8-13).

6. A loudspeaker as claimed in claim 5, **characterised in that** the port (14) extends substantially perpendicularly from the front wall (8).

7. A loudspeaker as claimed in any one of the preceding claims, **characterised in that** the port (14) is of rectangular cross-section perpendicular to the sound emission direction (17) with the longer sides extending perpendicularly upper and lower walls (12, 13) and throughout the height of the enclosure (8-13).

8. A loudspeaker as claimed in any one of the preceding claims, **characterised in that** the first transducer (1) has a sound emission direction (22) with a component (25) which is opposite the sound emission direction (17) of the port (14).

9. A loudspeaker as claimed in any one of the preceding claims, **characterised in that** the port (14) and the second chamber (6) are substantially symmetrical about a first plane which is parallel to the sound emission direction (17) of the port (14).

10. A loudspeaker as claimed in claim 9 when dependent on claim 8, **characterised in that** the first plane is perpendicular to a second plane which is parallel to the sound emission direction (17) of the port (14).

and the sound emission direction (22) of the first transducer (1).

11. A loudspeaker as claimed in any one of the preceding claims, **characterised by** comprising a second electro-acoustic transducer (2) disposed on a second baffle (4) which divides the second chamber (6) from an acoustically substantially sealed third chamber (7) behind the second transducer (2). 5 10
12. A loudspeaker as claimed in claim 11, **characterised in that** the second transducer (2) is substantially identical to the first transducer (1).
13. A loudspeaker as claimed in claim 11 or 12, **characterised in that** the third chamber (7) is substantially identical to the first chamber (5). 15
14. A loudspeaker as claimed in claim 13 when dependent on claim 9 or 10, **characterised in that** the first and third chambers (5, 7) are substantially symmetrical with respect to the first plane. 20
15. A loudspeaker as claimed in any one of claims 11 to 14, **characterised in that** the enclosure (8-13) is of cuboidal shape. 25
16. A loudspeaker as claimed in any one of the preceding claims, **characterised in that** the or each transducer (1, 2) is an electromagnetic transducer. 30
17. A loudspeaker as claimed in any one of the preceding claims, **characterised in that** the or each transducer (1, 2) has a frusto-conical diaphragm 8. 35
18. A sound reinforcement system **characterised by** including a loudspeaker as claimed in any one of the preceding claims. 40

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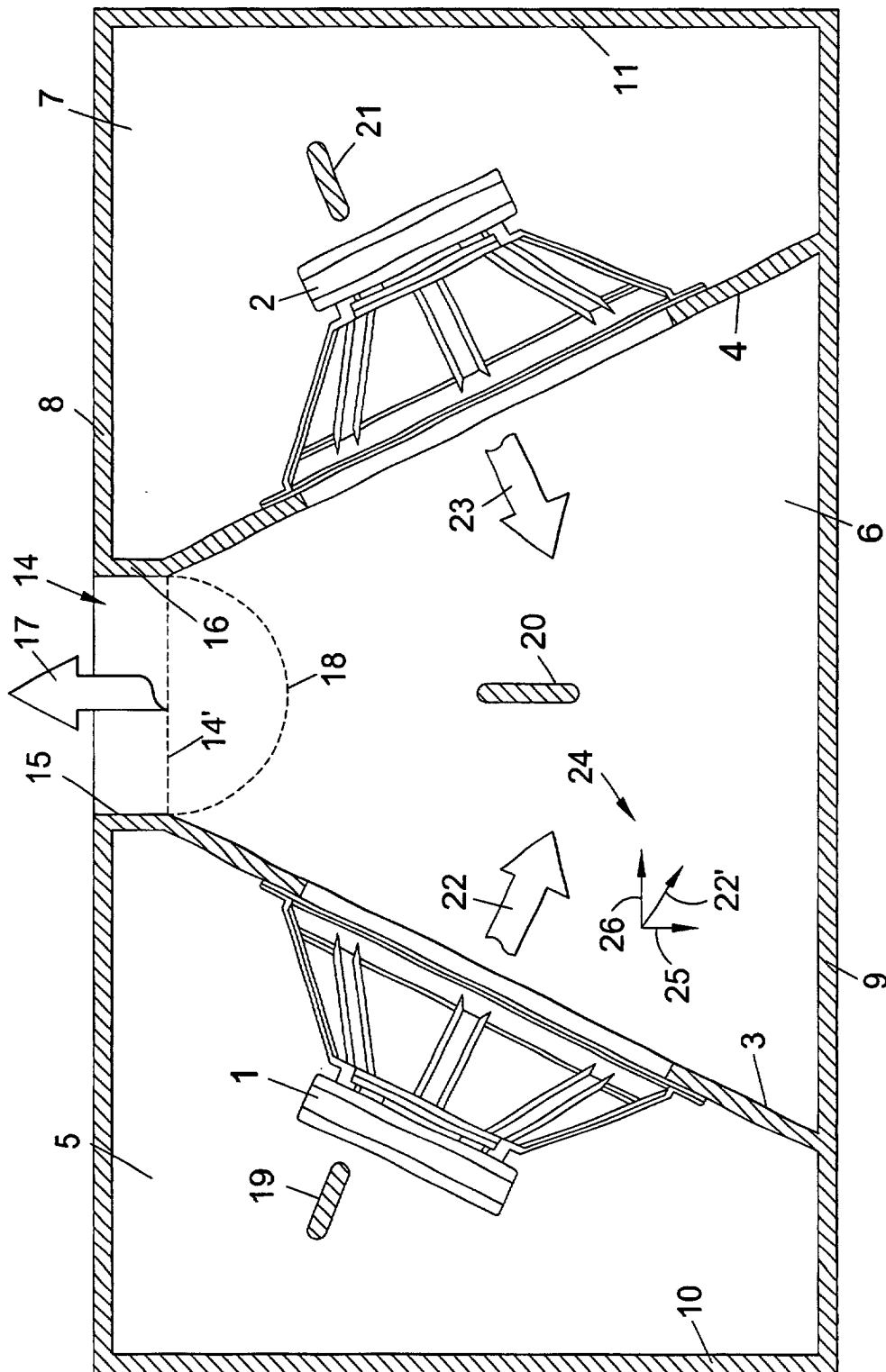


Fig. 1

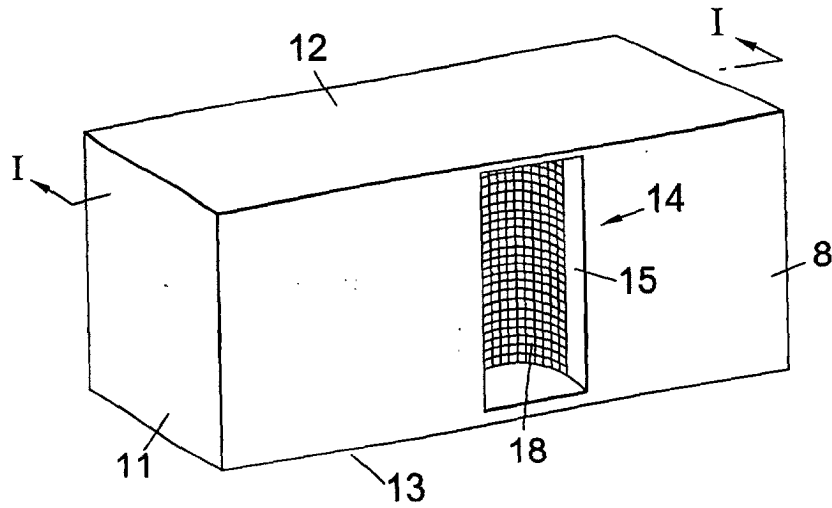


Fig. 2

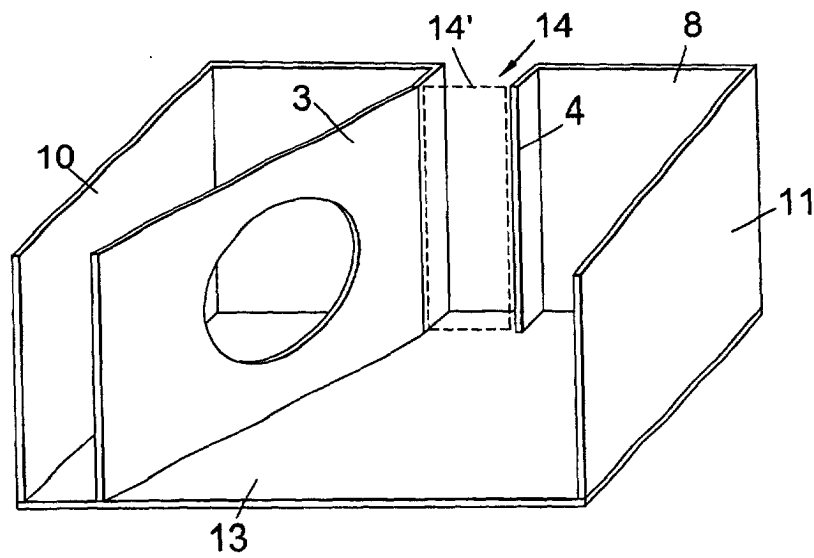


Fig. 3

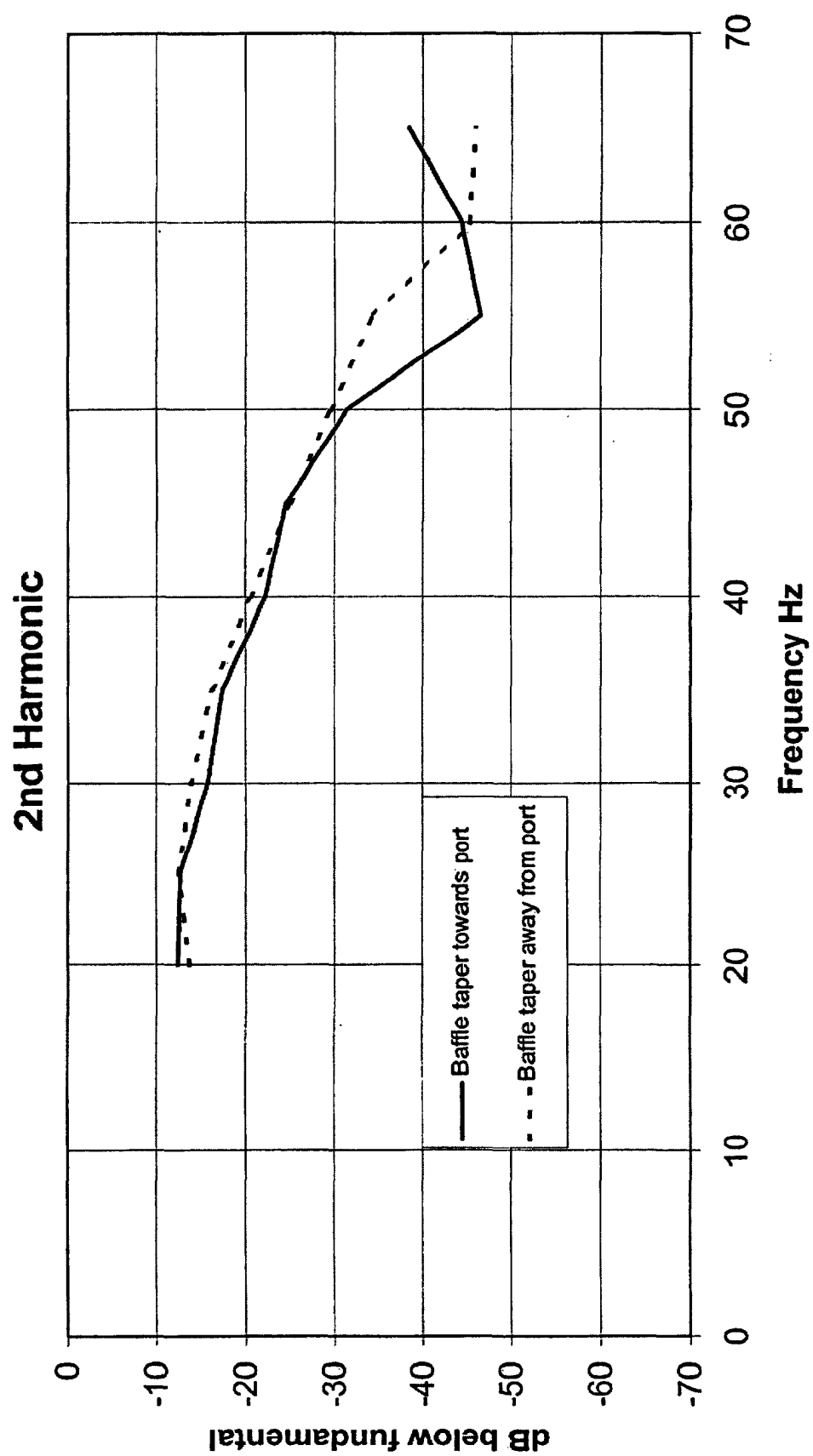


Fig. 4

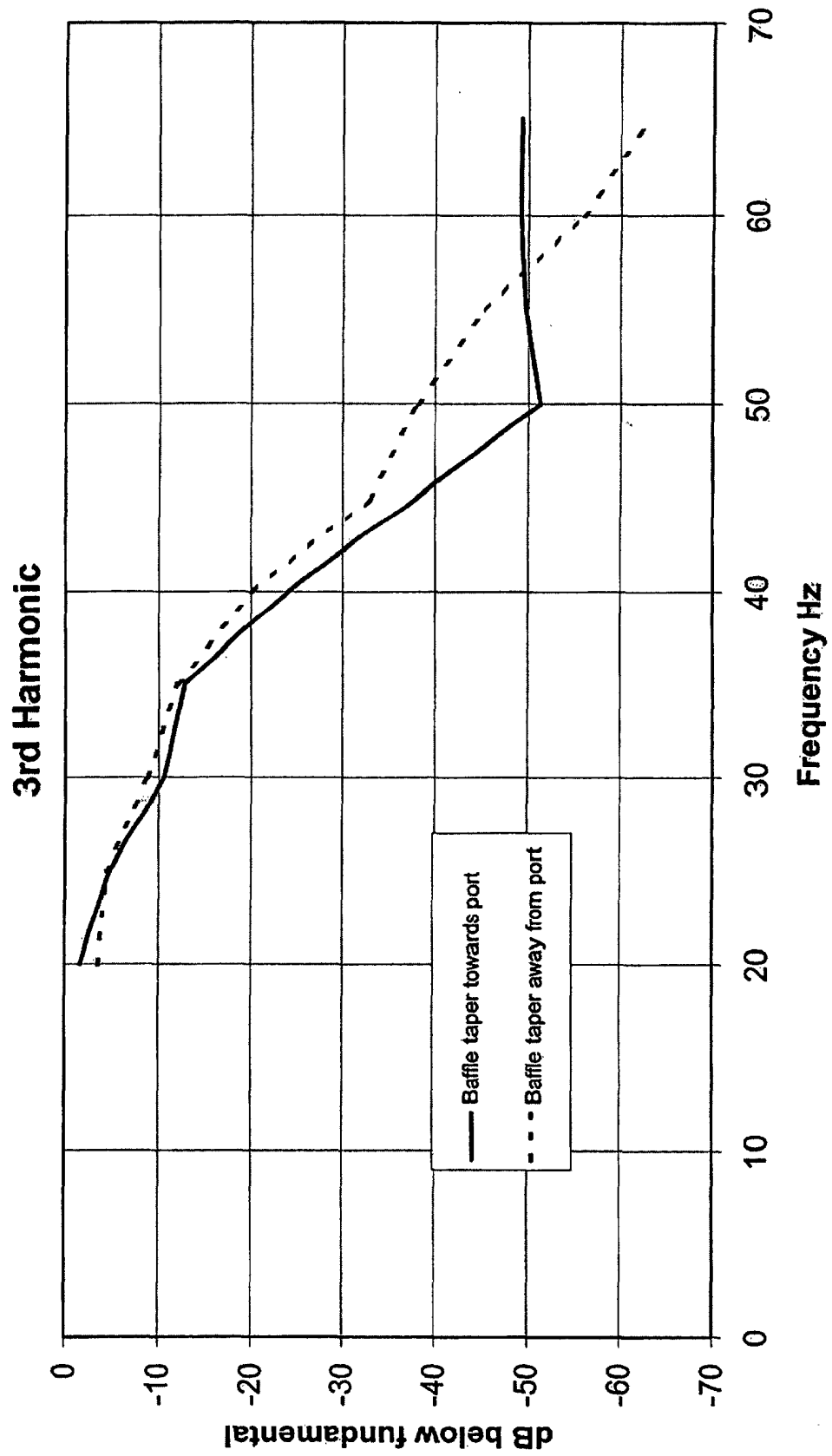


Fig. 5

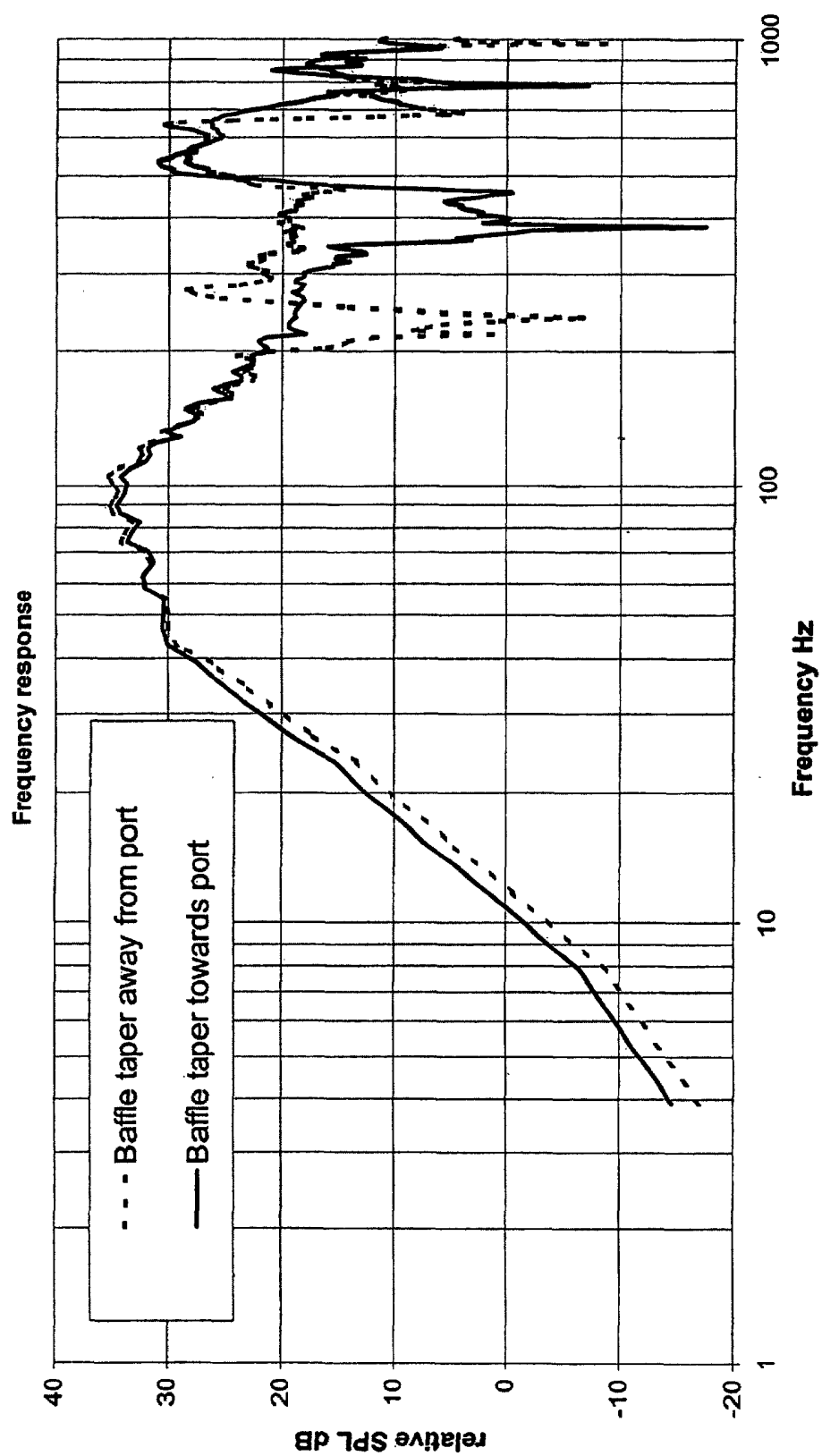


Fig. 6