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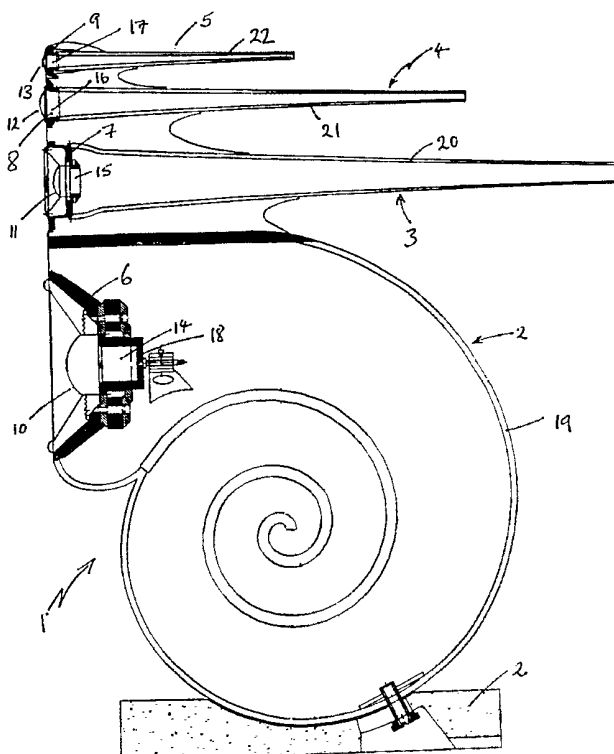
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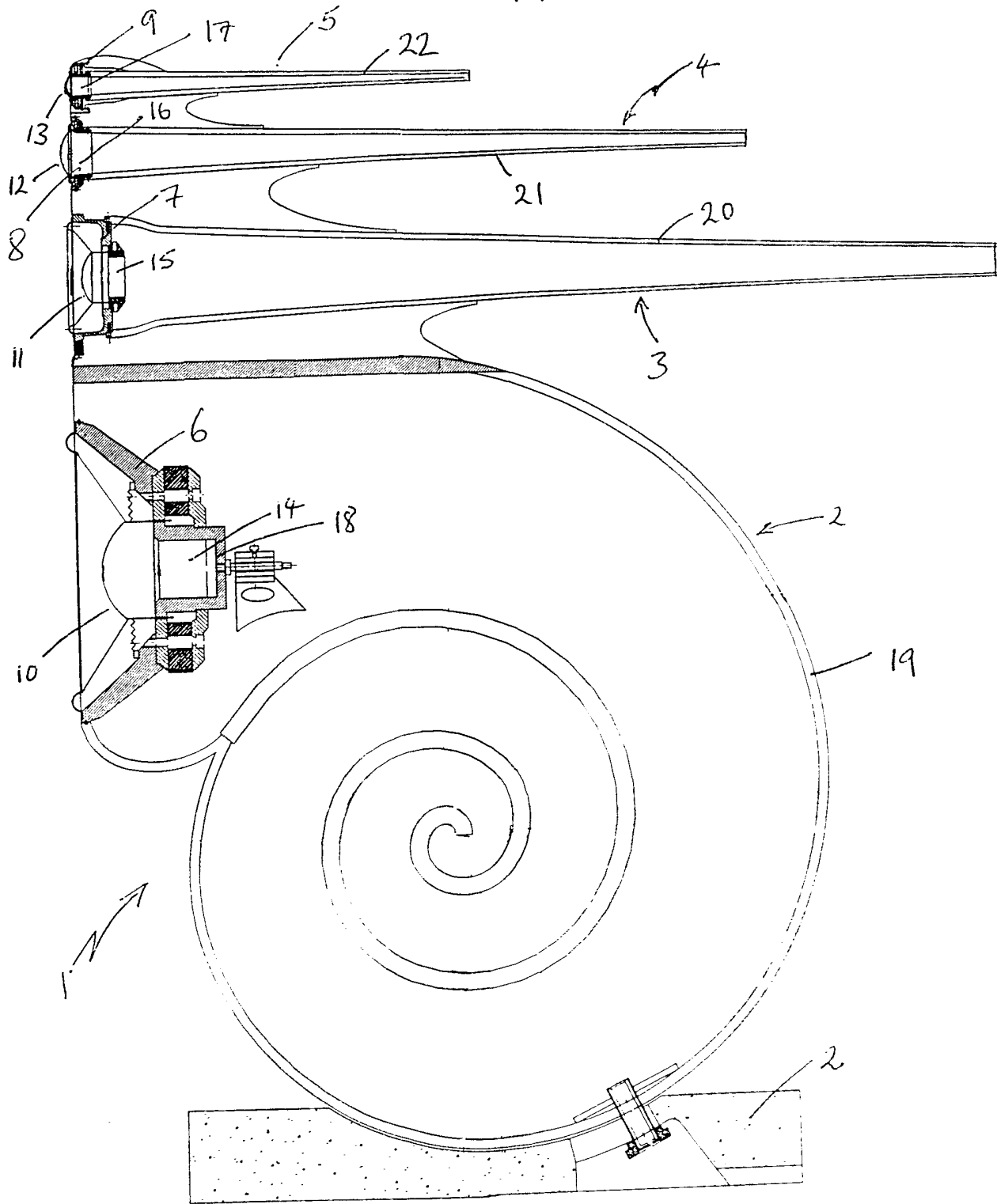
(54) Loudspeaker systems

(57) A loudspeaker system 1 comprises a bass unit 2, a mid-range unit 3, a treble unit 4, and a tweeter unit 5. Each of the units 2, 3, 4 and 5 includes a respective loudspeaker drive unit 6, 7, 8 and 9. The mounting for the loudspeaker drive unit 6, 7, 8 and 9 is such that there is substantially no rear reflecting surface behind the diaphragm of the loudspeaker drive unit. The pole piece of the respective magnet system of each loudspeaker drive unit 6, 7, 8 and 9 is provided with an aperture 14, 15, 16 and 17 through which, in use, sound from the rearward side of the diaphragm passes.

Each of the loudspeaker drive units 6, 7, 8 and 9 has a respective circular-section tube 19, 20, 21 and 22 extending from the rear of the loudspeaker drive unit. Each tube 19, 20, 21 and 22 contains sound-absorbent material (not shown) such as glass fibre and tapers away from the associated loudspeaker drive unit.



1/1



LOUDSPEAKER SYSTEMS

This invention relates to loudspeakers systems comprising at least one loudspeaker drive unit and a mounting for the at least one loudspeaker drive unit.

In a conventional speaker system the mounting is usually a cabinet at the rear of the loudspeaker drive unit into which sound passes. The main function of the rear cabinet is to prevent the rearward radiation coming round to the front and then, since it is out of phase, cancelling out the frontward radiation.

If the loudspeaker drive unit is of the type having a dome-shaped diaphragm, the voice coil will usually be at the outside edge of the dome and the pole piece of the magnet system will usually fill almost all of the entire space behind the diaphragm. There will usually be a small cavity between the top of the pole piece and the rear of the dome which itself acts as a small totally enclosed speaker box. Such a structure introduces resonance which will have the effect of "colouring" the sound from the loudspeaker system.

In the case of a cone shaped diaphragm, there is usually a "basket" or "chassis" immediately behind the diaphragm and the voice coil is situated in the middle of the diaphragm rather than at its edge. Such structures again have a tendency to introduce resonance.

The rear box can be totally enclosed, in which case all the direct rearward sound is prevented from coming

round to the front. Or the box may have a hole in it, in which case the mass of air in the hole and the stiffness of the air in the box produce a "Helmholtz" resonance which may be used to reinforce the bass response of the speaker.

Other ways of preventing the rear-front cancellation are (a) to place the speaker on a large baffle and (b) to pass the sound down a pipe of sufficient length so that when it emerges from the end, at the later time which depends on the length, it is in phase with the low frequency part of the front radiation which it then reinforces rather than cancels - this is the so called "transmission line speaker" approach.

In all cases when there is a box or a tube present at the rear, the rearward sound bounces around in the box or tube forming acoustic resonances inside them. Some of this resonant energy inevitably passes out through the diaphragm and/or through the box to colour undesirably the forward sound.

It is an object of the invention to provide a loudspeaker system which has greater freedom from resonance than known loudspeaker systems.

The present invention provides a loudspeaker system comprising at least one loudspeaker drive unit and a mounting for the loudspeaker drive unit characterized in that there is substantially no rear reflecting surface behind the diaphragm of the at least one loudspeaker

drive unit.

According to the invention, each loudspeaker driver, be it a cone-shaped diaphragm or a dome-shaped diaphragm, has substantially no obstructions behind it at all.

In the case of a dome-shaped diaphragm, the voice coil may be at the outside edge of the dome-shaped diaphragm and the pole piece of the magnet system provided with an aperture through which, in use, sound from the rearward side of the dome passes.

Preferably, the said aperture is approximately the same diameter as the loudspeaker driver unit

Thus, virtually all the sound from the rearward side of the dome is allowed to pass through a large hole right through the middle of the magnet system pole piece, so offering very few or no surfaces to reflect the rearward travelling sound waves.

If a cone-shaped diaphragm is used, then much attention is to be paid to minimizing the size of any reflecting surfaces such as chassis struts and the magnet structure itself so to render to the virtual minimum any surfaces which could reflect back the rearward travelling wave.

Preferably, a tube of diameter approximating to that of the loudspeaker drive unit and of length at least six times the diameter of the loudspeaker drive unit extends from the rear of the loudspeaker drive unit, the tube containing sound-absorbent material and tapering

away from the loudspeaker drive unit.

If an infinite tube were to be placed at the rear of the diaphragm or cone, then all the rearward sound would be "lead away" and would have no effect on the desired frontward sound at all. Furthermore there would be no reflecting surfaces to cause backwards reflection of the rearward travelling wave, and so no standing waves or resonances would occur.

If a "sufficiently long" open ended tube were to be used instead of an infinite one, this tube could be filled with a suitable sound absorber such that by the time the sound reached the open end of the pipe it would be attenuated by, say, 50dB with respect to the frontward radiation. Then the sound radiated from the far end of the tube would have little effect on the frontward radiation.

Blocking off the far end of such a tube would cause a forward-going reflection to occur. This reflection would already be, say, 50dB down on the forward radiation. By the time it reached the rear side of the diaphragm it would be, say, 100dB down having suffered attenuation twice over. After having further suffered the transmission loss on passing through the diaphragm, typically 15dB or so, the final rearward sound contribution would be reduced to 115dB down on the frontward radiation and would therefore be effectively inaudible.

By making the rearward "sufficiently long" pipe an inverted exponential horn, that is, one the area of which is decreasing rather than increasing according to an exponential taper factor (usually called "m"), then the effectiveness of any absorber placed inside the pipe has been found to be greatly increased as the acoustic impedance smoothly increases with the decreasing area of the tube. In fact if the horn reduces to within a few percent, for example, 1% or 2% of the starting diameter, the absorption of the air itself is sufficient to greatly reduce the sound intensity without the provision of acoustically absorbent material.

Since the change in area is exponentially smooth, there is no abrupt discontinuity in acoustic impedance to cause reflections anywhere along the horn except at its far end. This horn therefore acts as an acoustic transformer both for the acoustic impedance and for the rearward travelling wave and its interaction with the absorbing material.

The negatively tapering rearward horn enables the effectiveness of any absorption present to be greatly enhanced. Thus, both the length and the overall volume of a rearward absorbing pipe may be greatly reduced, while at the same time preserving or even enhancing, the more or less total absorption of the rearward travelling wave. With an expeditious choice of length, taper rate and absorption material the far end of the horn may be

blocked off with little or no measurable effect on the sound reaching the rear of the diaphragm, much as in the "sufficiently long tube" case.

To summarize: virtually all the rearward radiation is absorbed by a combination of an "acoustically transparent" magnet system coupled to an inversely tapering horn filled with a suitable absorbing material.

Thus, the rearward wave having passed through the magnet structure then passes not into a conventional cabinet but into an inverted horn at the rear with absorption present.

A loudspeaker system constructed in accordance with the invention will now be described, by way of example only, with reference to the single figure of the accompanying drawing which shows a cross-section through a loudspeaker system embodying the invention.

Referring to the accompanying drawing, a loudspeaker system 1 comprises a plinth 2 on which is mounted a bass unit 2, a mid-range unit 3, a treble unit 4, and a tweeter unit 5. Each of the units 2, 3, 4 and 5 includes a respective loudspeaker drive unit 6, 7, 8 and 9. The mounting for the loudspeaker drive unit 6, 7, 8 and 9 is such that there is substantially no rear reflecting surface behind the diaphragm of the loudspeaker drive unit.

The loudspeaker drive unit 6 has a cone-shaped diaphragm 10 and the loudspeaker drive unit 7 has a flat

diaphragm 11.

Each of the loudspeaker drive units 8 and 9 has a respective dome-shaped diaphragm 12 and 13. In each case, the voice coil (not shown) is at the outside edge of the dome-shaped diaphragm. The pole piece of each respective magnet system is provided with an aperture 14, 15, 16 and 17 through which, in use, sound from the rearward side of the associated diaphragm passes. The bass unit 6 has a diametral strut for mounting purposes passing across the aperture 14. Each of the apertures 16 and 17 is approximately the same diameter as the associated loudspeaker driver unit 8 and 9.

Each of the loudspeaker drive units 6, 7, 8 and 9 has a respective circular-section tube 19, 20, 21 and 22, of diameter approximating to that of the associated loudspeaker drive unit 6, 7, 8 and 9 and of length at least six times the diameter of the loudspeaker drive unit, extending from the rear of the loudspeaker drive unit. Each tube 19, 20, 21 and 22 is made of plastics material and contains sound-absorbent material (not shown) such as glass fibre and tapers away from the associated loudspeaker drive unit. In each case, the end of the tube remote from the loudspeaker drive unit is closed.

The tubes 21 and 22 taper to a diameter less than 25% of the starting diameter.

The tube 19 is coiled into a spiral .

The loudspeaker system is provided with cross-over units (not shown) for supplying each loudspeaker drive unit with drive signals over the range of frequencies at which it is to be driven.

The loudspeaker system is such that virtually no acoustic or electronic resonances are present. That is achieved by:

(a) grossly overdamping the low frequency roll off of the drive units, and particularly the bass unit for which the whole of its usable response region from 30 Hz to 100 Hz consists of a steady rise at 6db per octave. This gross overdamping means that the bass resonance of the drive unit effectively no longer exists, and the impulse response exhibits no ringing,

(b) ensuring that all drive units are perfect pistons to 2.5 octaves above their upper operating bands, that is, the first resonant mode occurs 2.5 octaves above the operating band. That means there are no cone or diaphragm resonances in their operating bands, and by the time the diaphragms do begin to "break up" the cross-over units have greatly attenuated any resulting adverse contributions to the sound radiation,

(c) using all electronic crossover units defined by subtracting, for example, the bass roll off from unity to produce the treble roll off. That means that when the responses are added up again they produce a perfect whole, that is, a continuous flat response throughout the

audio band, no off-axis vertical lobes being present, and

(d) the response, for example, the bass roll off, of the cross-over units is chosen to give the best impulse response (in particular, of Bessel or Gauss shape), so that even with one limb of the cross-over response present on its own, very little ringing would occur at the cross-over frequency.

Instead of drive units with dome-shaped diaphragms it is possible to use drive units with cone-shaped diaphragms.

The tubes 19, 20, 21 and 22 may be shaped differently from what is shown in the drawing. For example, the tube 19 may be wound into a tapered helix shape with the drive unit 6 at the apex of the taper and the base of the taper serving as a mount and resting on the floor (the overall configuration being like a cone standing on the floor). The tubes 20 and 22 may be curved, oppositely to each other, in a horizontal plane through 90° relative to the straight tube 21. The tubes 20, 21, 22 will then act as three "stand-offs" at 0, 90 and 180° to ensure that the system is not placed close to a wall.

Where several loudspeaker drive units are employed one, some or all may have cone-shaped diaphragms, one, some or all may have dome-shaped diaphragms, or one, some or all may have flat diaphragms.

Although in each case the end of the tube remote

from the associated loudspeaker drive unit is closed in the illustrated embodiment of the invention, one, some or all of the tubes may have open ends.

All exponential horns have a so-called "cut-off frequency" which depends only on the taper rate "m" (for example, $m = 3.7$ gives a cut-off of approximately 100 Hz; $m = 18.3$ gives a cut-off of approximately 500 Hz and so on).

Thus, in practice low values of "m", and thus relatively long tubes, are required for bass units but for tweeters, however, higher values of "m" are permissible, particularly if the tube is filled with material with excellent sound absorption characteristics, because tweeters are not generally operative below, say, 3000 Hz.

Hence, the tube for a drive unit for the high frequency part of the audio spectrum could be made with a relatively high value of "m" and indeed only a relatively short length of tube would be needed to reduce the diameter to a few percent of the starting diameter.

Although tapering tubes of length at least six times the diameter of the associated loudspeaker drive unit have been described, it is possible for the tubes to be of length, for example, 2, 3, 4 or 5 times that diameter.

Although tapered tubes have been described, it is possible for one, some or all of the tubes to be cylindrical or even flared.

C L A I M S:

1. A loudspeaker system comprising at least one loudspeaker drive unit and a mounting for the loudspeaker drive unit characterized in that there is substantially no rear reflecting surface behind the diaphragm of the at least one loudspeaker drive unit.

2. A loudspeaker system as claimed in claim 1 wherein the at least one loudspeaker drive unit has a cone-shaped diaphragm.

3. A loudspeaker system as claimed in claim 1, wherein the at least one loudspeaker drive unit has a dome-shaped diaphragm.

4. A loudspeaker system as claimed in claim 3, wherein the voice coil is at the outside edge of the dome-shaped diaphragm and the pole piece of the magnet system is provided with an aperture through which, in use, sound from the rearward side of the dome passes.

5. A loudspeaker system as claimed in claim 4, wherein the said aperture is approximately the same diameter as the loudspeaker driver unit.

6. A loudspeaker system as claimed in any preceding claim, wherein a tube of diameter approximating to that of the loudspeaker drive unit and of length at least six times the diameter of the loudspeaker drive unit extends from the rear of the loudspeaker drive unit, the tube containing sound-absorbent material and tapering away from the loudspeaker drive unit.

7. A loudspeaker system as claimed in claim 6, wherein the end of the tube remote from the loudspeaker drive unit is closed.

8. A loudspeaker system as claimed in claim 6 or claim 7 wherein the tube tapers to a diameter less than 25% of the starting diameter.

9. A loudspeaker system as claimed in any one of claims 6 to 8, wherein the tube is coiled into a helix.

10. A loudspeaker system as claimed in any preceding claim comprising a bass unit, a mid-range unit and a treble unit, each unit having the features specified in any one of the preceding claims, wherein the bass unit is grossly overdamped to provide a usable response over the range 30 Hertz to 100 Hertz consisting of a steady rise of about 6dB per octave.

11. A loudspeaker system as claimed in claim 6 comprising four loudspeaker drive units each with a respective tube, wherein one tube is wound into a tapered helix shape with the associated drive unit at the apex of the taper and the base of the taper serving as a mount to rest on the floor, another tube extends straight behind its associated drive unit, and the remaining two tubes are curved, oppositely to each other, in a horizontal plane through 90° relative to the straight tube, three "stand-offs" at 0, 90 and 180° being thereby created to ensure that the system is not placed close to a wall.

Relevant Technical Fields

- (i) UK Cl (Ed.N) H4J (JBA, JCA)
- (ii) Int Cl (Ed.6) H04R 1/02, 1/20, 1/22, 1/24, 1/26, 1/28,
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Search Examiner
MR P J EASTERFIELD

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Databases (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-
1 TO 11

(ii)

Categories of documents

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| <p>: Document indicating lack of novelty or of inventive step.</p> <p>: Document indicating lack of inventive step if combined with one or more other documents of the same category.</p> <p>: Document indicating technological background and/or state of the art.</p> | <p>P: Document published on or after the declared priority date but before the filing date of the present application.</p> <p>E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.</p> <p>&: Member of the same patent family; corresponding document.</p> |
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Category	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2130048 A (NAKAMURA) see Figure 1	1, 3, 4, 5
X	GB 1390002 A (BOSTEDT ET AL) whole document	1, 2
X	GB 0864683 A (DECCA) see Figure 1	1, 2, 6, 7, 8
X	GB 0547922 A (STANDARD TELEPHONES) whole document	1, 2, 6, 8, 9
X	GB 0434563 A (TURNER ET AL) whole document	1, 2
X	GB 0378286 A (KIRKE ET AL) whole document	1, 2
X	Hi-Fi News & Record Review, January 1992, page 17, "B & W Blue Skies Speaker Project"	1-5 at least
X	US 5206465 A (JUNG) whole document	1, 2
X	US 5073948 A (VANDERSTEEN) whole document	1, 2
X	US 4752963 A (YAMAZAKI ET AL) see Figure 3 and column 3 lines 53 to 56	1, 3, 4, 5
X	US 4657107 A (HARWOOD) whole document	1, 2
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X	US 4439644 A (BRUNEY) whole document	1, 2

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).