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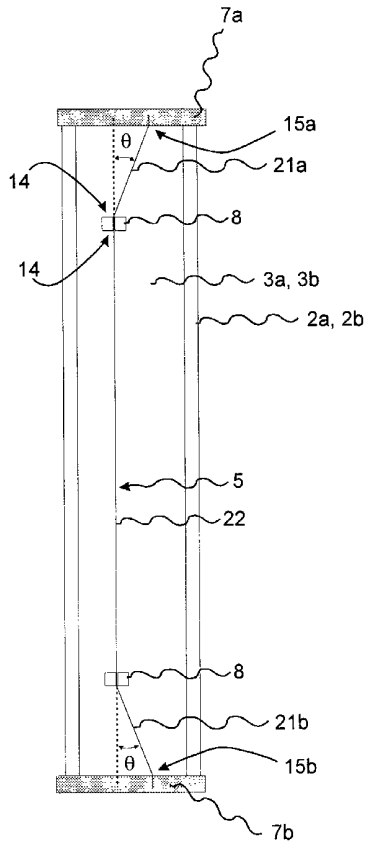
(54) Title: ELECTRO-ACOUSTIC TRANSDUCER OF RIBBON TYPE, LOUDSPEAKER SYSTEM COMPRISING SUCH A TRANSDUCER AND LOUDSPEAKER ARRANGEMENT COMPRISING AT LEAST TWO SUCH TRANSDUCERS.



(57) Abstract: The present invention relates to an electro-acoustic transducer of ribbon type comprising an elongated membrane unit (5) having a longitudinal main portion (22) that extends in a single plane.The membrane unit (5) further comprises at least one section (21a, 21b) that extends in another plane with a normal that deviates an angle (θ), preferably less than 15°, from the normal of the longitudinal main portion (22). The invention also relates to a loudspeaker system that comprises at least one such electro-acoustic transducer and to a loudspeaker arrangement that comprises at least two such electro-acoustic transducers arranged on top of each other to provide an essentially continuos curved line-source.

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ELECTRO-ACOUSTIC TRANSDUCER OF RIBBON TYPE, LOUDSPEAKER SYSTEM COMPRISING SUCH A TRANSDUCER AND LOUDSPEAKER ARRANGEMENT COMPRISING AT LEAST TWO SUCH TRANSDUCERS.

Technical field of the invention

The present invention relates to an electro-acoustic transducer, in particular of the type that comprises a source of sound formed from an electrically conducting membrane in a homogenous magnetic field with high flux.

Related art

Electro-acoustic transducers of this type usually are referred to as ribbon speakers, due to the ribbon shaped membrane. A ribbon speaker comprises an elongated, electrically conducting membrane, inserted between two elongated magnet elements. Such a speaker represents a linearly extended source of sound, having the ability to emit a high sound pressure. This type of electro-acoustic transducer can be used for all purposes where a natural sound is desired, such as for use in domestic Hi-Fi systems, in recording studios and in public address (PA) systems.

In conventional ribbon speakers, the magnet units comprise one or more magnets, supported by a frame structure (sometimes referred to as pole-pieces). One ribbon speaker of this type is disclosed in WO 99/55118, which is incorporated herein in its entirety by reference. As disclosed in WO 99/55118, electro-acoustic transducers of this type can, further, comprise two or more gaps with one membrane in each gap. Two other examples of ribbon speakers are disclosed in WO 96/07294 and US 4,049,926.

An elongated ribbon speaker can be considered as an idealised line-source of acoustical radiation. The characteristics of a line-source are described more in detail in "Multiple-array loudspeaker system.", E. J. Jordan, Wireless World,

March 1971, pp 132-134. A line-source is characterised by the vertical dispersion of the sound being minimised and the sound being concentrated in the direction of the listeners. The vertical distribution characteristics of a vertically orientated idealised line-source 40 are shown in figure 1.

These characteristics are often desired, but for some applications, where a wide vertical distribution is required together with the concentration of the sound energy, problems arise. One example of such an application is to address the people close to the stage, at events such as rock concerts and the like, using a public address (PA) system arranged above the stage. Another example, involve the transmission of verbal information to the customers in a mall, or passengers at an airport or a railway station, where the loudspeakers often are arranged above the persons to be addressed.

The conventional way of extending the vertical distribution is to arrange several elongated ribbon speakers, or other line-source like speakers, in a curved arrangement. However, due to the extremely narrow distribution in the vertical plane (0°-2°), the angle between two adjacent speakers in this plane is limited to a maximum of 5°, if a homogenous sound is desired at all listening positions. This limitation obviously makes it very difficult to achieve the desired wide distribution. One system, which uses an arrangement of this kind, is V-DOSC™ by Heil Acoustics, France. Information concerning this system can be found at www.coxaudio.com/innovations.html.

Summary of the invention

The object of the present invention therefore is to provide an electro-acoustic transducer of ribbon type, which, when vertically oriented, has an extended vertical distribution, compared with the prior art transducers, without increasing the complexity.

This object of the invention has been achieved by the invention as defined in claim 1. Embodiments of the invention are defined in the dependent claims.

An advantage with the transducer according to the invention is that a broader vertical distribution field may be covered using a smaller number of loudspeaker units, while a homogenous sound still is maintained.

In a further embodiment the vertical distribution is adjustable, whereby optimum characteristics may be achieved both for curved and straight arrangements.

Brief description of the drawings

The invention will now be described with reference to the attached drawing figures, wherein:

Fig. 1 shows the vertical distribution characteristics of a vertically orientated idealised line-source.

Fig. 2a is a perspective view of an electro-acoustic transducer according to prior art.

Fig. 2b is a top-view of the electro-acoustic transducer according to prior art.

Fig. 3 is a close up perspective view of a support portion.

Fig. 4 is a cross sectional view of an electro-acoustic transducer according to the invention.

Fig. 5a shows three electro-acoustic transducers according to prior art, in a curved arrangement.

Fig. 5b shows three electro-acoustic transducers according to the invention, in a curved arrangement.

Fig. 6 is a cross sectional view of a second electro-acoustic transducer according to the invention.

Fig. 7 is a cross sectional view of an embodiment with a cylindrical shape.

Fig. 8 is a close up perspective view of a mid-clamping unit.

Detailed description of the embodiments

In figures 2a and 2b, a conventional ribbon speaker unit is shown. This ribbon speaker unit 1 comprises two or more elongated pole pieces 2a, 2b arranged in parallel with each other and spaced apart from each other, comprising magnet units 3a, 3b. Two adjacent pole pieces 2a, 2b form an elongated slit 4 in which an elongated electrically conducting membrane unit 5 is moveably provided. Preferably the membrane unit 5 is centred in said slit 4, in such a way that it is located in the maximum magnetic field caused by the magnet units 3a, 3b. Each membrane unit 5 comprises at least one electrically conducting elongated membrane 6, which is further electrically coupled such that a drive current can be passed in the longitudinal direction thereof. Said magnet units 3a, 3b being arranged with a pole of one polarity of a first magnet unit 3a, 3b facing a pole of opposite polarity of a second magnet unit 3a, 3b.

The membrane unit 5 is clamped in the slit 4, by a top clamping unit 7a and a bottom clamping unit 7b, without being so stretched in its longitudinal direction that the motion of the membrane unit 5 caused by a current running in longitudinal direction of the membrane unit is affected. The ribbon speaker unit 1 may have a substantial length e.g. up to 2 meters or more depending on the purpose.

The membrane unit 5 has a somewhat smaller width than the width of the slit 4, and is provided to be centred between two adjacent pole pieces 2a, 2b. The membrane unit 5 typically is 2 mm narrower than the width of the slit 4. The

membrane unit 5 preferably comprises a body of polymeric material, such as MYLAR® or KAPTON® and the like, which is provided with at least one surface layer of an electrically conducting material, e.g. aluminium, which may be deposited by evaporation or laminated thereto. The thickness of the membrane unit 5 is very small, e.g. of the order of 5 - 30 μm including the surface layer. The membrane unit 5 has a width of the order of 10 - 50 mm, and a length corresponding to the length of the pole pieces 2a, 2b. The membrane unit 5 may also be comprised of a homogenous metal band, e.g. of copper, aluminium or silver. As previously is known, the membrane unit 5 could be pleated across its longitudinal direction, or have an imprinted pattern, e.g. of a honeycomb or leather structure.

Furthermore, two beamlike support portions 8 are provided between the adjacent pole pieces 2a, 2b at intervals along their length. The support portions 8 centre the membrane unit 5 in the magnetic field, and prevent the membrane unit 5 from leaving the magnetic field due to sudden changes in the surrounding atmospheric pressure. These support portions 8 divides the membrane unit 5 in three sections 9 along its length. Each membrane unit section 9 behaves like an individual ribbon speaker unit 1, and if the support portions 8 are made sufficiently narrow, two adjacent sections 9 will acoustically behave like a continuous ribbon speaker unit 1. Furthermore, the support portions 8 provide support between the adjacent pole pieces 2a, 2b. The support portions 8 may be fastened to the adjacent pole pieces 2a, 2b in several suitable ways, such as by screws, rivets, welding. The number of support portions 8 may be varied, depending on the length of the membrane unit 5.

Fig. 3 is a close up cross-sectional view of one support portion 8, which bridges the slit 4. The support portion 8 comprises a support clamping unit 10, by which the membrane unit 5 is clamped to the support portion 8. If the support portion 8 and/or the support clamping unit 10 are made of an electrically conducting material, an insulating unit 11 prevents electrical contact between the conducting membrane unit 5 and the support portion 8 and the support clamping unit 10. The support clamping unit 10 is preferably fastened to the

support portion 8 by one or more screws, but it may be fastened by other means, such as rivets, snap-lock structures or the like.

An edge at which the membrane unit 5 is supported by a support portion 8, is hereafter referred to as a support edge 14, and the edges at which the membrane unit is clamped by one of the end clamping units 7a, 7b are referred to as an end clamping edge 15a and 15b respectively.

Fig. 4 shows a cross sectional view of an electro-acoustic transducer of ribbon type according to the invention, comprising two support portions 8. To increase the vertical distribution, the end clamping units 7a, 7b have been modified such that the end clamping edges 15a, 15b are displaced towards the rear of the ribbon speaker unit 1. By this modification, the normal of each of the end sections 21a, 21b of the membrane unit 5 no longer points in the same direction as the normal of a longitudinal main portion (intermediate section) 22 between the two support portions 8. The angle between the normal of each of two adjacent membrane unit sections, e.g. 21a and 22 is denoted by θ, and is hereafter referred to as the bending angle. The maximum practical bending angle equal to the angle at which a substantial deviation in sound pressure level (i.e. –6dB) occurs in the $\theta/2$ direction. For a substantially flat ribbon speaker unit 1 θ is less than 15°, preferably less than 10°, and even more preferably approximately 5°. If this angle is exceeded, deviations will appear in the resulting vertical distribution pattern, and a homogenous sound cannot be achieved over the whole distribution range. In the preferred embodiment, the membrane unit 5 is bent such that the normal of each membrane unit section 21a, 21b, 22 all remain in the same plane. To preserve the desired directional characteristics of the elongated ribbon transducer 1 the longitudinal main portion 22 have to be substantially longer than each of the end sections 21a and 21b.

In this embodiment the pole pieces 2a, 2b and the magnet units 3a, 3b are essentially straight, as the membrane unit will stay essentially within the magnetic field at such small bending-angles. However, if larger bending-angles

are desired or if several adjacent sections are to be bent, the shape of the pole pieces 2a, 2b and the magnet units 3a, 3b must be adapted to the shape of the membrane unit 5, as will be discussed in greater detail below.

The bending of the membrane unit according to the present invention, thus increase the vertical distribution angle from approximately 2° up to 30° if both end sections of the elongated ribbon speaker unit 1 are bent. This improvement makes it possible to increase the angle between two adjacent speaker units in a curved arrangement, and thus makes it easier to provide a homogenous sound in all desired directions. In fig. 5a and 5b, a curved arrangement using ribbon speaker units 1 according to the present invention, is compared with an arrangement using conventional ribbon speaker units (or other types of elongated electro-acoustic transducers). From this figure, the effect of the present invention is clearly seen by a comparison of the total distribution angles α and β.

In a second embodiment of the present invention, the end clamping units 7a, 7b have been modified such that the end clamping edges 15a, 15b for the membrane unit are adjustable, whereby the bending angle θ can be adjusted over the range $0° \leq \theta \leq 15°$. The adjustment of the bending angle θ, is preferably performed in such a way that the distance between the support portions 8 and the end clamping edges 15a, 15b, is kept constant at all points. This embodiment makes it possible to optimise the bending angle θ, such that it is essentially equal to half the angle between two adjacent speaker units in a curved arrangement.

Although, the bending of the membrane unit 5, in the embodiments presented to this point, is accomplished by altering the position of the end clamping edges 15a, 15b, the bending may also be provided by, e.g. altering the position of one or more support edge 14.

In the embodiments that have been presented above, the elongated ribbon speaker unit 1 has been arranged in a vertical manner. However, in some

applications the elongated ribbon speaker unit 1 preferably is arranged horizontally, or at an intermediate angle between vertical and horizontal.

In fig.6 another embodiment of the present invention is shown. In this embodiment, the pole pieces 2a, 2b and the magnet units 3a, 3b are adapted to the bent membrane unit 5, such that the membrane unit 5 always is provided in the maximum magnetic field. One further development of this embodiment is shown in fig. 7, in which 8 membrane unit sections 9 of the same membrane unit 5 form an essentially cylindrical radiating source.

If at least one of the support portions is substituted by a mid-clamping unit 30, the membrane unit 5 may comprise two or more membranes 6. A mid-clamping unit 30 is shown in fig. 8, and it is arranged to clamp the ends of two membranes 6 at opposite ends thereof. The mid-clamping unit 30 is either arranged such that the two membranes are electrically connected to each other, or such that the membranes 6 are connected to input terminals.

The ribbon speaker unit 1 described herein, is preferably used in a loudspeaker system comprising at least one low/mid frequency line-source, although it may be used in systems of other types as well.

Above a number of embodiments have been described. However, it is obvious that the design could be varied without deviating from the inventive idea, of providing a ribbon speaker unit with extended vertical distribution, by bending the membrane unit 5.

Therefore the present invention should not be regarded as restricted to the above disclosed embodiments, but can be varied within the scope of the appended claims.

CLAIMS

1. Electro-acoustic transducer of ribbon type (1) comprising an elongated membrane unit (5) comprising a longitudinal main portion (22) that extends in a single plane, **characterized in** that the membrane unit (5) further comprises at least one section (9, 21a, 21b) that extends in another plane with a normal that deviates an angle θ (bending angle) from the normal of the longitudinal main portion.

2. Electro-acoustic transducer of ribbon type (1) according to claim 1 **characterized in** that the bending angle θ is greater than 0° and less than 15°.

3. Electro-acoustic transducer of ribbon type (1) according to claim 1 or 2 **characterized in** that the bending angle θ is less than 10°.

4. Electro-acoustic transducer of ribbon type (1) according to any of the claims 1 to 3 **characterized in** that the bending angle θ is approximately 5°.

5. Electro-acoustic transducer of ribbon type (1) according to any of the claims 1 to 4, further comprising at least one beamlike support portion (8), and two clamping units (7a, 7b) arranged to clamp the membrane unit (5) at the top and bottom of the electro-acoustic transducer of ribbon type (1), and said support portions (8) centre the membrane unit (5) in the magnetic field, **characterized in** that

   at least one of the end clamping units (7a, 7b) or the support portion (8) is arranged such that bending of the membrane unit (5) occur.

6. Electro-acoustic transducer of ribbon type (1) according to claim 5, wherein the edges at which the membrane unit (5) are clamped to the end clamping units (7a, 7b) are referred to as end clamping edges (15a, 15b), **characterized in** that the end clamping edges (15a, 15b) are adjustably

provided.

7. A loudspeaker system, **characterized in** that it comprises at least one electro-acoustic transducer according to any of the claims 1 to 6.

8. Loudspeaker arrangement for producing a homogenous sound, **characterized in** that it comprises at least two electro-acoustic transducers according to any of the claims 1 to 6 that are arranged on top of each other to provide an essentially continuous curved line-source.

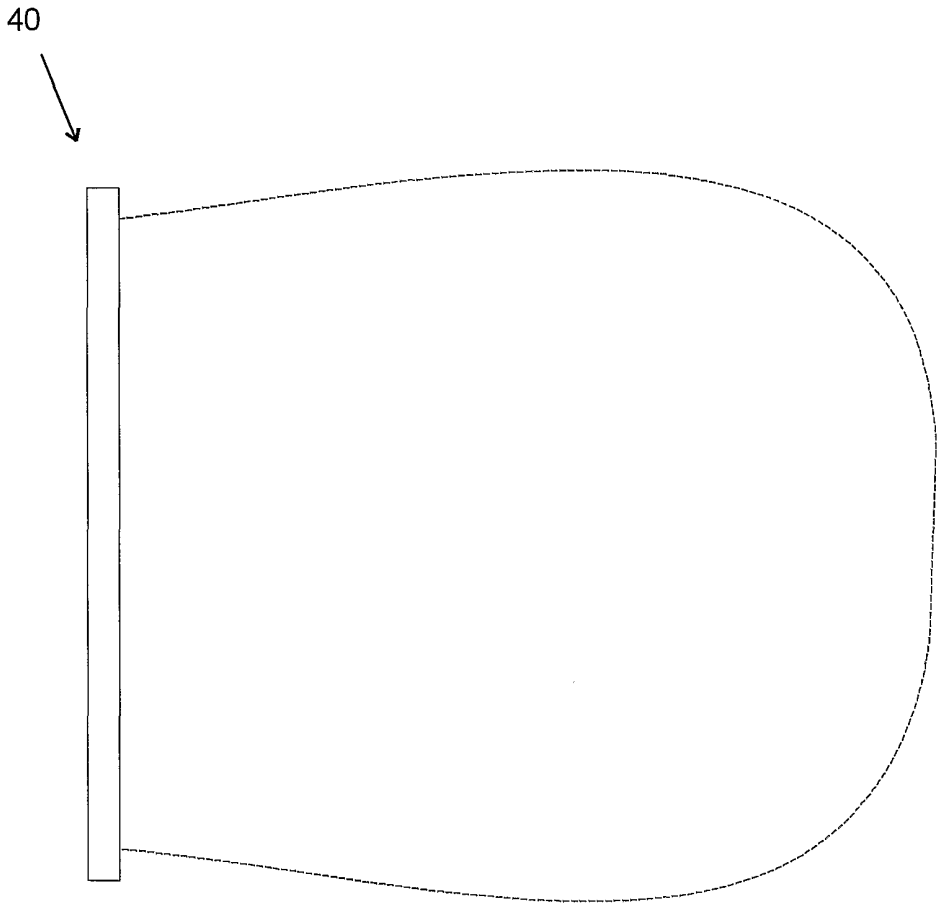

Fig 1

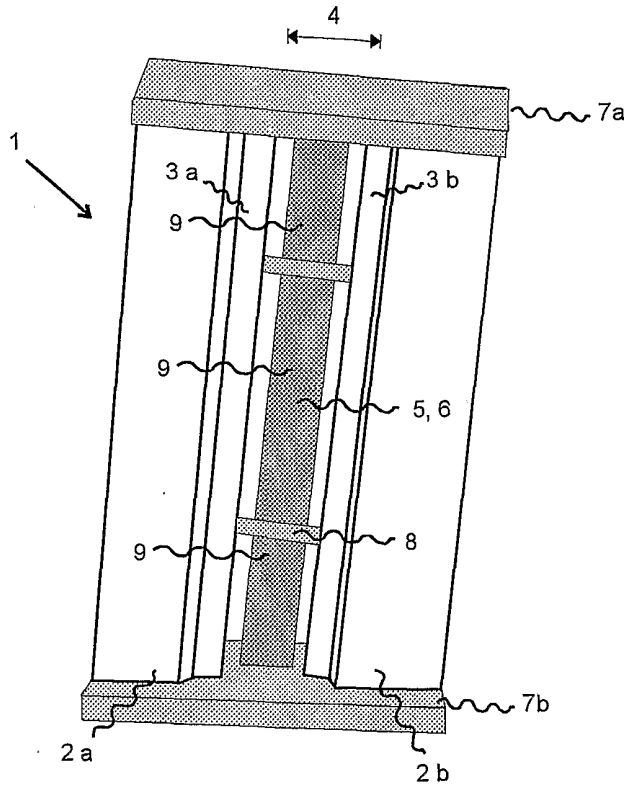

Fig 2a

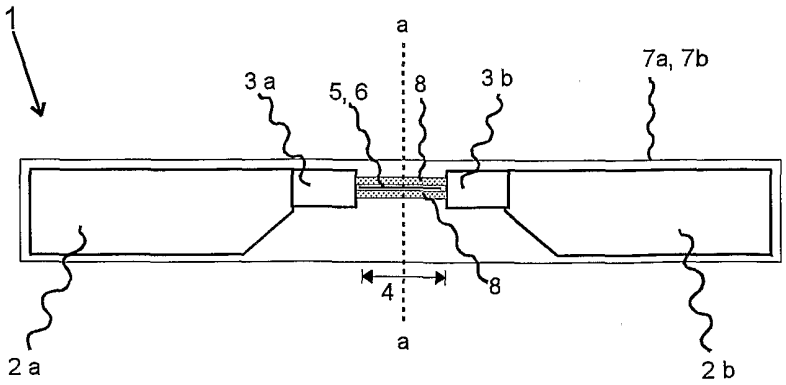

Fig 2b

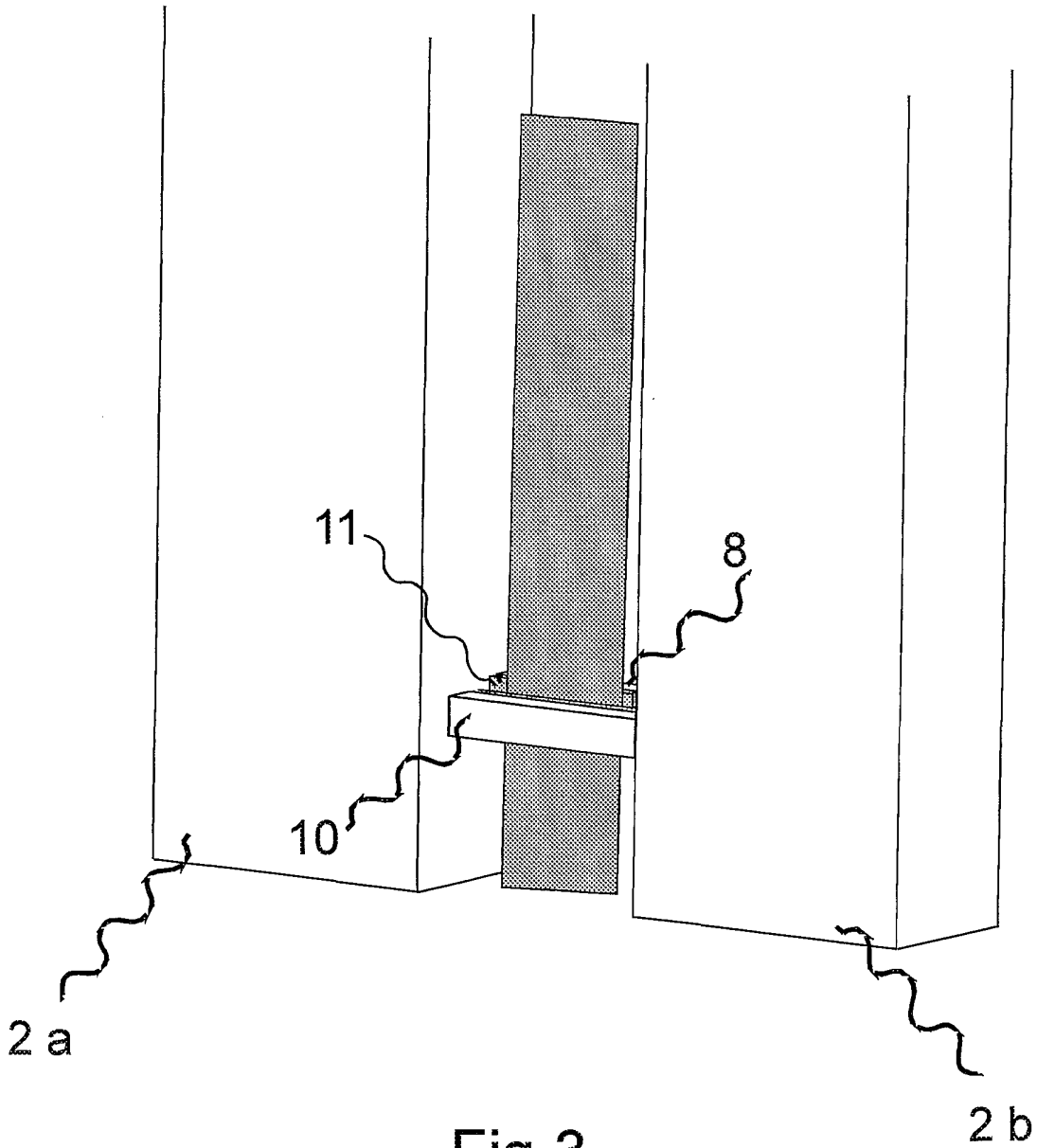

Fig 3

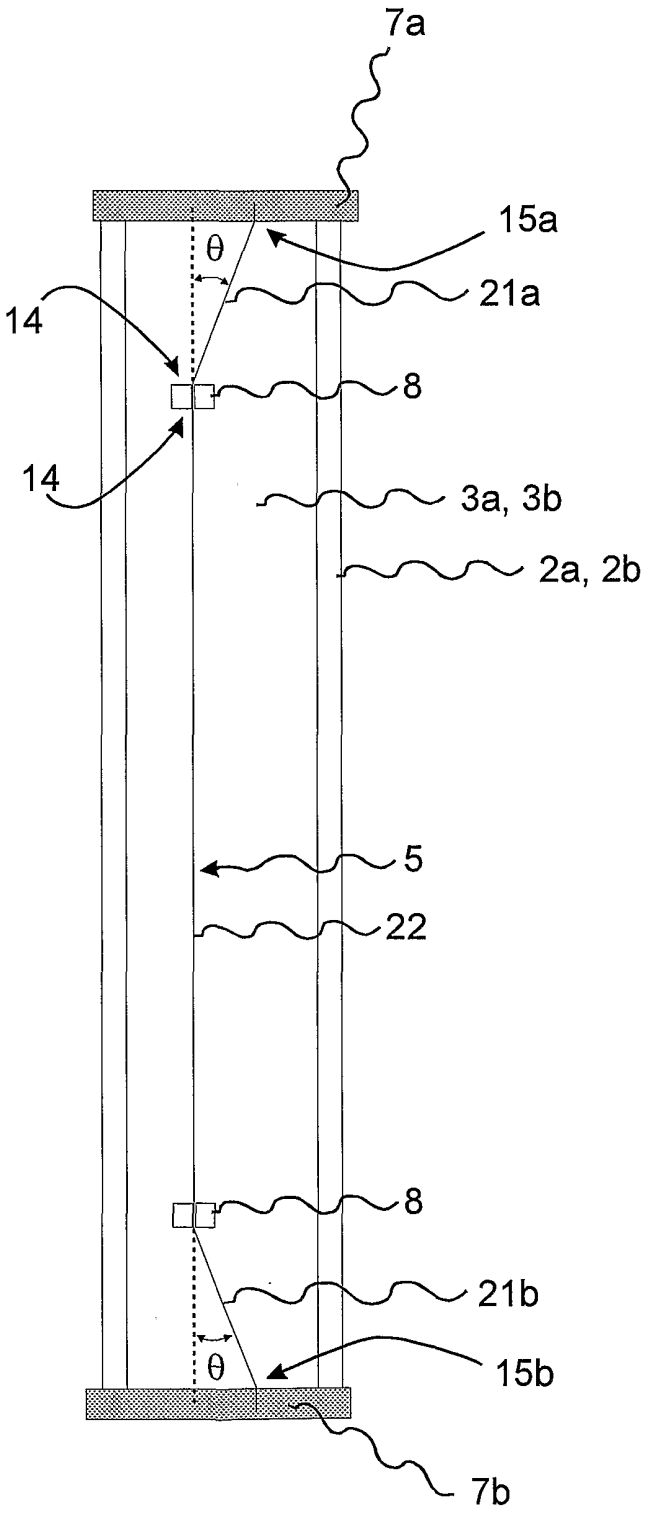

Fig 4

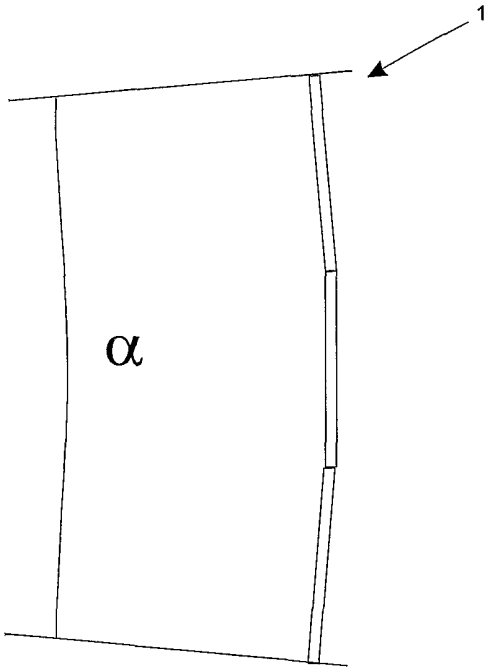

Fig 5a

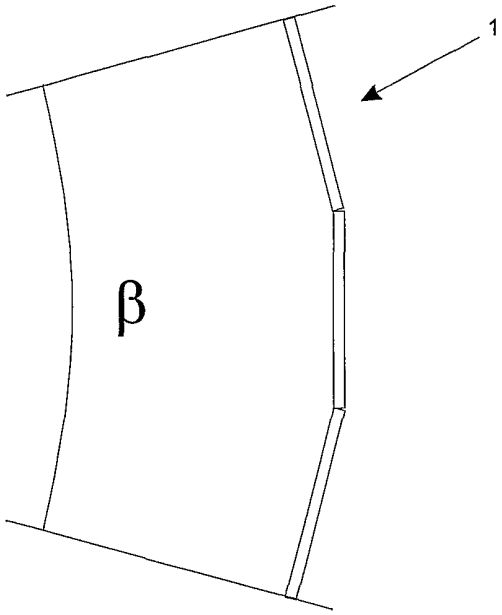

Fig 5b

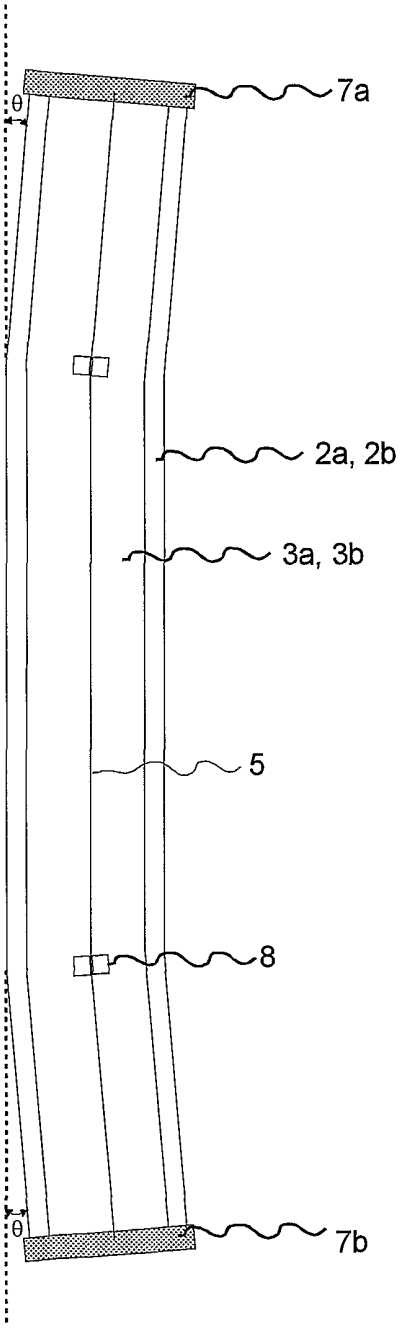

Fig 6

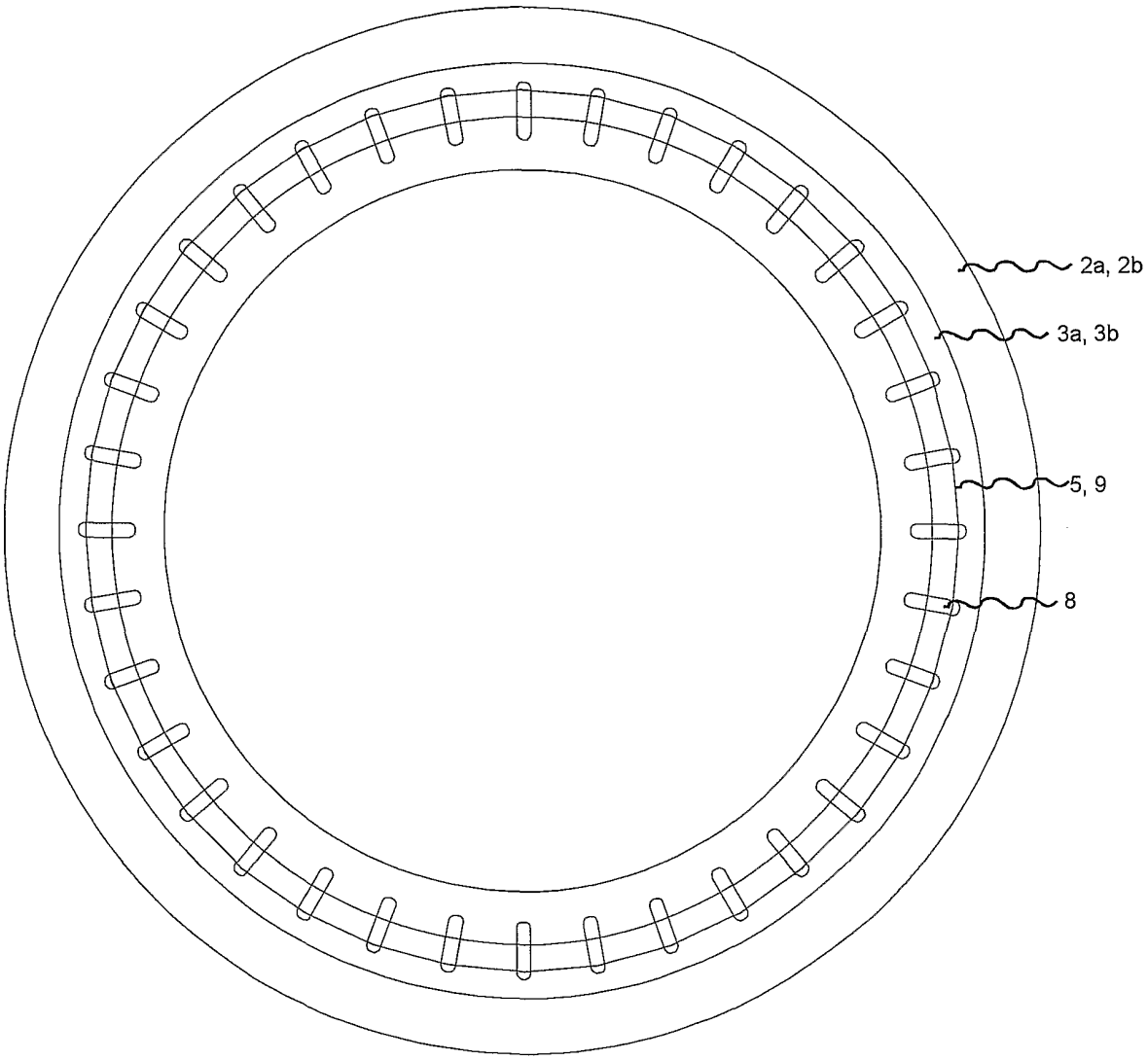

Fig 7

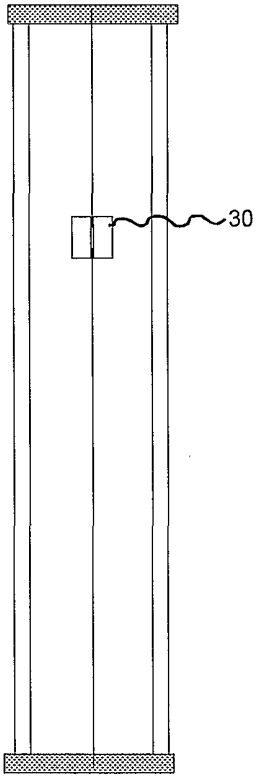

Fig 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01456

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04R 1/32, H04R 7/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 776782 A (GOODMANS INDUSTRIES LIMITED), 12 June 1957 (12.06.57), page 1, line 38 - line 42, figure 2	1,7,8
Y	--	2-4
Y	DK 2530/88 A (D. KRISTENSEN), 10 November 1989 (10.11.89), page 2, line 17 - line 20, figures 1,2	2-4
	--	
Y	DE 1234266 B (AKUSTISCHE U. KINO-GERÄTE GESELLSCHAFT M.B.H.), 16 February 1967 (16.02.67), column 5, line 20 - line 22, figure 11	2-4
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2001	16 -10- 2001
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Leif Vingård / MRo Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01456

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4027111 A (A.F. KASATKIN ET AL), 31 May 1977 (31.05.77), figure 2, end of abstract --	2-4
A	US 4484037 A (J.A.M. NIEUWENDIJK ET AL), 20 November 1984 (20.11.84), figure 3 -- --------	1-4

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SE 01/01456

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 776782 A	12/06/57	NONE	
DK 2530/88 A	10/11/89	NONE	
DE 1234266 B	16/02/67	AT 239344 B	00/00/00
US 4027111 A	31/05/77	CS 179242 B	31/10/77
		DD 123419 A	12/12/76
		DE 2556591 A,B,C	24/06/76
		GB 1509240 A	04/05/78
		HU 173343 B	28/04/79
		JP 52073722 A	21/06/77
		SE 404122 B,C	18/09/78
		SE 7514211 A	18/06/76
		SU 581598 A	25/11/77
US 4484037 A	20/11/84	CA 1199397 A	14/01/86
		DE 3266647 D	00/00/00
		EP 0065808 A,B	01/12/82
		EP 0123343 A	31/10/84
		JP 57199400 A	07/12/82
		NL 8102572 A	16/12/82