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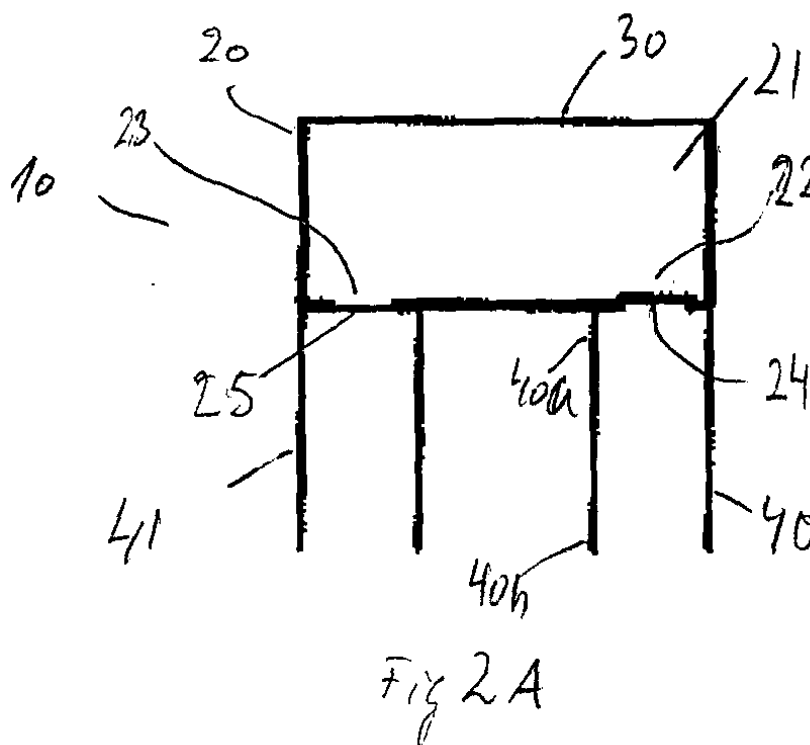
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**(54) Portable radio communication equipment with an air pump**

(57) A portable radio communication equipment (1) comprising a cover (2); a first membrane (30) provided within said cover (2); means for vibrating said first membrane (30); a variable volume cavity (21) defined at least by said first membrane (30); an inlet (22) to said cavity (21); and an outlet (23) from said cavity (21), where the inlet (22) has a one-way inlet valve (24) adapted for letting air into the cavity (21), and said outlet (23) having a one-way outlet valve (25) adapted for letting air out of the cavity (21).



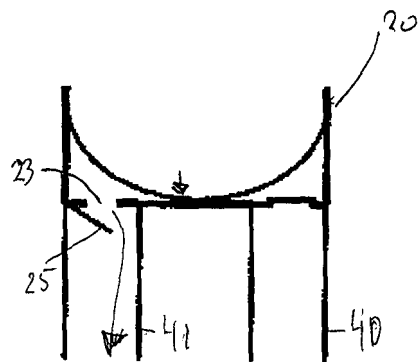


Fig. 2B

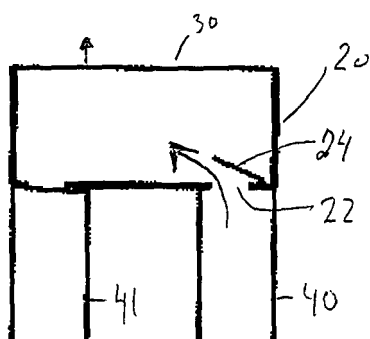


Fig. 2C

**Description**Technical field

5 **[0001]** The invention relates to cooling in a portable radio communication equipment comprising a cover, a PCB, a first membrane, means for vibrating the first membrane, and a variable volume cavity defined at least by said first membrane.

Related prior art

10 **[0002]** Portable radio communication equipment of the kind mentioned above become increasingly smaller, and at the same time the need for new functionalities increase. New functionalities often require that additional electrical components needs to be fitted on the PCB. Electrical components radiates heat (when in use), and due to the increasing compactness of the equipment, and the number of heat radiating electrical components on the PCB of such a portable  
15 radio communication equipment a need for cooling the PCB or at least some of the electrical components fitted thereon may arise. State of the art portable radio communication equipment does not usually comprise mechanisms for artificial/forced cooling, but are passively air cooled. From the field of e.g. computers it is known to provide forced cooling of internal electrical components placing a fan in the cabinet. However, a fan and the needed noise reducing equipment would take up considerable space in portable radio communication equipment, which is highly disadvantageous in this  
20 field. Further, a fan uses a lot of energy. This poses no or only a small problem in computers where there is either a connection to the public power network or a relatively high capacity battery, but would quickly drain a battery used in portable radio communication equipment.

25 **[0003]** From US-A-3-778-551 it is known to cool transistors of an audio amplifier by providing air passage between the speaker cavity of the audio amplifier and a section of the cabinet where the transistors are placed. When in use the speaker sets the air in the speaker cavity in motion. Some of the air will pass the transistors thus cooling the transistors.

Object of the invention

30 **[0004]** It is the object of the present invention to provide a portable radio communication equipment including a space efficient, low energy and yet efficient cooling system.

**[0005]** It is a further object of the invention to provide a method of cooling one or more electrical components on a PCB of a portable radio communication equipment, which is efficient, silent, and energy efficient and which allows for a compact portable radio communication equipment.

35 **[0006]** It is yet a further object of the invention to provide a method of cooling one or more electrical components on a PCB of a portable radio communication equipment and a cooling mechanism for one or more electrical components on a PCB of portable radio communication equipment that constitutes an alternative to prior art methods and equipment.

Summary of the invention

40 **[0007]** The object of the invention is achieved by ... [citation of the claims when agreed upon]

**[0008]** It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

45 **[0009]** The term electronic equipment includes portable radio communication equipment. The term portable radio communication equipment, which herein after is referred to as a mobile radio terminal, includes all equipment such as mobile telephones, pagers, communicators, i.e. electronic organizers, smart-phones or the like.

Description of the drawings

50 **[0010]** The invention will be described in detail in the following with reference to the drawings in which

- Fig. 1 shows a section through a portable radio communication equipment in schematic form;
- Fig. 2A shows a loudspeaker for a portable radio communication equipment according to an embodiment of the  
55 invention, in a first state;
- Fig. 2B shows the loudspeaker of Fig. 2A in a second state;

- Fig. 2C shows the loudspeaker of Fig. 2A in a third state;
- Fig. 3 shows a details of a loudspeaker for a portable radio communication equipment according to an embodiment of the invention; and
- Fig. 4 shows a section through a portable radio communication equipment according to another embodiment of the invention.

#### Detailed description of embodiments of the invention

**[0011]** Referring firstly to fig. 1, showing a section through a portable radio communication equipment 1, the portable radio communication equipment 1 comprises a cover 2 for protecting internal parts of the portable radio communication equipment 1, and a printed circuit board, PCB, 3 provided inside the cover, and a loudspeaker 10. A number of different other electrical components may be mounted on and/or electrically connected to the PCB 3, such as liquid crystal displays, key pads microphones, cameras, processing unites, and various components for controlling the operation of the portable radio communication equipment 1. The cover 2 typically comprises a lower part 2a and an upper part 2b, as indicated in fig. 1. The loudspeaker 10 is typically placed close to the cover 2, typically the upper cover part 2b intended to face the user during use, e.g. in connection to an aperture (or apertures) 4 of the cover 2, in order to efficiently convey the sound waves from the portable radio communication equipment 1 to the user of the portable radio communication equipment 1. To avoid moisture to penetrate into and damage the interior parts of the cover 2 the aperture (or apertures) 4 is often covered with a thin moisture barrier 5, which barrier 5 is very thin in relation to the thickness of the cover 2.

**[0012]** Fig. 2A shows a loudspeaker 10 according to an embodiment of the invention, where the loudspeaker 10 comprises a housing 20 and a first membrane 30, the housing 20 and the first membrane 30 defining an internal space or speaker cavity 21 of the loudspeaker 10. Further, the loudspeaker will comprise means (not shown) for vibrating the first membrane 30, in order for the speaker 10 to produce sound as known in the art. In accordance with the present invention the speaker 10 is additionally adapted for pumping or circulating a volume of air contained inside the speaker cavity 21 in order to ventilate and cool the inside of the cover 2 of the portable radio communication equipment 1.

**[0013]** The loudspeaker 10 shown in fig. 2, accordingly, is provided with an inlet 22 and an outlet 23 in the form of apertures in the housing 20. The inlet 22 is preferably provided with a one-way inlet valve 24 adapted for letting air into the speaker cavity 21, through inlet 22, and preventing air from escaping through the aperture defining said inlet 22. Correspondingly the outlet 23 is provided with a one-way outlet valve 25 adapted for letting air out of the speaker cavity 21, through the outlet 23, and preventing air from entering the speaker cavity 21 through the aperture defining said outlet 23.

**[0014]** The apertures defining inlet 22 and outlet 22 may be cylindrical rectangular or having other suitable geometrical shapes.

**[0015]** In the embodiment shown in Fig. 2, the inlet valve 24 comprises a valve membrane attached to a section of a perimeter of the aperture defining the inlet 22 on the inside of said housing 20. The outlet valve 25 valve may correspondingly comprise a valve membrane attached to a section of a perimeter of the outlet 23 on the outside of said housing 20.

**[0016]** The above mentioned valve membranes preferably have a resiliency such that they are biased towards a closed position, but will open when a pressure is applied due to a difference in air pressure over the valve membrane. The movement in one direction is disabled because of the abutment of the membrane on the perimeter of the apertures defining the inlet 22 or outlet 23, respectively.

**[0017]** However, other types of valves may be used, e.g. valves, the opening and closing of which can be controlled e.g. electronically.

**[0018]** Thus, the loudspeaker 10 has means, such that it may function as an air pump. Figs. 2A-C shows different stages of the pumping process. In Fig. 2A the loudspeaker 10 is shown in a stage where the air pressure in the speaker cavity 21 is equal to the pressure outside the speaker housing 20. The first membrane 30 (loudspeaker membrane) is at rest in its unstressed position. The valve membranes of valves 24, 25 therefore are both biased towards closed position. In fig. 2B the first membrane 30 has been activated, such that it is displaced towards the speaker cavity 30. Thus the air inside the speaker cavity is compressed and the outlet valve 25 membrane is therefore forced open against its bias, in order to equalize the pressure difference on each side of the valve membrane. Since the valve membrane of inlet valve 24 abuts the perimeter of the inlet aperture 22, inlet valve is kept closed. Thus a volume of air contained inside speaker cavity 21 is forced out through the outlet 23.

**[0019]** In fig. 2C the first membrane 30 is shown oscillating back, now passing its rest position. Immediately after the first membrane 30 starts to retract from the extreme position shown in fig 2B the outlet valve 25 will close, and the inlet valve 24 will open, in order to equalize the air pressure drop in the speaker cavity 21. Thus air is drawn into the speaker cavity 21. Continuous pumping can be obtained by repeatedly vibrating the first membrane 30.

**[0020]** Thus a circulation of air inside the cover 2 is provided, which circulation will provide a transport of heat from warm to cooler parts of the cover 2, whereby a cooling of heated components will be obtained.

**[0021]** The portable radio communication equipment (1) may further comprise means for controlling the activation of the first membrane (30).

**[0022]** The pumping/cooling may be applied continuously whenever the portable radio communication equipment (1) is turned on, or alternatively only when in actual use, i.e. when the heat development from the internal components is at its highest. In another embodiment the portable radio communication equipment (1) may further comprise a heat sensor (not shown). Thus the control system may be adapted to switch on the pumping/cooling function when the temperature inside the cover 2 reaches a certain threshold value. Such a sensor may preferably be situated close to components that are particularly heat producing, in order for the cooling to quickly kick in when the temperature inside the cover starts to rise. Alternatively, the sensor may be placed close to particularly heat sensitive parts in order to be able to initiate cooling when the temperature in the vicinity of such parts rises towards a critical limit. In embodiments where no sensor is present the control system of the portable radio communication equipment (1) may be adapted to initiate cooling whenever a particularly heat producing component is turned on.

**[0023]** The loudspeaker 10 shown in Fig. 2 further has an inlet channel 40. This channel is adapted to lead air to the speaker cavity 21. A first end 40a of channel 40 is in communication with the aperture 22, and the second end 40b may be in communication with an opening (not shown) in the cover 2, so as to draw air into the cover 2 from the outside. However, the second end may just be situated inside the cover 2, or it may be omitted. The loudspeaker 10 shown in Fig. 2 may further have an outlet channel 41. This channel is adapted to lead air from the speaker cavity 21 to a position inside of the cover 2. A first end 41a of channel 41 is in communication with the aperture 23, and the second end 41b is preferably directed to particularly heat generating or heat sensitive components inside the cover 2. The channel 41 may also be omitted. Alternatively, one or both the channels 41, 42 are arranged so as to provide maximum circulation inside the cover dependent on the topography of the components on the PCB. Also, the topography of the components on the PCB may be arranged such that pathways for the flow of air are led to and past specific components.

**[0024]** The vibrating frequency applied to the first membrane 30 for providing the pumping/ventilating function of the loudspeaker 10 should preferably not be detectable to human ear. The audible range is approximately 20-20000 Hz. Therefore, a preferred vibrating frequency of the first membrane 30 is preferably less than 20 Hz, more preferably 5-19 Hz, more preferably 10-18, and most preferably approximately 15 Hz, e.g. in the range 14-16 Hz. However, in the event that it is desired that it must be detectable when the ventilation has started, the vibrating frequency of the first membrane 30 may be adapted to vibrate at a frequency in the audible range. Also the vibrating frequency of the first membrane 30 may in any event be in the low audible range, since the size of the membrane, and the small space in which it is situated will not render the vibrations audible, due to the damping effects of the cover.

**[0025]** Also, the control system can be adapted to adjust the frequency of the vibration of the first membrane 30, in order to vary the ventilation according to the need for cooling. Thus the change of frequency from the non audible to the audible range could be applied in order to warn the user that a specific component or more components may reach a critically high temperature, as well as provide increased cooling.

**[0026]** In an embodiment, the valve 24, 25 membranes should preferably be adapted to be operational at a desired frequency range, e.g. the approximately 15 Hz. described above. At higher frequencies, the valves 24, 25 would thus be inactive, i.e. closed. This can be obtained e.g. as illustrated in Fig. 3, by the valves 24, 25 comprising a stiff membrane which is spring loaded and damped by a hinge in the form of a spring damper 26, e.g. a silicon damper.

The first membrane 30 may be provided with sections of different stiffness, such that each section is adapted to set the air in vibrations in certain ranges of frequencies, e.g. such that one or more regions are adapted to frequencies in the audible range, and one or more other regions are adapted to frequencies suitable for driving the air pump function of the loudspeaker 10.

**[0027]** In a further alternative embodiment the first membrane 30 of portable radio communication equipment 1 is not placed in a housing of the loudspeaker 10. The loudspeaker 10 thus consist of first membrane 30 and means 11 for vibrating the first membrane 30. In Fig. 4 such a portable radio communication equipment 1 is shown. In this figure the speaker 10 has a conical first membrane 30 and means 11 for vibrating the first membrane 30. The loudspeaker 10 is shown mounted in a socket 5 provided on the PCB 3. In this embodiment the outer edge(s) of the first membrane 30 is situated very close to the inside of said cover 2, such that the inside of the cover 2 constitute a variable volume cavity 21, such as described above for the housing 20. The inside of the cover 2 may comprise a flange 8 in order to increase this effect.

**[0028]** In a further alternative embodiment the portable radio communication equipment 1 has the pumping/ventilating function integrated into a microphone of the portable radio communication equipment 1. A typical microphone (not shown) of a portable radio communication equipment 1 comprises a housing, a first membrane, and means for detecting vibrations in the membrane. According to the invention the microphone may additionally be adapted for pumping or circulating a volume of air contained inside a microphone cavity in order to ventilate and cool the inside the cover 2 of the portable radio communication equipment 1. The microphone, accordingly, is provided with means for vibrating the first membrane,

and an inlet and an outlet in the form of apertures in the housing. The inlet is preferably provided with a one-way inlet valve adapted for letting air into the microphone cavity, through inlet, and preventing air from escaping through the aperture defining said inlet. Correspondingly the outlet is provided with a one-way outlet valve adapted for letting air out of the microphone cavity, through the outlet, and preventing air from entering the microphone cavity through the aperture defining said outlet.

**[0029]** As described above in relation to the loudspeaker embodiments, the first membrane of the microphone may be provided with sections of different stiffness, such that one or more section(s) of the first membrane 30 are adapted to set the air in vibrations in certain ranges of frequencies suitable for driving the air pump function of the microphone. One or more other sections of the first membrane are adapted to vibrate when exposed to frequencies in the audible range, and thus functions as a microphone.

**[0030]** The control system of the portable radio communication equipment 1 may be adapted to filter the possible noise from the pumping function of the first membrane from the microphone signal, such that this noise is not transferred from the portable radio communication equipment 1.

**[0031]** The microphone according to the invention may be adapted to work within the same frequency ranges as described for the loudspeaker embodiments above. Also the portable radio communication equipment 1 may be equipped with channels and/or a temperature sensor as described for the loudspeaker embodiments above.

**[0032]** A portable radio communication equipment 1 may be equipped with a combination of both the above described microphone air pump and the above described loudspeaker air pump.

**[0033]** In order to cool components contained in a cover of a portable radio communication equipment 1, said portable radio communication equipment 1 may in addition to a loudspeaker and a microphone also be equipped with an air pump comprising a housing, a first membrane, and means for vibrating the first membrane, the housing and the first membrane defining an internal space or cavity. The housing is provided with an inlet and an outlet in the form of apertures in the housing. The inlet is preferably provided with a one-way inlet valve adapted for letting air into the cavity, through inlet, and preventing air from escaping through the aperture defining said inlet. Correspondingly the outlet is provided with a one-way outlet valve adapted for letting air out of the cavity through the outlet, and preventing air from entering the cavity through the aperture defining said outlet. Said means for vibrating the first membrane may in this instance be a linear vibrator.

## Claims

1. A portable radio communication equipment (1) comprising

- a cover(2);
- a first membrane (30) provided within said cover (2);
- means for vibrating said first membrane (30);
- a variable volume cavity (21) defined at least by said first membrane (30);
- an inlet (22) to said cavity (21); and
- an outlet (23) from said cavity (21),

**characterized in that** said inlet (22) has a one-way inlet valve (24) adapted for letting air into the cavity (21), and said outlet (23) having a one-way outlet valve (25) adapted for letting air out of the cavity (21).

2. A portable radio communication equipment (1) according to claim 1 **characterized in that** said first membrane (30) is attached to the inside of said cover (2) and that said inlet valve (24) and said outlet valve (25) are arranged through said cover (2).

3. A portable radio communication equipment (1) according to claim 1 **characterized in that** a housing (20) is provided within said cover (2), said first membrane (30) being connected to said housing 20, said cavity (21) being defined by said first membrane (30) and said housing, and said inlet valve (24) and outlet valve (25) being arranged in said housing.

4. A portable radio communication equipment (1) according to claim 3 **characterized in that** said inlet valve (24) comprises a valve membrane attached to a section of a perimeter of the inlet (22) on the inside of said housing (20).

5. A portable radio communication equipment (1) according to claims 3 or 4, **characterized in that** said outlet valve (25) comprises a valve membrane attached to a section of a perimeter of the outlet (23) on the outside of said housing (20).

6. A portable radio communication equipment (1) according to any of claims 1-5, **characterized in that** a control system of the portable radio communication equipment (1) is adapted to vibrating said first membrane (30) continuously.
- 5 7. A portable radio communication equipment (1) according to any of claims 1-5, **characterized in that** a control system of the portable radio communication equipment (1) is adapted to vibrating said first membrane (30) in intervals of time, or when one or more pre-elected electrical components arranged within said cover (2) are turned on.
- 10 8. A portable radio communication equipment (1) according to any of claims 1-7, **characterized in that** a control system of the portable radio communication equipment (1) is adapted to vibrating said first membrane (30) at a frequency below the audible range.
- 15 9. A portable radio communication equipment (1) according to any of claims 3-8, **characterized in that** the portable radio communication equipment (1) further comprises means for sensing vibration of the first membrane (30).
- 20 10. A portable radio communication equipment (1) according to any of claims 1-9, **characterized in that** the first membrane is divided into sections of varying stiffness.
- 25 11. A portable radio communication equipment (1) according to any of claims 1-10, **characterized in that** a channel (41) is provided from the outlet (23) to a position inside said cover.
- 30 12. A portable radio communication equipment (1) according to any of claims 1-11, **characterized in that** a channel (40) is provided from the inlet (22) to a position inside said cover.
- 35 13. A portable radio communication equipment (1) according to any of claims 1-11, **characterized in that** a channel (40) is provided from the inlet (22) to an opening in said cover.
- 40 14. A method of cooling the inside of a cover (2) of a portable radio communication equipment (1), said portable radio communication equipment (1) further comprising
  - a first membrane (30) provided within said cover (2);
  - means for vibrating said first membrane (30);
  - a variable volume cavity (21) defined at least by said first membrane (30);
  - an inlet (22) to said cavity (21); and
  - 45 - an outlet (23) from said cavity (21),wherein,
  - 40 - in a first step, air is drawn into said variable volume cavity (21) through a one-way inlet valve (24) arranged at the inlet (22) by a motion in a first direction of the first membrane (30) induced by said means for vibrating said first membrane (30);
  - in a second step, air is expelled from said variable volume cavity (21) through a one-way outlet valve (25) arranged at the outlet (23), by a motion in a second direction of the first membrane (30) induced by said means for vibrating said first membrane (30); and wherein
  - 45 - steps one and two are repeated by vibration of said first membrane (30) in order to provide circulation of air inside said cover (2)
- 50 15. A method according to claim 14, **characterized in that** said first membrane (30) is vibrated continuously controlled by a control system of the portable radio communication equipment (1).
- 55 16. A method according to claim 14, **characterized in that** said first membrane (30) is vibrated in intervals of time, controlled by a control system of the portable radio communication equipment (1).
17. A method according to claims 14 or 16, **characterized in that** said first membrane (30) is vibrated when one or more pre-elected electrical components arranged within said cover (2) are turned on, controlled by a control system of the portable radio communication equipment (1).
18. A method according to any of the claims 14-17, **characterized in that** said first membrane (30) is vibrated at a

frequency below the audible range.

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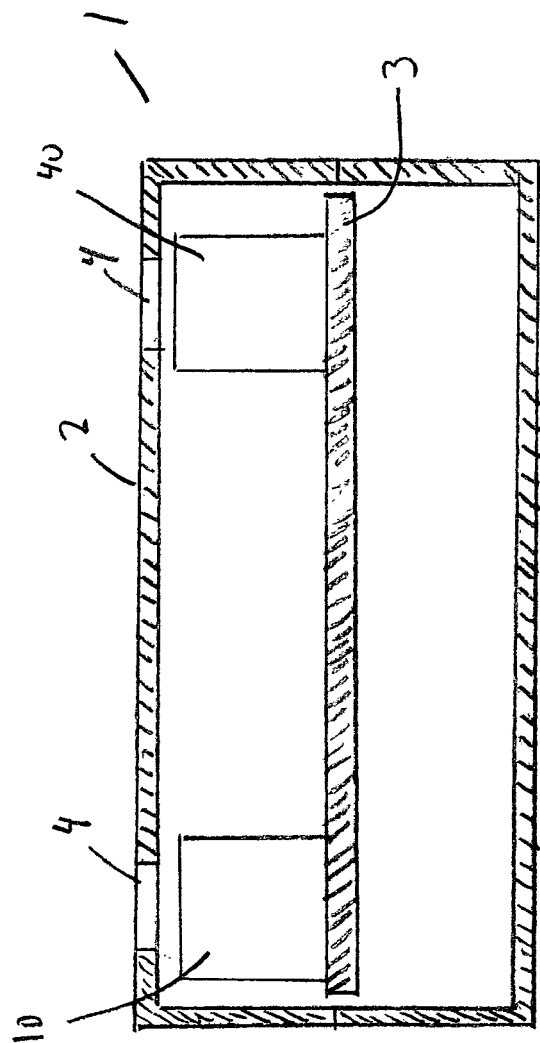
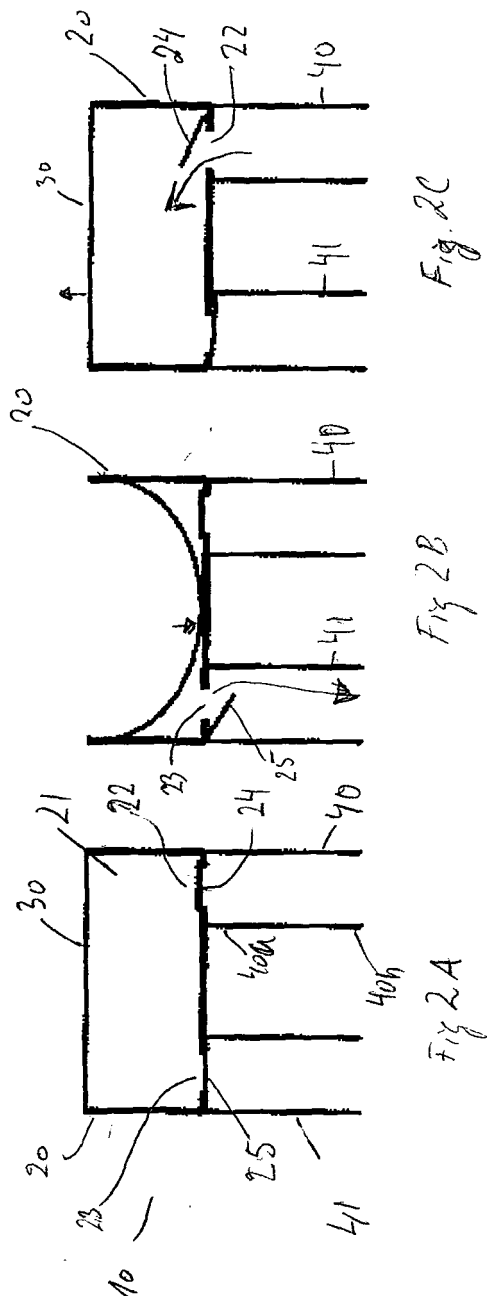
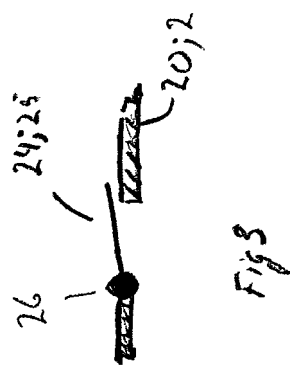


Fig. 1





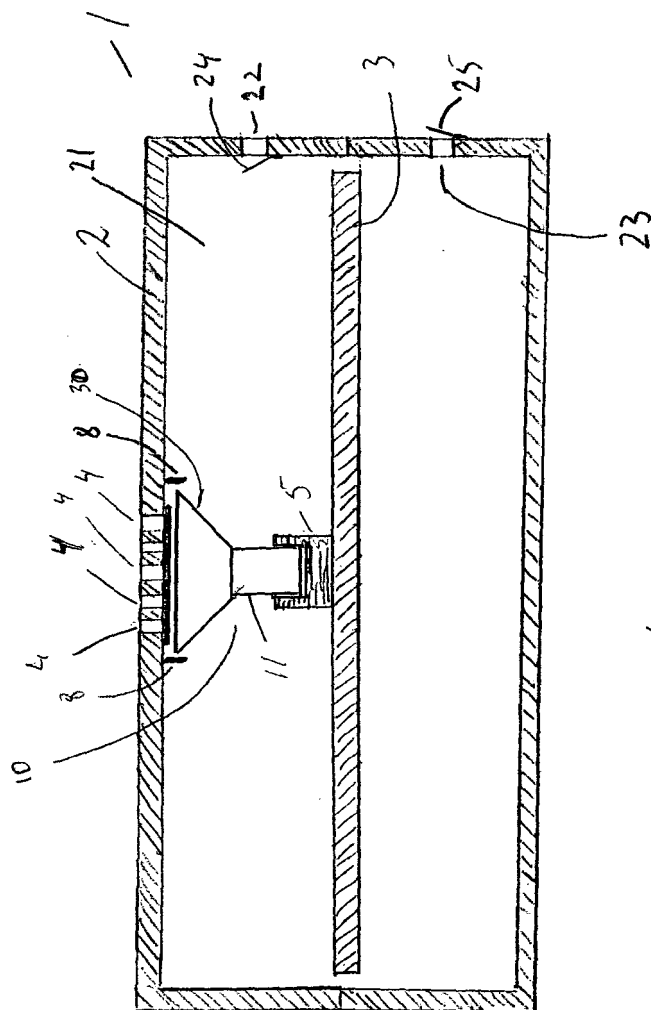


Fig. 4



European Patent  
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# EUROPEAN SEARCH REPORT

Application Number  
EP 05 38 8016

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 11, 30 September 1998 (1998-09-30) -& JP 10 148181 A (SHINTEN SANGYO KK; TAKAYANAGI JUN), 2 June 1998 (1998-06-02) * abstract *	1-18	H04R9/02 H04R1/02
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A	WO 00/21329 A (BABB, BURTON, A) 13 April 2000 (2000-04-13) * page 8, lines 3-20 * * figure 1 * * page 13, line 1 - page 15, line 6 * * page 15, line 29 - page 16, line 14 *	1-18	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			H04R
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 10 August 2005	Examiner Zanti, P
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EP 05 38 8016

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10-08-2005

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