

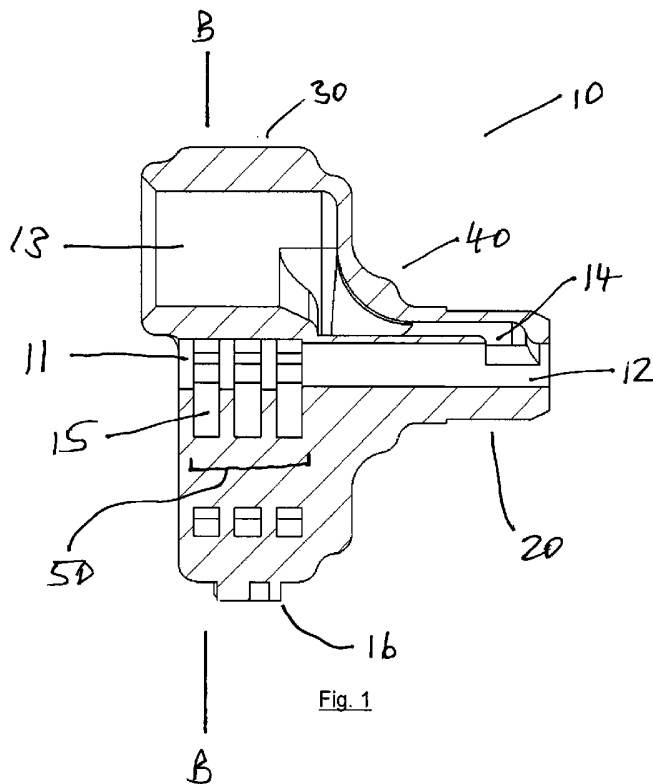


- (51) International Patent Classification: *G10K 11/172* (2006.01) *A61F 11/08* (2006.01)
- (72) Inventor: **ATHERTON, Mark**; c/o Brunel University, Michael Sterling Building, Kingston Lane, Uxbridge Middlesex UB8 3PH (GB).
- (21) International Application Number: PCT/GB2014/052198
- (74) Agent: **TOLLETT, Ian**; Williams Powell, 11 Staple Inn, London Greater London WC1V 7QH (GB).
- (22) International Filing Date: 18 July 2014 (18.07.2014)
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM,
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 1313187.5 24 July 2013 (24.07.2013) GB
- (71) Applicant: **BRUNEL UNIVERSITY** [GB/GB]; Michael Sterling Building, Kingston Lane, Uxbridge Middlesex UB8 3PH (GB).

[Continued on next page]

(54) Title: PASSIVE NOISE CANCELLING DEVICE

(57) Abstract: A device for use by a dental patient fits in the patient's ear and has at least one curved resonator tube to reduce the perceived volume of a dental drill. The device may have multiple layers of resonator tubes and a port into which recorded music can be played to calm the patient further.





TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**(84) Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

**Published:**

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

## PASSIVE NOISE CANCELLING DEVICE

The present invention relates to a device for use by a dental patient to reduce the perceived sound volume of a dental drill, and in particular to a passive device  
5 which can optionally allow the user to continue to hear a personal music player and/or to communicate with the dentist.

For many, a visit to the dentist is an anxiety-inducing affair, and the noise of the dental drill is a significant cause of this anxiety. Accordingly, a device which can  
10 reduce the perceived sound volume of the drill is also likely to be useful in reducing levels of anxiety. Ideally, such a device will also allow the patient to be able to listen to their own music (for example played on an MP3 player) and/or continue to communicate with the dentist.

15 Conventional noise-cancelling headphones are designed to deal with noise frequencies well below 1 kHz, such as that experienced inside aircraft cabins. Dental drills rotate at speeds reaching beyond 200,000 rpm, and produce noise peak frequencies in the region of 3-6 kHz that are of relatively high power and hence very distinctive. Passive ear defenders work well in reducing sound  
20 amplitude at such high frequencies, but they do not effectively address the key issue of simultaneously maintaining communication between the dentist and the patient. The simultaneous provision of noise suppression and communication requires a more sophisticated system.

25 EP 0933007 A1 (Syracuse University) discloses an ear muffler device comprising a pair of muffler tubes in the form of headphones. The muffler tubes are configured to isolate the ear canal from ambient air and to reduce the acoustic impedance at the entrance of the ear canal across a wide range of frequencies. However, the device is bulky and looks uncomfortable and unattractive to wear.

30

US 2006/0042867 A1 (Hausmann *et al.*) discloses a hearing protection ear plug to be worn in the ear canal having an acoustic filter element and a resonance

cavity which is individually designed for the acoustic requirements of the user. Accordingly, such a device would be impracticable as a mass-manufactured item for use by any of a plurality of users.

5 US 4437538 A1 (Ohlsson *et al.*) discloses an ear cap which includes a cushion formed of an elastic and porous material in combination with a perforated disk defining a cavity to attenuate the sound passing through the device.

A number of active (electronic) noise cancelling devices are disclosed in WO  
10 02/100287 A2 (Zilberman *et al.*) and US 2009/0010447 A1 (Waite *et al.*).

There is a need for a noise cancelling device which is smaller in size than prior art devices, passive (and therefore easy and inexpensive to operate) and which can optionally allow the user to continue to listen to a personal music player and/to the  
15 dentist. It will be appreciated that such a device would have noise cancelling uses which go beyond those of a dental patient.

In accordance with the first aspect of the invention, there is provided a device for use by a dental patient to reduce the perceived sound volume of a dental drill,  
20 which device comprises a body having a first port for communication with the external auditory canal of the patient's ear, a vent for communication with the external environment, a first channel connecting the first port and the vent, at least one resonator tube having a first end and a second end, wherein the first end is proximate to and in communication with the first channel and the second end is  
25 closed, and wherein the resonator tube is curved along at least part of its longitudinal axis in order to reduce the length of a straight line from the first end to the second end.

The provision of a curved resonator tube enables the device to be provided in a  
30 compact form, whilst retaining its noise cancelling properties.

In a preferred embodiment, the device comprises a plurality of resonator tubes and ideally each of the resonator tubes is curved as defined above. The provision of the plurality of tubes enables the noise cancelling effect of the device to be maximized, whilst retaining the compact form.

5

The device may include a set of said resonator tubes which are disposed in the same plane (in other words, a layer of tubes) and the plane is preferably normal to the longitudinal axis of the channel. The provision of a set of tubes enables a plurality of tubes to be provided in a particularly compact form.

10

In a preferred embodiment, the device comprises a plurality of said sets, more preferably from 2 to 5 sets and most preferably three sets of resonator tubes. It has been discovered that the provision of a plurality of sets results in a device which is particularly effective at cancelling noise, with two layers being better than one and three layers being better than two.

15

The number of resonator tubes in each set may range independently from three to five, and preferably each set has the same number of resonator tubes. In a preferred embodiment, at least two of the resonator tubes may have the same length as each other, and there may be a plurality of pairs of resonator tubes of the same length within the set. Without wishing to be constrained by theory, it is thought that use of matched tubes that cancel out specific frequencies of sound may have a particularly effective noise cancelling effect. Also, the use of tubes of different lengths within the device enables a plurality of different frequencies of sound to be addressed.

20  
25

Ideally, the tube or tubes have a spiral or helical configuration. This has been found to be a particularly effective way to maximize the noise cancelling effect of the tubes whilst miniaturizing the device.

30

In a particularly preferred embodiment, the body of the device additionally comprises a second port into which sound can be played, and an audio

communication route from the first port to the second port. This enables the patient to continue to hear the dentist whilst the device is reducing the volume of the drill. Alternatively, a personal music player such as an MP3 player can be connected directly to a second port in order that the patient can listen to music to  
5 calm their nerves whilst the dentist is operating the drill.

The second channel may connect the second port to the first channel.

A number of preferred embodiments of the present invention will now be  
10 described, with reference to the accompanying drawings, in which:

Figure 1 shows a cross section through a noise cancellation device in accordance with the invention;

15 Figure 2 is an external 3D render of a device as shown in Figure 1;

Figure 3 is a schematic render of a cross section through B-B in Figure 1;

Figure 4 is an end view of an alternative device in accordance with the invention;  
20

Figure 5 is a cross-sectional view through B-B in Figure 4, showing a device with a single layer of resonator tubes;

Figure 6 is a cross-sectional view through B-B of an alternative device to that  
25 shown Figure 4, showing a device with a double layer of resonator tubes;

Figure 7 is a graph of noise against frequency to demonstrate the noise-reducing effect of a 2-layer device compared to a 1-layer device; and

30 Figure 8 is a graph of noise against frequency to demonstrate the noise-reducing effect of a device as shown in Figures 1 to 3 compared to a Comply™ foam plug.

Turning to the Figures, a noise cancellation device 10 comprises a cylindrical drum 30 of diameter 18.6mm having cylindrical protrusion 20 of diameter 5.6mm sharing a common longitudinal axis with and connected to drum 30 by curved shoulder 40.

5 A channel is formed along the longitudinal axis of device 10 through drum 30 and protrusion 20 with the channel opening at vent 11 in the face of drum 30 and opening at port 12 in the face of protrusion 20. The internal diameter of this channel is about 3.00mm at vent 11 and about 3.90mm at port 12.

10 It should be noted that noise cancellation device 10 is a laboratory model and is therefore larger in size than the envisaged production model of the device.

A further vent, namely music vent 13 is formed in the external face of drum 30 offset from vent 11 towards the periphery of drum 30. Music vent 13 forms a  
15 chamber internally in device 10 and then connects via music channel 14 with port 12. The version number is moulded at 16.

Drum 30 also incorporates three layers 50 of resonator tubes 15, with five tubes  
15 in each layer 50. As can be seen from Figure 3, resonator tubes 15 are in a  
20 spiral configuration with vent 11 at the centre of each spiral and perpendicular to the plane of each layer 50. The resonator tubes are 1.6mm or 2.00mm wide by 1.15mm deep and range in length from 8.5mm to 19mm.

Noise cancellation device 10 is used as follows:

25

Protrusion 20 is carefully fitted into the patient's external auditory canal so that port 12 aligns with the canal. It will be appreciated that shoulder 40 and drum 30 are shaped so as to prevent device 10 being pushed too far into the patient's canal and inadvertently causing damage.

30

External noise (such as the noise of a dentist's drill) passing through vent 11 has to pass through layers 50 of resonator tube 15 before exiting the device at port 12

and passing into the patient's ear canal. En route, layers 50 of resonator tubes 15 act as quarter-wave resonators and filter out the frequencies of the drill. At the same time, they act as the low-pass filter to enable speech frequencies to pass through to the patient's ear, which means that the patient can still hear the dentist speaking.

If desired, the output from a personal musical player (such as an MP3 Player) can be fitted to music vent 13 in which case musical sound produced by this device bypasses the resonator tubes 15 via music channel 14 to pass through ports 12 into the patient's ear canal without being attenuated by device 10. Thus, the patient can listen to music whilst having the sound of the drill blocked out.

#### EXAMPLE 1

Two devices were tested which were identical apart from the number of layers of resonator tubes. The device 50 shown in Figure 5 had a single layer 55 5mm wide of five resonator tubes and the device 60 shown in Figure 6 had a double layer 65 of five resonator tubes in each layer (each layer being 2.4mm wide so that it fits in the same space as the single layer of Fig. 5). Both devices looked identical from the end view, and that is shown in Figure 4.

The devices did not have a separate music vent or channel. Music could be played through the central vent 51,61 along with the ambient sound.

#### 25 Experimental procedure

- (a) Each device was fitted with a 'fir tree' seal (also known as a 'polybud' and easily available from, for example, Canford Audio plc in the UK) and earphone (see Figure 4).
- 30 (b) The device was located in a GRAS Ear and Cheek Simulator Type 43AG (ECS).
- (c) White noise was played through a loudspeaker placed 150mm from the device.



- (d) The sound reaching the ECS microphone was recorded on a lab computer.
- (e) The white noise was also recorded without a device in the ECS.
- (f) The sound recordings with and without devices were then plotted as sound pressure level against frequency using MATLAB (see Figure 7).

5

Figure 7 shows the greater noise reduction effect achieved with a 2-layer device (v16x) compared to a 1-layer device (v15x), particularly over 2.5 kHz. The 2-layer device reduces the white noise recorded with no device to a lower level than the 1-layer device (v15x).

10

### EXAMPLE 2

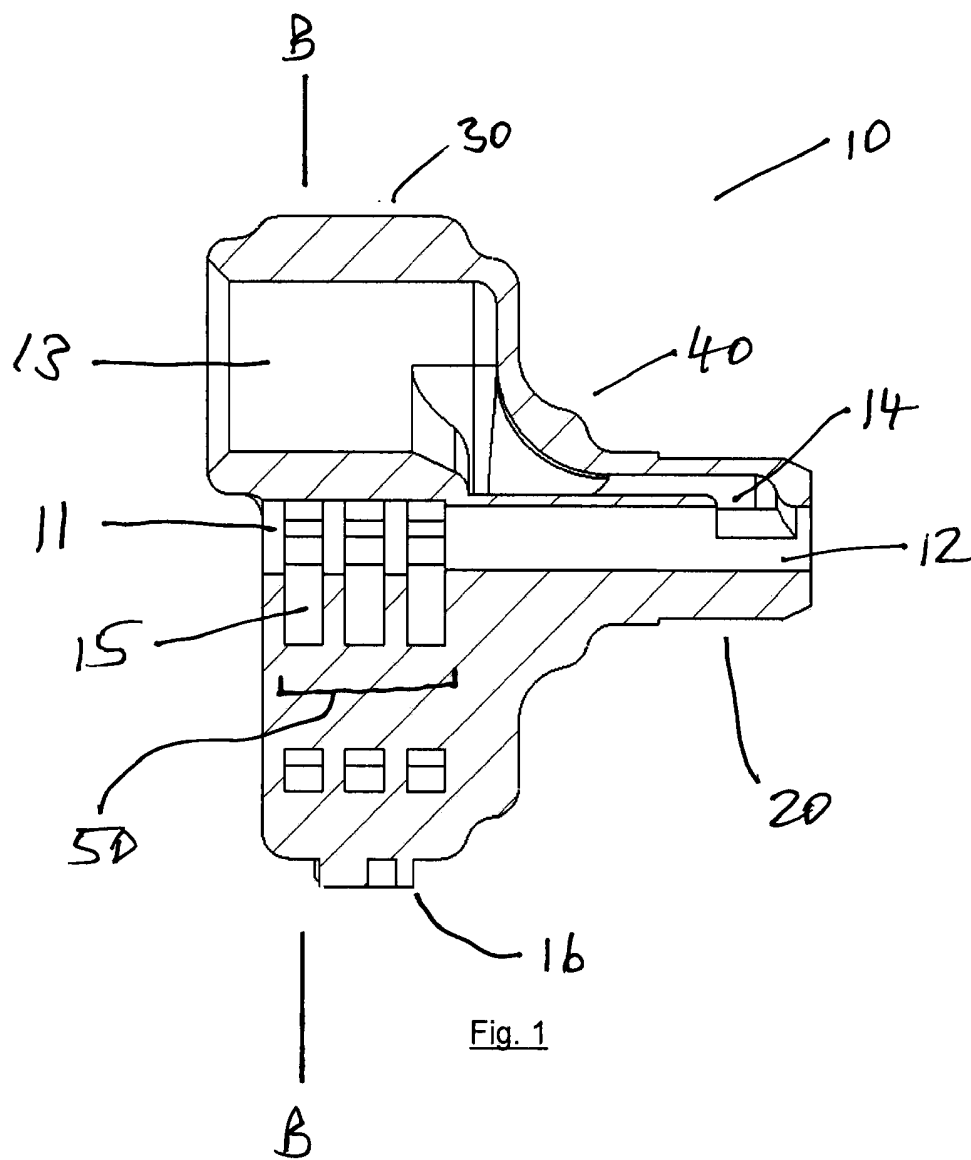
The noise-reducing effect of a three layer device as shown in Figures 1-3 was compared to a Comply™ foam plug (marketed by Hearing Components, Inc. of Oakdale, MN, US) by using the same experimental procedure as in Example 1 above. The results are shown in Figure 8. It can be seen that the device in accordance with the invention is more effective than the foam plug at reducing noise in the frequency range 4-10 kHz but leaves the (0-3.5 kHz) virtually unaffected.

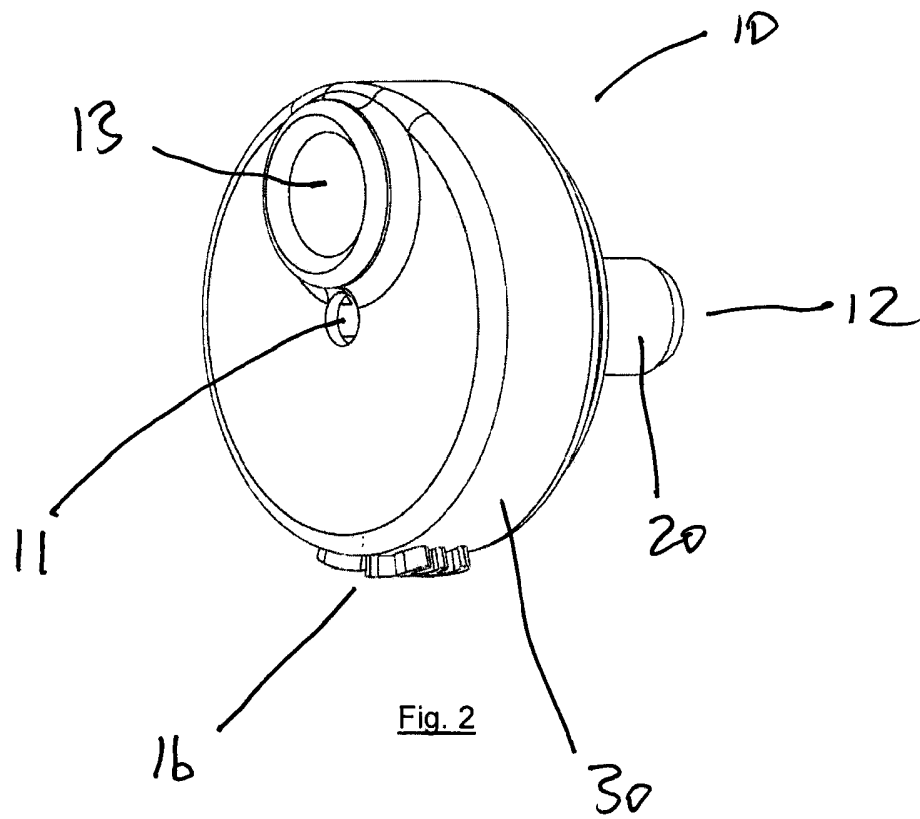
20

## CLAIMS

1. A device for use by a dental patient to reduce the perceived volume of a dental drill, which device comprises a body having  
5 a first port for communication with the external auditory canal of the patient's ear,  
a vent for communication with the external environment,  
a first channel connecting the first port and the vent,  
at least one resonator tube having a first end and a second end, wherein  
10 the first end is proximate to and in communication with the first channel and the second end is closed, and wherein the resonator tube is curved along at least part of its longitudinal axis in order to reduce the length of a straight line from the first end to the second end.
- 15 2. A device as claimed in claim 1, comprising a plurality of resonator tubes.
3. A device as claimed in claim 2, wherein each of the resonator tubes are so curved.
- 20 4. A device as claimed in claim 2 or 3, including a set of said resonator tubes which are disposed in the same plane.
5. A device as claimed in claim 4, wherein said plane is normal to the longitudinal axis of said channel.
- 25 6. A device as claimed in claim 4 or 5, comprising a plurality of said sets.
7. A device as claimed in claim 6, wherein the number of sets is at least 3.
- 30 8. A device as claimed in any of claims 4 to 7, wherein the number of resonator tubes in each set is independently from 3 to 5.

9. A device as claimed in claim 8, wherein each set has the same number of resonator tubes.
10. A device as claimed in any of claims 2 to 9, wherein at least two of the resonator tubes have the same length as each other.
11. A device as claimed in claim 10, comprising a plurality of pairs of resonant tubes of the same length within the set.
- 10 12. A device as claimed in any preceding claim, wherein at least one of the resonator tubes has a spiral or helical configuration.
13. A device as claimed in any preceding claim, wherein the body additionally comprises a second port into which sound can be played, and an audio communication route from the first port to the second port.
- 15 14. A device as claimed in claim 13, having a second channel connecting the second port to the first channel.
- 20 15. Use of a device as claimed in any preceding claim to reduce the perceived volume of a dental drill.





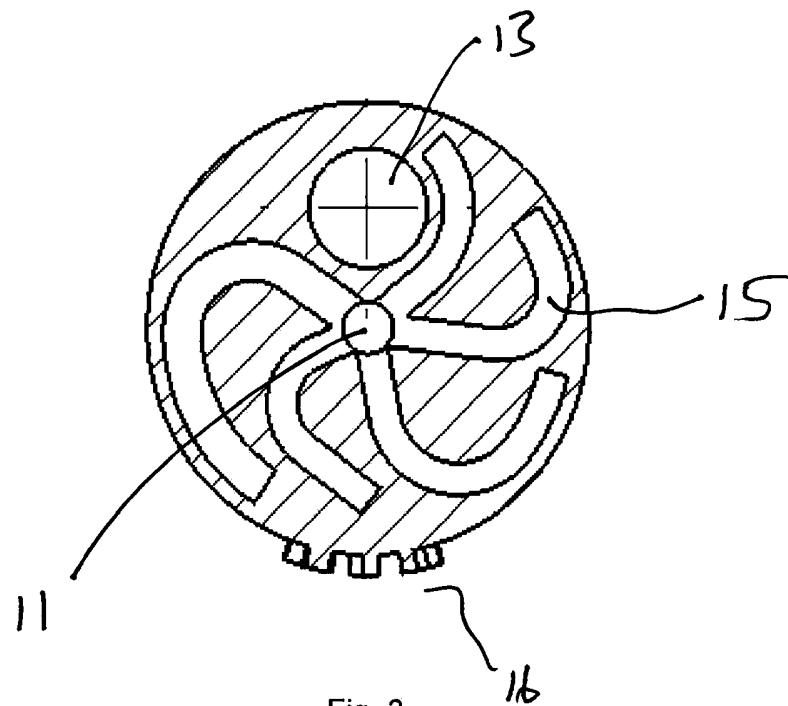


Fig. 3

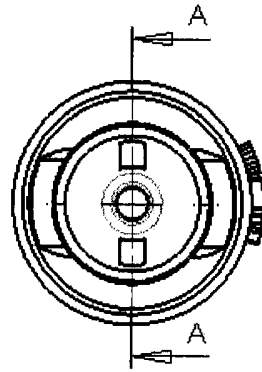


Fig. 4

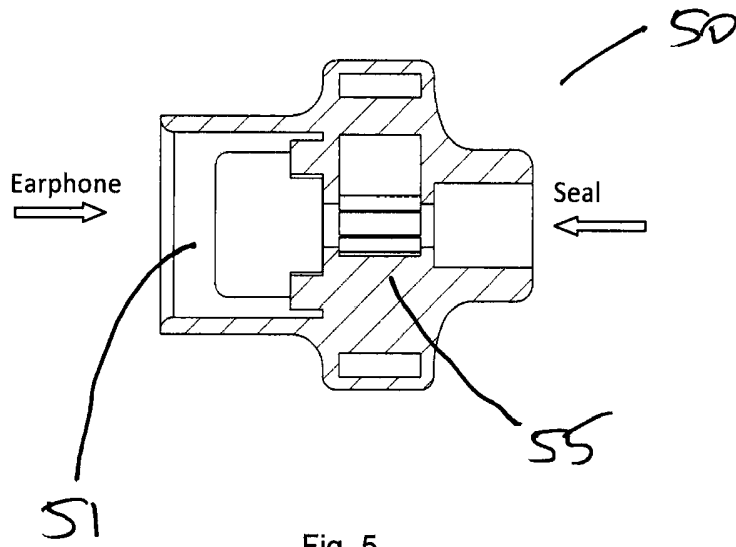


Fig. 5



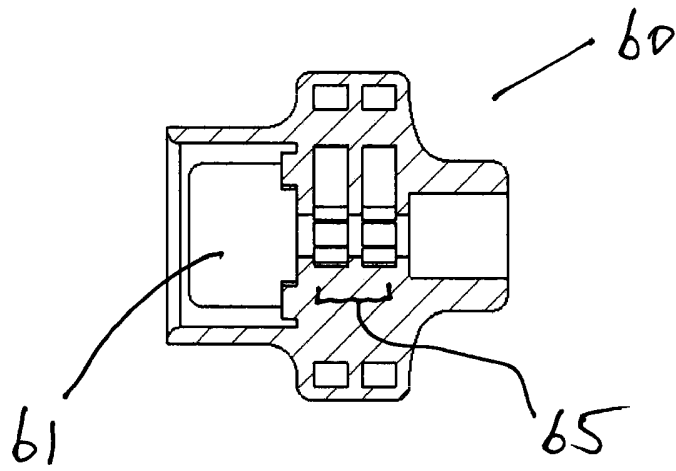


Fig. 6

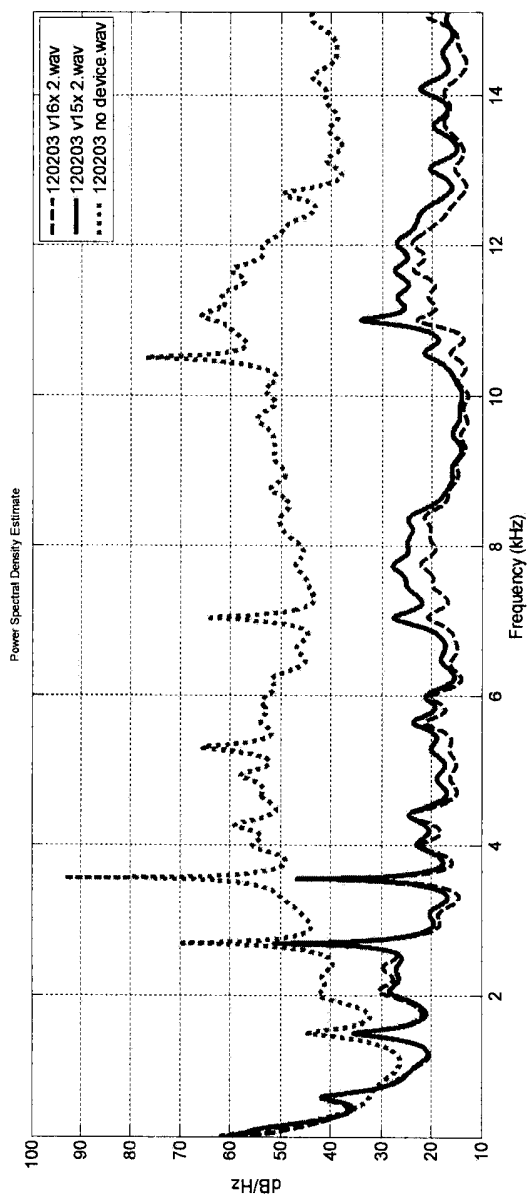


Fig. 7

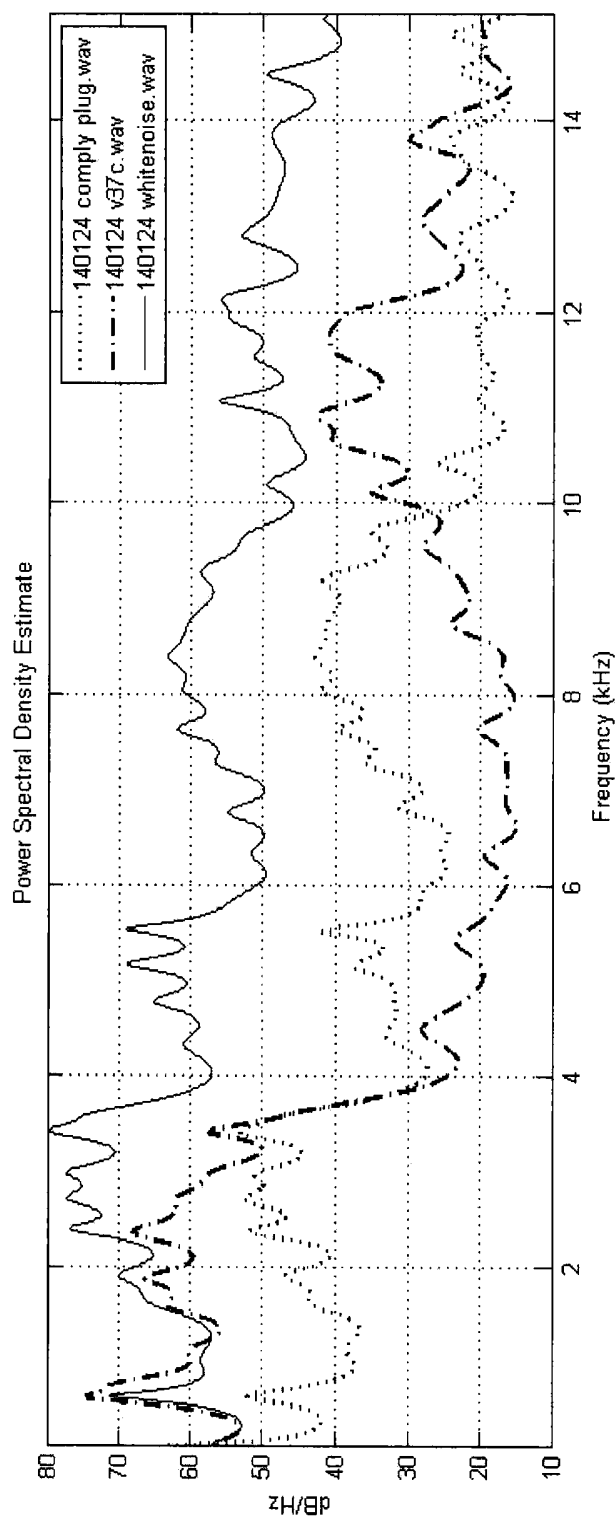


Fig. 8

# INTERNATIONAL SEARCH REPORT

International application No PCT/GB2014/052198
---

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> INV. G10K11/172 A61F11/08 ADD.				
According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b>				
Minimum documentation searched (classification system followed by classification symbols) G10K A61F				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X	US 4 441 576 A (ALLEN CLAYTON H [US]) 10 April 1984 (1984-04-10)	1-12,15		
Y	columns 10-12,14; figures 1,2,6 -----	13,14		
Y	US 5 832 094 A (LE HER FRANCOIS [FR]) 3 November 1998 (1998-11-03)	13,14		
A	columns 3-4; claim 20; figures 1,2,4 -----	1-12,15		
A	US 4 807 612 A (CARLSON ELMER V [US]) 28 February 1989 (1989-02-28)	1-15		
A	columns 3,6,7; figures 4A,4B ----- EP 0 336 487 A1 (SCHOONENBERG HOORTOESTELLEN B [NL]) 11 October 1989 (1989-10-11)	1-15		
	columns 3,4; figure 2 ----- -/--			
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.</td> <td style="width: 50%; border: none;"><input checked="" type="checkbox"/> See patent family annex.</td> </tr> </table>			<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> See patent family annex.
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> See patent family annex.			
* Special categories of cited documents :				
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention			
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone			
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art			
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family			
"P" document published prior to the international filing date but later than the priority date claimed				
Date of the actual completion of the international search	Date of mailing of the international search report			
1 December 2014	16/12/2014			
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Bream, Philip			

## INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2014/052198

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/042867 A1 (HAUSSMANN MATHIAS [CH] ET AL) 2 March 2006 (2006-03-02) cited in the application paragraphs [0030] - [0043]; figures 2,3 -----	1-15

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2014/052198

Patent document cited in search report	A	Publication date	Patent family member(s)	Publication date
US 4441576	A	10-04-1984	CA 1188997 A1 DE 3381916 D1 EP 0092362 A2 US 4441576 A	18-06-1985 08-11-1990 26-10-1983 10-04-1984
-----				
US 5832094	A	03-11-1998	AT 113192 T AU 653328 B2 AU 7188891 A CA 2066441 A1 DE 69104737 D1 DE 69104737 T2 DK 0440572 T3 EP 0440572 A1 ES 2066403 T3 FR 2657716 A1 JP H04504795 A US 5832094 A WO 9111160 A1	15-11-1994 29-09-1994 21-08-1991 02-08-1991 01-12-1994 24-05-1995 03-04-1995 07-08-1991 01-03-1995 02-08-1991 20-08-1992 03-11-1998 08-08-1991
-----				
US 4807612	A	28-02-1989	CA 1327021 C DE 3880965 D1 DE 3880965 T2 DK 625488 A EP 0315942 A1 JP H0412977 B2 JP H01155848 A US 4807612 A	15-02-1994 17-06-1993 26-08-1993 10-05-1989 17-05-1989 06-03-1992 19-06-1989 28-02-1989
-----				
EP 0336487	A1	11-10-1989	DE 68909825 D1 DE 68909825 T2 EP 0336487 A1 NL 8800780 A	18-11-1993 24-02-1994 11-10-1989 16-10-1989
-----				
US 2006042867	A1	02-03-2006	NONE	
-----				