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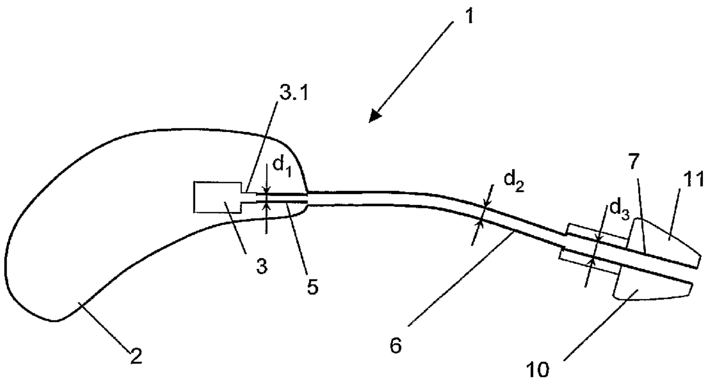

Fig. 1

(57) Abstract: The invention concerns a slim tubing, hookless hearing instrument (1) with a behind-the-ear component that has a housing (2) and a receiver (3) arranged in the housing. Further, the hearing instrument has a slim sound conduction tubing acoustically coupling an output of the receiver with a tubing output to be arranged in an interior of a user's ear canal. To that end, the tubing may comprise, as is known from the state of the art, a contiguous interior ranging from the receiver outlet to an orifice to be placed in the ear canal's interior. The hearing instrument further comprises an earpiece (10) suitable of being anchored in the ear canal. The tubing comprises a flexible tube (6) with a first end attached to the behind-the-ear component, and a second end attached to the earpiece. According to an aspect of the invention, the tubing comprises at least a first tubing section with a first tubing interior cross section, and a second tubing section with a second tubing interior cross section, the second tubing section at a larger distance from the receiver than the first tubing section, areas of the first and the second interior tubing cross sections being constant and different from each other.

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HEARING INSTRUMENT

FIELD OF THE INVENTION

The invention relates to a hearing instrument, in particular a hearing aid.

BACKGROUND OF THE INVENTION

State of the art hearing instruments are usually either behind-the-ear (BTE) hearing instruments, in-the-ear (ITE) hearing instruments, in-the-canal (ITC) hearing devices or completely-in-the-canal (CIC) hearing instruments. In BTE hearing instruments, the receiver is generally arranged in the behind-the-ear component, and the sound is transmitted into the ear by a tubing, one end of which is coupled to the behind-the-ear component, and the other end of which is held by a so-called earpiece. The tubing leads generally through a dimensionally stiff hook (also called 'earhook') that also helps to keep the hearing instrument in place.

In the last few years, a further category (or sub-category) of hearing instruments has gained increasing popularity, namely so-called 'open BTEs', which are also called 'open fitting BTEs' or 'slim tube' hearing instruments. Such hearing instruments do not comprise a hook but only a thin, flexible tube from the behind-the-ear component to an interior of the ear canal. Also, the earpiece is generally not an earmold shaped to fit exactly to the user's ear canal and closing the ear canal off (with the possible exception of a 'vent'), but a not custom-made, open, flexible part, for example comprising a so-called 'dome'. The reasons for the popularity are on the one hand aesthetics (the thin tubes are barely visible) and comfort (less occlusion), and on the other hand the fact that because of, the open, flexible earpieces no individual earmolds are required any more.

One important disadvantage of such thin tubes, however, is the relatively high losses from the receiver to the eardrum and as a consequence a relative small net acoustic power in the high frequency range. Slim tubings compared to standard BTE tubings have a reduced acoustic pressure output for a given receiver and a given load, the reduction is typically in the range of –10dB above 1-2 kHz; at higher frequencies the losses are even higher.

An example of a 'slim tubing' hearing instrument is disclosed in WO 98/31193. This document also teaches the use of the well-known horn effect to improve sound transmission. The horn effect relies on a gradual widening of the sound transmission passage towards its end. More concretely, WO 98/31193 teaches to use a tip following the end of the slim tube and to provide the tip with a horn. While such a horn is beneficial, manufacturing an according tip is complex, and also from the sound transmission point of view, there is room for an improvement.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a slim tube behind-the-ear hearing instrument with improved sound transmission characteristics.

This object is achieved by the invention as defined in the claims.

The invention concerns a slim tubing, hookless hearing instrument with a behind-the-ear component that has a housing and a receiver arranged in the housing. Further, the hearing instrument has a slim sound conduction tubing acoustically coupling an output of the receiver with a tubing output to be arranged in an interior of a user's ear canal. To that end, the tubing may comprise, as is known from the state of the art, a contiguous interior ranging from the receiver outlet to an orifice to be placed in the ear canal's interior. The hearing instrument further comprises an earpiece suitable of being anchored in the ear canal. The earpiece may be custom fit to the ear canal's shape. In a preferred embodiment, however, the earpiece may be a universal earpiece suitable of being placed in different ear canals of a certain size category. Such open fitting universal earpieces are as such well-known in the art.

The tubing comprises a flexible tube with a first end attached to the behind-the-ear component, and a second end attached to the earpiece, and, as is generally the case for 'slim tubings', no 'hook' portion.

According to an aspect of the invention, the tubing comprises at least a first tubing section with a first tubing interior cross section, and a second tubing section with a second tubing interior cross section, the second tubing section at a larger distance from the receiver than the first tubing section, areas of the first and the second interior tubing cross sections being constant and different from each other.

In this, the 'distance' is a distance along a tubing path, i.e. along the track defined by a tubing axis. Of course, the actual physical distance in the three-dimensional space may vary depending on the actual orientation of the flexible tube etc.

The concept of the aspect of the invention implies that the interior cross section area is stepped between different sections. Generally, the cross section area will be the greater the more remote from the receiver. The cross sectional area against the distance from the receiver is generally a stepped, monotonously increasing function. In systems with circular cross sections, this means that the diameter is an according stepped, monotonously increasing function.

Preferably, the entire tubing consists of regions with constant inner cross sections. However, optionally, in addition to the sections with the stepped feature there may also be regions with a continuous variation of the inner cross sectional area, for example towards the orifice in the earpiece. Especially, all cross sections with the possible exception of the one closest to the orifice in the earpiece may have a constant cross section along their entire length.

It is an insight forming a basis of the present invention that for the relatively high frequencies concerned (primarily frequencies around 1 kHz and higher), that such a tubing with a stepped characteristics is advantageous in terms of sound transmission, compared to constant diameters. As a consequence, the maximum power output (MPO), the overall gain and the gain frequency response as well as the overall efficiency are improved. Further, tubings with a sectionwise constant cross section are easy to manufacture.

In state of the art systems, in terms of horn effect at most partial systems have been considered; while the approach of the invention provides a – surprisingly simple – solution that considers the entire sound path along the tubing. Also, in preferred embodiments of the invention, the internal tubing from the receiver output to the onset of the flexible tube portion is also used for implementing the approach of the invention.

According to a preferred embodiment, the tubing comprises three sections. A first, interior section is within the behind-the-ear component casing and may be defined by the latter. A second, flexible section is defined by the tube connecting the behind-the-ear component with the earpiece. A third section is at least a portion of the segment that is held by the earpiece. The third section may, like the first section, be rigid. At least the second section compared to the first section or the third section compared to the second section has a larger cross sectional area of the inner tubing cross section, and preferably $A_1 < A_2 < A_3$, where A_i denotes the area of the inner cross section of the respective section. In this, earpiece may be but does not necessarily have to be at the end of the tubing's third section.

Generally, a preferred ratio of cross sectional areas between neighboring sections is $1.4 < A_{i+1}/A_i < 4$. In the above-referenced case of three sections, therefore, preferably $1.4 < A_2/A_1 < 4$ and/or preferably $1.4 < A_3/A_2 < 4$.

These area ratios are optimized for a certain frequency range of between about 1 kHz and 6 kHz, i.e. the frequency range that is important for the 'open fitting' hearing instruments. It has further been found that the ratios are valid for earpieces of different plugging up characteristics (different grades of occlusion), i.e. in the frequency range concerned they are approximately independent of the grade of occlusion by the earpiece.

Further, preferably in the section of the flexible sound conduction tube, the inner cross section area is at most 1.5 mm^2 or less, corresponding to an inner diameter of about 1.4 mm or less for circular cross section. Especially preferred are cross section areas in the section of the flexible sound conduction tube of 1 mm^2 or less, for example a circular cross section with a diameter of 1 mm or less. All diameters in principle can be scaled to larger or smaller diameters while maintaining the ratios.

Higher diameters correspond to higher overall gain, while a compromise has to be made in terms of aesthetics.

In any case (be it with two, three or more sections), in special embodiments, the section immediately following the receiver may have an inner cross section area that is smaller than an inner cross section area of a receiver outlet, i.e. a mouth defined by the receiver through which the sound exits. Such a configuration has been proven to be advantageous for certain configurations. This is especially because it makes possible that there is a step in the inner diameter from the first to the second section, when the second (or a subsequent) section corresponds to the flexible tube section, without the second section's outer diameter having to bee too large (which would have consequences in terms of aesthetics).

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, embodiments of the invention are described referring to drawings. In the drawings, same reference numerals relate to same or analogous elements. The drawings show:

- Fig. 1 a schematical cross section of a hearing instrument;

- Fig. 2 a schematical cross section of variant of the hearing instrument;

- Fig. 3 results of a computer simulation of first examples, and

- Fig. 4 results of a computer simulation of second examples.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The hearing instrument 1 depicted in **Figure 1** comprises a behind-the-ear component with a hearing instrument casing 2 housing the components used for picking up acoustic and/or electric signals and processing these into the desired sound signals. The components will usually include a battery compartment, at least one microphone, a digital signal processing stage, an amplifier that may optionally be integrated in the digital signal processing stage, (all not depicted) and at least one receiver 3. The components may further include at least one antenna, telecoil or the like for communication with other devices and/or the other hearing instrument. The details of the way the receiver 3 is supplied with a signal and of how this signal is generated are as such known in the art and are not described any further here.

The receiver comprises a mouth 3.1 (outlet) from which the sound signals exit. Following the receiver, a first duct 5 is defined that forms the first section of the tubing. The first duct 5 may be a feature of the housing or may be a separate tube-like or pipe-like element inserted in the housing. The first duct 5 is directly coupled to the receiver mouth 3.1, i.e. the mouth opens into, and communicates directly with, the interior of the first duct.

The hearing instrument 1 further comprises a flexible tube 6 forming the second section of the tubing and being the main portion of the tubing. The tube 6 has a uniform cross section and is for example transparent. The tube may be circular in cross section. Normally, the tube's inner diameter will not be greater than about 1.4 mm (or, in case of non-circular cross sections, cross sectional area of the tube's interior will not be greater than 1.5 mm^2). However, scaling to higher tube diameters is not ruled out.

The flexible tube 6 connects the behind-the-ear component with the earpiece 10. The earpiece 10 comprises an anchoring portion 11 to be anchored in the ear canal, for example by the joint action of an appropriate shape (and approximately appropriate size) and an elastic deflection. The earpiece 10 may be a 'universal' (i.e. not individual) earpiece that is non-occluding, i.e. there are large channels between the outside and the inside of the ear canal, and sounds may pass by the earpiece. For example, the earpiece may comprise a so-called open dome as the anchoring portion 11. The earpiece in addition comprises a third duct 7 that forms the third section of the tubing. The third duct may be stiff or may be flexible.

The first, second, and third sections of the tubing in the depicted embodiment are each uniform in their inner cross section. The first and the second section as well as the second and the third section open out into each other and are thus immediately coupled to each other.

In a variant, the third section of the tubing could comprise an orifice with a non-uniform cross section at the end towards the eardrum.

The inner diameters d_1, d_2, d_3 of the first, second, and third sections of the duct are ascending. The first diameter d_1 is smaller than the diameter of the receiver's mouth 3.1. As an example, the diameter of the mouth may be 0.9 mm, the diameter d_1 of the first section 0.67 mm, the diameter d_2 of the second section 0.96 mm, and the diameter d_3 of the third section 1.4 mm.

The earpiece may in addition comprise not shown clip and/or handgrip means as known in the art.

The embodiment of **Figure 2** differs from the embodiment of Figure 1 in that the tubing comprises two portions 6, 7 of an elastic tube, which portions are plugged one on the other. The portion 7 that is farther away from the receiver 3 is the third section of the tubing. It is attached to a systematically shown anchoring portion 11 that forms the earpiece. The interface between the two elastic tube portions 6, 7 may, when in use, be inside or outside of the ear canal.

As a further difference, independent difference to the embodiment of Figure 2, the tubing protrudes further into the ear canal than the anchoring portion.

While the depicted embodiments comprise three tubing sections with different diameters, the invention works also for two sections. For example, in the above-depicted embodiments, the diameters of the inner tubing 5 and the tubing's main portion 6 may be equal, or possibly the diameters of the tubing's main portion and of the tubing's earpiece portion may be equal. Also, it would be possible to provide more than three sections, for example four sections.

Figures 3 and 4 show computer simulations of the frequency response for different ratios of the diameters d_1, d_2, d_3 of the tubing sections in the embodiment as depicted in Fig. 1. The lengths l_1, l_2, l_3 of the respective sections for the example depicted in Fig. 3 and 4 are chosen to be realistic and are 8.5 mm, 32.8 mm, and 15 mm respectively.The box on the top left of each figures shows the sequence of the inner diameters d_1, d_2, d_3 (in mm, for circular cross section) of three different examples according to the invention and a comparative, state-of-the-art example with constant cross section.

Figure 3 clearly shows that the examples that are according to the invention have a strongly improved frequency response for frequencies above about 1 kHz compared to the comparative example. Between the embodiments of the invention, the ones with larger diameters have a better frequency response than the ones with smaller diameters (this is not surprising), but surprisingly the effect brought about by the approach according to the invention compared to the state of the art for most frequencies above 1 kHz has a higher impact than making the tubing diameters larger, the latter at the cost of significantly deteriorated aesthetics.

The examples shown in Figure 4 show a variation of the diameter of the third section (the earpiece section) only, i.e. in the embodiment shown in Fig. 1 the diameter d_1 of the internal tubing section is assumed to be equal to d_2. Again, for frequencies above about 1 kHz, the approach according to the invention is beneficial compared to the prior art. Also, the example shows that the improved frequency response effect is especially strong for diameter ratios d_3/d_2 of between 1.2 and about 2, whereas above a ratio of 2 in the depicted configuration a saturation-like effect occurs.

Various other embodiments may be envisaged without departing from the scope and spirit of the invention.

WHAT IS CLAIMED IS:

1. A slim tubing, hookless hearing instrument (1) comprising a behind-the-ear component with a housing (2) and a receiver (3) arranged in the housing, and further comprising a slim sound conduction tubing acoustically coupling an output of the receiver with a tubing output to be arranged in an interior of a user's ear canal, and an earpiece (10, 11) suitable of being anchored in the ear canal, the tubing comprising a flexible tube (6) with a first end attached to the behind-the-ear component, and a second end attached to the earpiece, wherein the tubing comprises at least a first tubing section (5; 6) with a first tubing interior cross section, and a second tubing section (6; 7) with a second tubing interior cross section, the second tubing section at a larger distance from the receiver than the first tubing section, areas of the first and the second interior tubing cross sections being constant, and the area of the second interior cross section being greater than the area of the first interior cross section.

2. The hearing instrument according to claim 1, wherein the second interior cross section is larger than the first interior cross section by a factor of between 1.4 and 4.

3. The hearing instrument according to claim 1 or 2, wherein the tubing comprises a third section (7).

4. The hearing instrument according to claim 3, wherein the second interior cross section is larger than the first interior cross section by a factor of between 1.4 and 4, and the third interior cross section is larger than the second interior cross section by a factor of between 1.4 and 4.

5. The hearing instrument according to claim 3 or 4, wherein the first section is within the housing (2), and the second section comprises at least a portion of the flexible tube (6).

6. The hearing instrument according to claim 5, wherein the third section (7) is defined by the earpiece.

7. The hearing instrument according to claim 1 or 2, wherein the first section comprises the flexible tube and wherein the second section is defined by the earpiece.

8. The hearing instrument according to claim 1 or 2, wherein the first section is within the housing (2), and the second section comprises the flexible tube (6).

9. The hearing instrument according to any one of the previous claims, wherein a cross section area of a tubing section immediately adjacent an outlet of the receiver is smaller than an internal cross section area of the receiver outlet.

10. The hearing instrument according to any one of the previous claims, wherein an cross sectional area of the flexible tube' interior is not greater than 1.5 mm^2, preferably not greater than 1 mm^2.

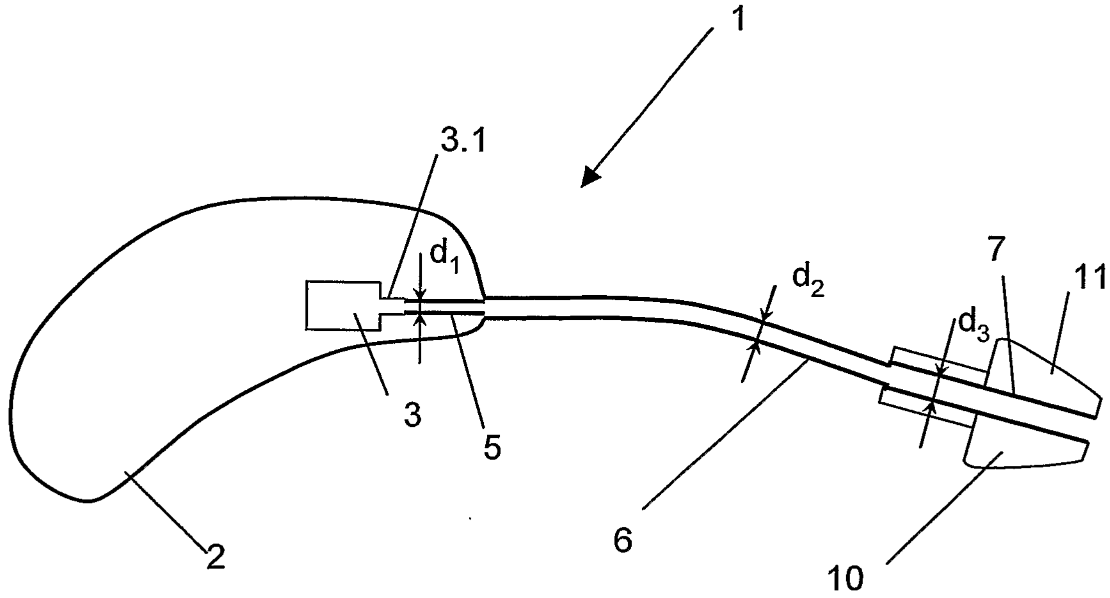


Fig. 1

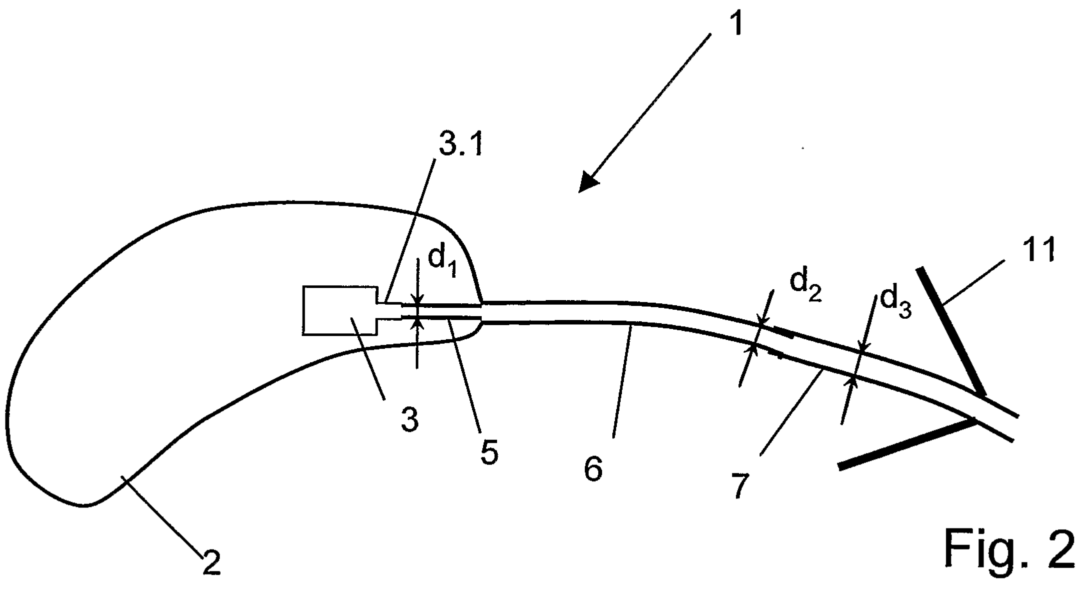
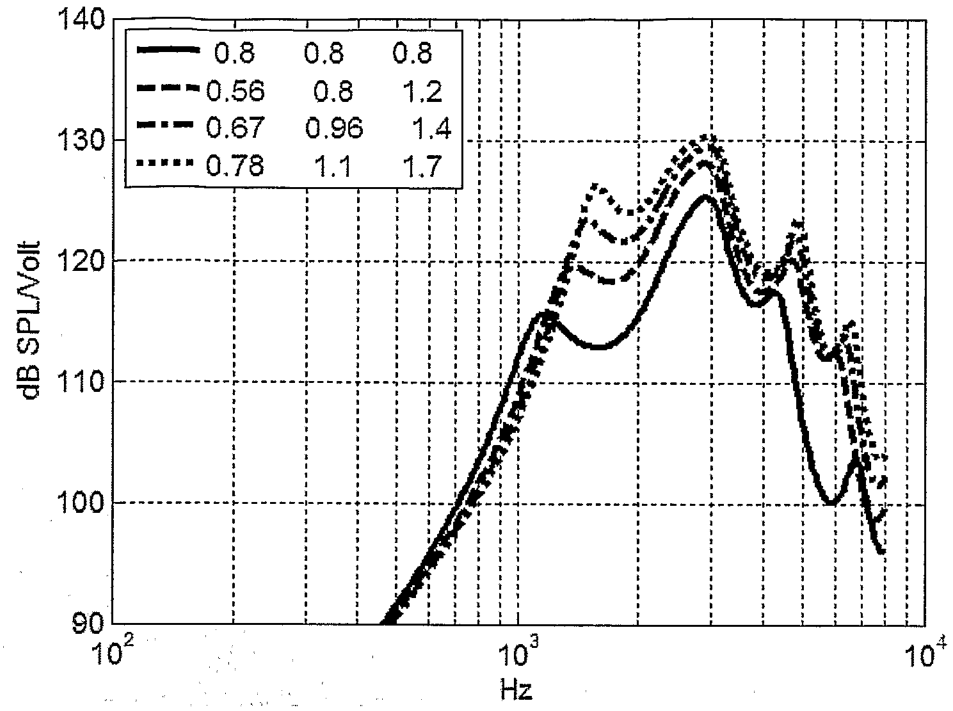


Fig. 2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110
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Fig. 3

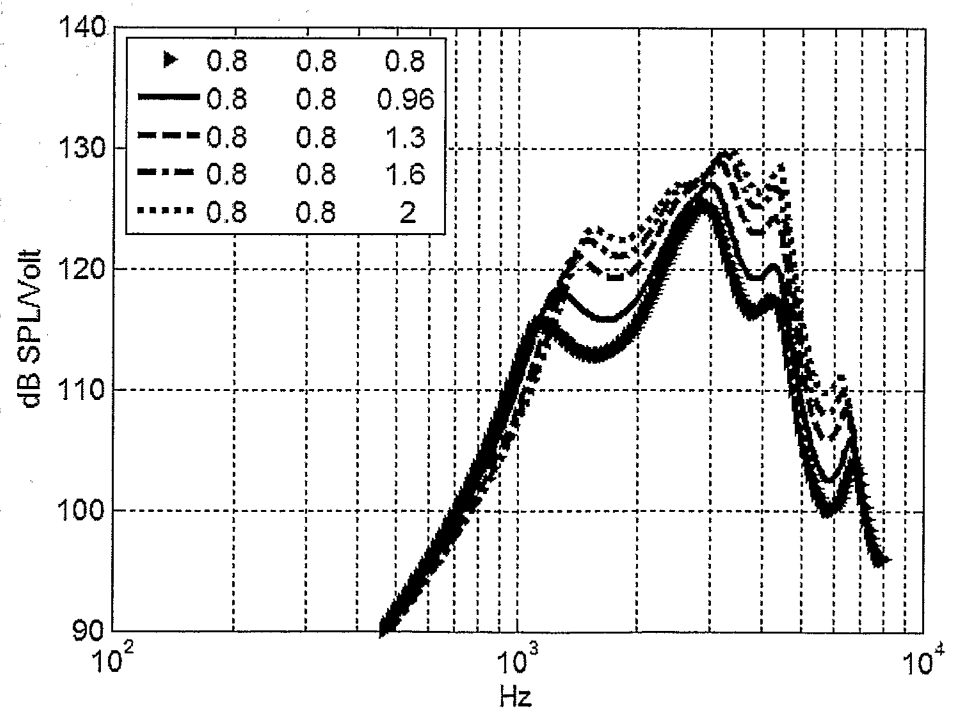
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Fig. 4