(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 448 110 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **91104475.8**

(51) Int. Cl.5: **H04R 1/10**, G10K 11/16

(22) Date of filing: **21.03.91**

(30) Priority: **23.03.90 JP 73814/90**

(43) Date of publication of application: **25.09.91 Bulletin 91/39**

(84) Designated Contracting States: **DE GB**

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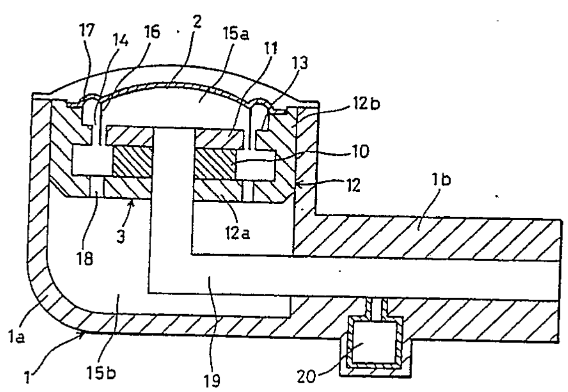
(54) **Headphone apparatus.**

(57) An inner-ear type headphone apparatus includes a diaphragm (2), a driving portion (3), a case (1), a duct (19), and a sound-absorbing portion (20). The driving portion (3) drives the diaphragm (2). A diaphragm backside space (15a) is formed between the diaphragm (2) and the driving portion (3). The driving portion (3) is attached to the case (1). The duct (19) conducts the diaphragm backside space (15a) to the external space outside the case (1). The sound-absorbing portion (20) communicates with the duct (19). The sound-absorbing portion (20) absorbs sound of high frequency range emitted to the external space outside the case (1) through the duct (19). The amount of unpleasant high frequency range sound leaking outside is reduced.

FIG. 2



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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to headphone apparatus, and more particularly, to a headphone apparatus having frequency characteristics improved in low frequency range. This invention has applicability to an inner-ear type headphone apparatus, for example.

Description of the Background Art

The structure of a conventional inner-ear type headphone apparatus will first be explained. Fig. 1 is a sectional view of a structure of a conventional headphone apparatus.

Referring to Fig. 1, a diaphragm (vibration plate) 30 is provided in a cylinder portion 38a of a case 38. Diaphragm 30 is arranged to cover an opening at the upper side of cylinder portion 38a. A driving portion 40 is provided in close proximity of diaphragm 30 at an inward position of case 38. The bottom side of cylinder portion 38a is sealed as shown in the figure. Case 38 has a projection 38b extending sidewards in the figure. Projection 38b extends sidewards from the lower portion of the outer peripheral surface of cylinder portion 38a.

Driving portion 40 implements a magnetic circuit portion constituted by a ring-like magnet 31, a top plate 32, and a yoke 33. Top plate 32 is fixed to the upper surface of magnet 31. The section of yoke 33 is roughly U-shaped. The bottom portion of yoke 33 is fixed to the lower surface of magnet 31. The outer peripheral surface of the cylinder portion of yoke 33 is formed to enclose magnet 31 and top plate 32. The outer peripheral surface of the cylinder portion of yoke 33 is fitted and fixed at the upper end of the inner peripheral surface of cylinder portion 38a of case 38. A protrusion 34 is formed at the upper portion of the inner peripheral surface of the cylinder portion of yoke 33. Protrusion 34 protrudes inward of the diameter direction of yoke 33 to face the outer peripheral surface of top plate 32. A gap 34a having a predetermined intervening space is formed between protrusion 34 and top plate 32.

Diaphragm 30 is connected to the upper surface of yoke 33 by means of an edge portion 35 of the peripheral edge thereof. The upper end of a hollow cylindrical voice coil 37 is connected at the inner side of edge portion 35. The lower end of voice coil 37 is located in gap 34a. Diaphragm 30 vibrates by transmitting audio signal current to voice coil 37. This vibration generates compression waves in the air at the forward side of diaphragm 30 (the upper side in the figure) to produce sounds.

It is necessary to suppress influence of compression waves also generated in the air at the backward side of diaphragm 30 and enhance the low frequency range. A back cavity 36b is provided at the backward side of yoke 33 for this purpose. Back cavity 36b communicates with diaphragm backside space 36a between diaphragm 30 and driving portion 40. A duct 39 for enhancing the low frequency range is provided that penetrates projection 38b in case 38 to communicate with external space (the outside of the headphone apparatus) also for the above-mentioned purpose. Duct 39 penetrates the centers of top plate 32, magnet 31, and yoke 33 and through back cavity 36b into projection 38b in case 38. Back cavity 36b also communicates with external space via duct 39. The frequency characteristics in the low frequency range is improved with this configuration.

Japanese Utility Model Publication No. 64-6636 (1989) discloses a headphone having a structure similar to that of the above described headphone with the frequency characteristics improved in the low frequency range.

With the structure of such conventional headphones, the sound of the frequency range that resonates to the air within duct 39 is emitted outside through duct 39 provided for enhancing the low frequency range. This sound emitted outside is normally a sound of high frequency range. This means that this sound of high frequency range is audible to other people close to the person wearing the headphone. There was the problem that people close to a person listening with a conventional headphone is annoyed with high frequency range sounds leaking from the headphone.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a structure of a headphone apparatus capable of reducing the amount of sound of high frequency range leaking through a duct.

A headphone apparatus according to the present invention includes a diaphragm, a driving portion, a case portion, a duct portion, and a sound absorber. The driving portion forms a predetermined space between the diaphragm and the driving portion to drive the diaphragm. The driving portion is attached to the case portion. The duct portion conducts the predetermined space between the diaphragm and the driving portion to the external space outside the case portion. The sound absorber communicates with the duct portion to absorb sound waves of the frequency range emitted outside the case portion.

According to a preferred embodiment of the present invention, the sound absorber includes space resonating to the frequency range sound emitted from the duct. The sound absorber also includes space communicating with an opening provided at the outer peripheral surface of the duct. This space preferably includes a first cylindrical space communicating with the duct, and a second cylindrical space adjoining the first cylindrical space. The diameter of the first cylindrical space is smaller than that of the second cylindrical space. The sound absorber includes a sealed space communicating with the duct.

The frequency range sound emitted to external space from the case through the duct is absorbed by the sound-absorbing means in the present invention. This lowers the intensity of the sound of the frequency range emitted through the duct. As a result, the amount of sound leaking through the duct is reduced. The disturbance due to high frequency range sound leaking from a headphone annoying people close to the person using a headphone may be solved.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view showing a structure of a conventional headphone apparatus.

Fig. 2 is a sectional view showing a structure of an embodiment of a headphone apparatus according to the present invention.

Fig. 3 is a partial sectional view enlarging the sound-absorbing portion provided in the headphone apparatus of Fig. 2.

Fig. 4 is a graph showing a frequency analysis result of sound leaking outside through a duct in the headphone apparatus of the present invention in comparison with the measured result of a conventional headphone apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention will be explained hereinafter with reference to the drawings.

Fig. 2 is a structure of an inner-ear type headphone apparatus according to the present invention. Referring to Fig. 2, a case 1 comprises a cylinder portion 1a and a projection 1b. Cylinder portion 1a is formed to have an opening at the upper end. Projection 1b is formed to extend sidewards from the lower portion of the outer peripheral surface of cylinder portion 1a. A diaphragm 2 is provided to cover the opening of the upper portion in cylinder portion 1a. A driving portion 3 is provided internal of cylinder portion 1a in close proximity to diaphragm 2. The driving portion 3 drives diaphragm 2.

Driving portion 3 constitutes a magnetic circuit portion including a magnet 10, a top plate 11, and a yoke 12. The ring-like magnet 10 is arranged to be coaxial with cylinder portion 1a. Top plate 11 is fixed to the upper surface of magnet 10. The section of yoke 12 is roughly U-shaped. Yoke 12 comprises a cylinder configuration having a bottom. A hole is formed through the axis of bottom 12a of yoke 12. The lower surface of magnet 10 is fixed on the bottom 12a. Magnet 10 and top plate 11 are provided in the interior of the cylinder portion 12b of yoke 12 coaxially. The outer peripheral surface of the cylinder portion 12b of yoke 12 is fit and fixed in the upper portion of the inner peripheral surface of cylinder portion 1a. Accordingly, driving portion 3 is attached within case 1. Top plate 11 has an outside diameter slightly larger than that of magnet 10. The inner peripheral surface of cylinder portion 12b of yoke 12 is provided with a protrusion 13 protruding in the direction of the axis. Protrusion 13 is formed to face top plate 11 in the diameter direction. A gap 14 having a predetermined space is formed between protrusion 13 and top plate 11.

The peripheral edge of diaphragm 2 is provided with an edge portion 17. Diaphragm 2 is connected to the upper surface of cylinder portion 12b of yoke 12 by edge portion 17. The upper end of a voice coil 16 is connected at the inside of edge portion 17 of diaphragm 2. Voice coil 16 extends downwards having a hollow cylindrical configuration. The lower portion of voice coil 16 is located within gap 14.

A back cavity 15b is provided in the interior of cylinder portion 1a of case 1. Back cavity 15b is the space portion beneath the driving portion 3. A diaphragm backside space 15a between diaphragm 2 and driving portion 3 communicates with back cavity 15b through gap 14 and a communicating hole 18. A hollow cylindrical duct 19 is provided to extend from diaphragm backside space 15a into the internal of back cavity 15b. Duct 19 is formed to pass through the center holes of top plate 11, magnet 10, and bottom 12a of yoke 12. Duct 19 has a configuration bending substantially 90° inside back cavity 15b. Duct 19 communicates with external space through the interior of projection 1b of case 1. Diaphragm backside space 15a therefore also communicates with external space through duct 19.

A sound-absorbing portion 20 is provided in the interior of projection 1b of case 1. Sound-absorbing portion 20 communicates with an opening portion provided in duct 19. It is appreciated from Fig. 3 that sound-absorbing portion 20 is constituted by a small diameter cylindrical portion (referred to as the neck portion hereinafter) 21, and a large diameter cylindrical portion (referred to as the body portion hereinafter) 22 having a diameter larger than that of neck portion 21. Neck portion 21 extends in a direction substantially at right angles from the outer peripheral surface of duct 19. The body portion 22 adjoins neck portion 21.

A constant magnetic flux is generated in gap 14 in the headphone apparatus having the above described structure. When audio signal current flows to voice coil 16, a driving force according to Fleming's left-hand rule acts on voice coil 16. Voice coil 16 vibrates in response to the audio signal current. This vibration is propagated to diaphragm 2. The vibration of diaphragm 2 generates compression waves in the air at the forward side of diaphragm 2 (the upper side in Fig. 2) to produce a sound.

Because of the vibration of diaphragm 2 described above, compression waves are also generated in the air at the backside of diaphragm 2, i.e. within diaphragm backside space 15a. Diaphragm backside space 15a communicates with back cavity 15b as well as with external space through duct 19, so that sound emitted to the forward side, particularly sound wave of the low frequency range is not attenuated by interference with the backside compression waves. This allows sound output having low frequency range enhanced.

In this case, the sound of the frequency range that resonates according to the configuration of the duct is emitted outside through the duct that is provided to enhance low frequency range. When the whole length of duct 19 of Fig. 2 is 2cm, for example, sound of a frequency range having a wave length two times this entire length is emitted to external space through duct 19. The sound of the frequency range emitted corresponds to the sound of high frequency range centered at the frequency of 8500Hz.

Therefore, the configuration of sound-absorbing portion 20 is formed to resonate with the frequency of the emitted sound to absorb the sound of the frequency range emitted outside through duct 19. For example, when the length of duct 19 is 2cm as mentioned above, the configuration of sound-absorbing portion 20 is designed to resonate to a frequency of 8500Hz. When sound-absorbing portion 20 is constituted by neck portion 21 and body portion 22, the resonant frequency f is obtained by the following equation:

$$f=\frac{v}{2\pi}\sqrt{\frac{S}{\ell \times w}}$$

where v is the sound velocity through air, π is the circle ratio, S is the opening area to duct 19 in neck portion 21, ℓ is the length of neck portion 21, and w is the capacity of body portion 22.

It is assumed that v is 340m, the diameter of neck portion 21 is 2mm, the length ℓ is 2mm, and the capacity w of body portion 22 is 6.366 x 10^{-2}cc, for example. Resonant frequency f is obtained by substituting these values into the above equation. This gives the resonant frequency f of 8500Hz in sound-absorbing portion 20. Sound-absorbing portion 20 having a space configuration designed as above resonates to sound of high frequency range centered about a frequency of 8500Hz propagated to external space through duct 19. This reduces the amount of sound leaking to external space through duct 19.

Fig. 4 shows an example of frequency analysis result of sound leaking outside propagated through the interior of duct 19. It is appreciated from the broken line B resulted by a conventional headphone apparatus in Fig. 4 that sound wave in the frequency range around 8500Hz resonates through duct 19 to be enhanced and emitted to external space outside of the headphone apparatus. In comparison, it is appreciated by solid line A according to the headphone apparatus of the above described embodiment that sound of the frequency range around 8500Hz is sufficiently attenuated to a sound volume level substantially equal to the sound of other frequency range. Hence, the annoyance of high frequency range sound audible to people nearby may be eliminated. According to the above embodiment, sound output of low frequency range is enhanced for the user of the headphone with almost no leakage of sound from the headphone to external space. The user of the headphone does not have to worry about annoying other people nearby. Comfortability is improved in the usage of a headphone apparatus.

An approach may be taken such as providing a cover at the opening of the duct communicating with external space to reduce sound leaking outside through the duct. However, such an approach will reduce the essential effect of a duct that is to enhance the low frequency range of sound towards the user. The structure of the headphone apparatus of the present invention allows reduction of sound leaking to external space through duct 19 without decreasing the low frequency range enhancement effect by duct 19.

The present invention is not limited to the above described embodiment and various modifications can be carried out to the structure of the headphone apparatus within the scope of the present invention. For example, it is possible to provide sound-absorbing portion 20 at an arbitrary position other than projection 1b of case 1 as long as it is located at a position communicating with duct 19. Sound-absorbing portion 20 is formed to include a space configuration resonating to the frequency of sound wave propagated to external space through the duct in the above embodiment. The sound-absorbing means of the present invention is not limited to one employing resonance phenomenon, and any means may be employed as long as it absorbs energy corresponding to the frequency of sound propagating to external space through a duct.

Although the above-mentioned embodiment was described in which an inner-ear type headphone apparatus is employed, the present invention can be applied to other electroacoustic transducers such as an overhead type headphone apparatus.

As set forth throughout the present invention, the amount of sound leaking outside through a duct portion is reduced to solve the annoyance of high frequency range sound leaking which disturbs people nearby.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

Claims

1. A headphone apparatus comprising:
   a diaphragm (2),
   a driving portion (3) forming a predetermined space (15a) between said diaphragm and said driving portion for driving said diaphragm,
   a case portion (1) attached with said driving portion,
   a duct portion (19) conducting said predetermined space between said diaphragm and said driving portion to the external space outside said case portion, and
   sound-absorbing means (20) communicating with said duct portion for absorbing sound of the frequency range emitted to the external space outside said case portion through said duct portion.

2. The headphone apparatus according to claim 1, wherein said sound-absorbing means (20) comprises space (21, 22) resonating to sound of the frequency range emitted through said duct portion.

3. The headphone apparatus according to claim 1, wherein said sound-absorbing means (20) comprises space communicating with an opening portion provided in the outer peripheral surface of said duct portion (19).

4. The headphone apparatus according to claim 1, wherein said sound-absorbing means (20) comprises cylindrical space (21, 22) communicating with said duct portion.

5. The headphone apparatus according to claim 4, wherein said sound-absorbing means (20) comprises a first cylindrical space (21) communicating with said duct portion, and a second cylindrical space (22) adjoining said first cylindrical space.

6. The headphone apparatus according to claim 5, wherein the diameter of said first cylindrical space (21) is smaller than that of said second cylindrical space (22).

7. The headphone apparatus according to claim 1, wherein said sound-absorbing means (20) comprises sealed space (22) communicating with said duct portion.

8. The headphone apparatus according to claim 1, wherein said duct portion (19) extends inside said case portion (1).

9. The headphone apparatus according to claim 1, wherein said case portion (1) comprises sealed space (15b) communicating with said predetermined space (15a) between said diaphragm and said driving portion.

FIG. 1

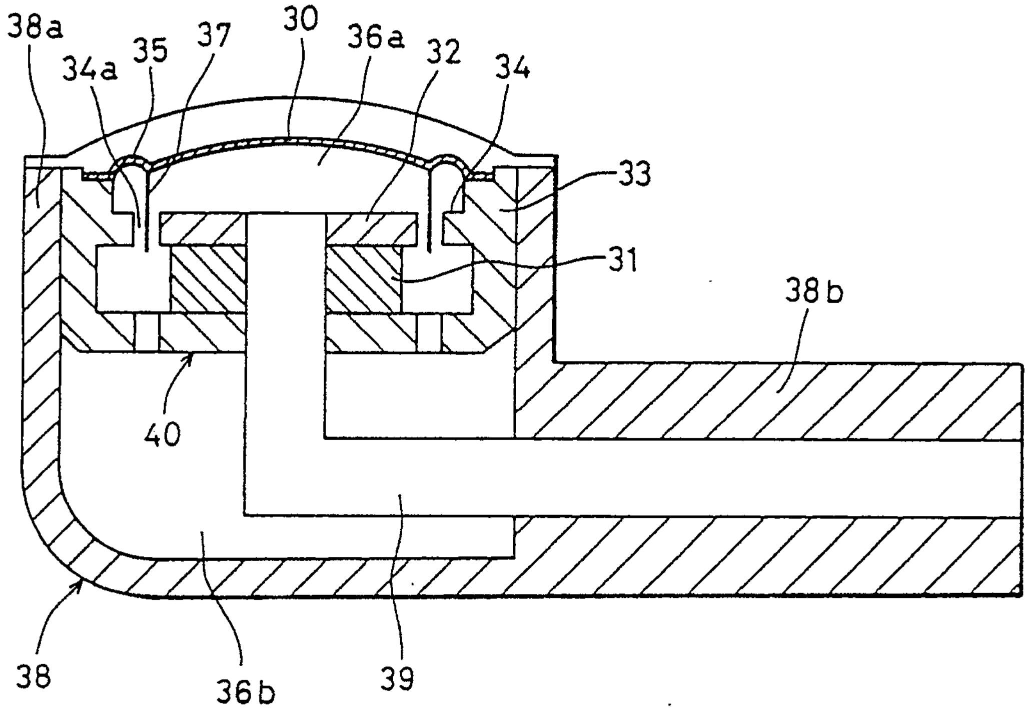

FIG. 2

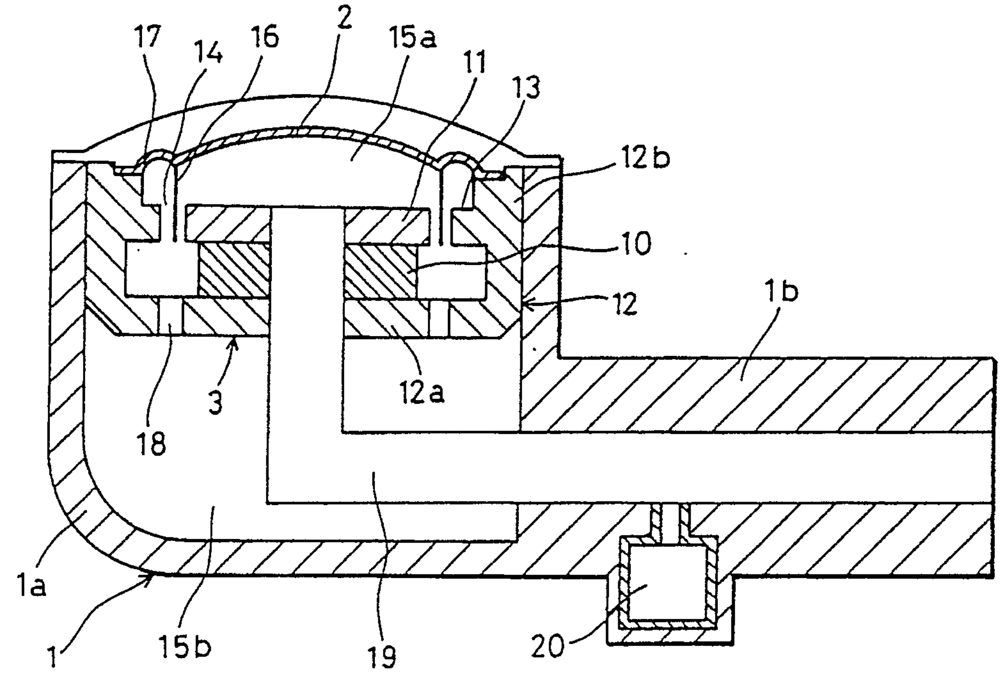

FIG. 3

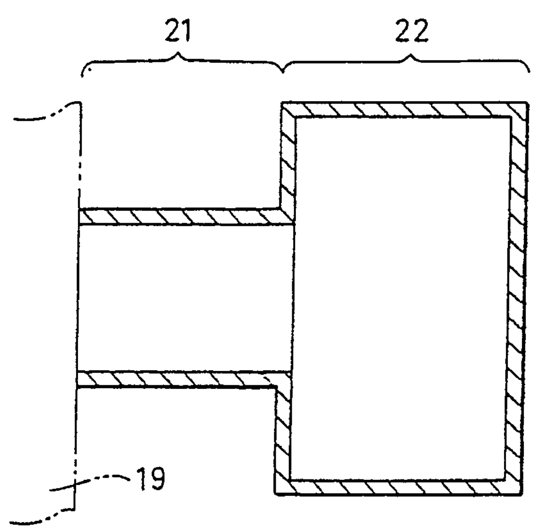

FIG. 4