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EARPHONE

This invention generally relates to an earphone and more particularly, is directed to a compact earphone which is adapted to be engaged with and attached to a cavum of a concave portion in an auricle during operation.

5 The low frequency range reproduction limit of a prior art open air-type earphone is mainly determined by a compliance C_{md} (reciprocal number of stiffness S) of a vibration system and an equivalent mass M_d of the vibration system. In this case, the response in the low frequency
10 range in which the lowest resonance frequency is lower than f_0 is lowered. In general, the resonance frequency f_0 is substantially given as



$$f_0 = 1/2 \pi / \sqrt{M_d \cdot C_{md}}$$

In order to make the resonance frequency f_0 low, the
15 compliance C_{md} (cm/dyne) of the vibration system must be made high and/or the equivalent mass M_d (gram) thereof must be increased. There is, however, a limit in increasing the compliance C_{md} . Further, if the equivalent mass M_d of the vibration system is increased, the auditory sensitivity
20 becomes low and the acoustic characteristic in the high

frequency range is deteriorated etc. Accordingly, there is naturally a limit in increasing the equivalent mass M_d .

As is known, since there is a tendency that the lowest resonance frequency f_0 becomes higher as the diameter of the speaker unit becomes smaller, it is recognized that reproduced sound in a low frequency range is not heard by those who use an earphone of small diameter.

For instance, in the earphone which is disclosed in European patent publication No. 0064553, a magnetic circuit is formed of a magnet of a disc-shape, a cylindrical yoke and a plate surrounding the magnet. A diaphragm is coupled to a voice coil that is inserted into the air gap of the magnetic circuit and is incorporated in the front portion thereof to form a speaker unit. The outer peripheral portion of the speaker unit is mounted to a housing. At the rear surface of through-holes formed through the outer peripheral portion of the speaker unit, there is provided a damping layer and through-holes are formed through the housing to thereby control the frequency characteristic.

In other words, the acoustic circuit of this prior structure is expressed by a series circuit formed of an equivalent mass M_d of the vibration system, a compliance C_{md} thereof, an acoustic resistance R_d , a signal source V_s and an acoustic resistance R_a provided by the damping layer or the like, and a parallel circuit connected to the series circuit and formed of an acoustic resistance R_b by the

through-hole of the housing and the compliance C_b by the back cavity.

However, since the acoustic resistance R_b provided by the through-holes of the housing is negligibly small as compared with the acoustic resistance R_a of the damping layer or the like and the compliance C_b can be also neglected substantially, the effects of the acoustic resistance R_b and the compliance C_b constituting the parallel circuit are small, and thus the acoustic circuit substantially becomes a series resonance circuit formed of the equivalent mass M_d , the compliance C_{md} and the acoustic resonances R_d and R_a . Accordingly, the lowest resonance frequency f_0 is substantially given as



$$1/2 \pi \sqrt{M_d \cdot C_{md}}$$

and it becomes difficult to set the frequency f_0 low.

Further, if the acoustic resistance R_a is small, a peak of acoustic characteristic is produced near the lowest resonance frequency f_0 so that only the nearby sound is emphasized and becomes a resonant sound, whereas if the acoustic resistance R_a is large, the acoustic characteristic is lowered from the frequency higher than the lowest resonance frequency f_0 so that the reproduction of low frequency range becomes insufficient.

According to the present invention, there is provided an earphone comprising :

a housing having a front opening;

a speaker unit having front and rear portions
5 mounted in said housing with the front of the speaker positioned in said opening;

a cavity in said housing formed between a rear portion of said speaker unit and said housing; and

a duct acoustically coupled to said cavity to lower
10 the lowest resonance frequency, said duct comprising an opening through said housing by which said cavity and the rear outside of said housing communicate with each other, said duct being provided with a mesh thereacross which is
15 acoustically transmissive while preventing the ingress of water into the cavity.

As will become apparent from the following description, the illustrated embodiment of the invention can provide an earphone in which without modifying a speaker
20 unit, an acoustic circuit provided at the rear surface of the speaker unit is devised to improve the frequency characteristic at the low frequency range. As means for improving the reproduction of low frequency range, a duct is formed in communication with the housing of an earphone
25 and is used to pass the sound emanated from the rear surface of the speaker unit to the outside and water repellent means is provided within the duct so that even if the earphone is submerged into water, the original acoustic characteristic

of the earphone can be rapidly recovered after it is removed from the water. The illustrated earphone is of a simple construction in which the lowest resonance frequency can be set at a low frequency and which can be used as an all
5 weather earphone in the outdoors.

These and features and advantages of an earphone according to the present invention will become apparent from the following detailed description of the preferred embodiment taken in



conjunction with the accompanying drawings, throughout which like reference numerals designate like elements and parts.

In the drawings:.

FIG. 1 is an assembly view illustrating the present
5 invention applied to a stereo earphone system;

FIG. 2 is an enlarged cross-sectional view showing
an embodiment of the earphone according to this invention;

FIG. 3 is a diagram showing an acoustic equivalent
circuit of FIG 2; and

10 FIGS. 4 to 7 are respectively frequency vs. response
characteristic graphs useful for explaining the present
invention.

An embodiment of an earphone according to this
invention will be described hereinafter with reference to
15 the attached drawings. As shown, the earphone of this
invention is used to form, for example, a stereo earphone as
shown in FIG. 1. FIG. 2 is an enlarged cross-sectional view
showing the main body of such earphone. Referring to FIG.
2, the earphone itself will be described. In this
20 embodiment, a speaker unit 1 is accommodated and fixed in a
housing 2 of substantially frusto-conical-shape, and within
the housing 2 at the rear portion of this speaker unit 1,
there is formed a predetermined back cavity 8. A duct 7,
which is acoustically coupled to the back cavity 8, and
25 having an opening 7a is formed integrally with the housing
2. The opening 7a of the duct 7 is covered with a housing
cap 9 having a grid of, for example, Y-shape. The grid of

Y-shape provides the housing cap 9 with an opening 9a (refer to Fig. 1).

At the inside of the housing cap 9 which covers the opening 7a of the duct 7, there is provided a mesh 10 made of stainless steel of 100 to 200 meshes per inch having a relatively good ventilation property and which is subjected to a water repellent treatment such as a fluorine treatment or silicone treatment. It is also possible to provide such mesh 10 in the ducts 7. Further, through the housing 2 at its portion corresponding to the outer peripheral portion of the back cavity 8 there are formed a large number of through-holes 4 which serve to communicate between the inside and the outside of the housing 2. In this embodiment, at the inside of the through-holes 4 that are formed through the housing 2 there is provided a damping filter 11 which is made, for example, of a water repellent nylon screen and a material into which urethane resin as a damping material is polymerized.

Further, at the front of the speaker unit 1, there is provided a grille 12 made of a metal plate which has a large number of openings through which the sound emanated from the diaphragm of the speaker unit 1 is passed. At the front side of this grille 12, there are laminated a water repellent urethane resin 13 which is used as a damping material and a grille screen 14. In FIG. 2, reference numeral 5 designates a cord holder and 6 a cord supported by

the code holder 5. Upon usage, the housing 2 of the earphone is inserted into the auricle.

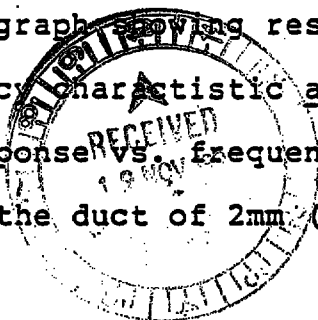
The acoustic equivalent circuit of the earphone of such structure when it is inserted into the auricle becomes as shown in FIG. 3. In FIG. 3, reference letters M_d , C_m and R_d designate an equivalent mass, a compliance and an acoustic resistance of the vibration system of the speaker unit 1, respectively. Reference letter R_a designates an acoustic resistance provided by the openings or the like formed at the outer peripheral portion of the speaker unit 1 and in this case, $R_a = 0$ is established substantially. Reference letter V_s designates a signal source. M_{cup} , C_{cup} and R_{cup} encircled by a circle G respectively designate an equivalent mass, a compliance and an acoustic resistance of a coupler used when the earphone is measured. Further, reference letter C_b designates a compliance presented by the back cavity when the housing 2 is formed as a frustoconical shape; reference letter R_b is an acoustic resistance presented by the urethane resin 13 used as the damping material; and reference letters L_d and R'_d an inductance (mass) and an acoustic resistance presented by the duct 7. In this case, the acoustic resistance R'_d is very small, Accordingly, the damping at the rear surface of the diaphragm of the earphone becomes a parallel resonance circuit formed of the acoustic resistance L_d , the compliance C_b and the acoustic resistance R_d . This circuit is added to

the series resonance circuit formed of the equivalent mass M_d , the compliance C_{md} and the acoustic resistance R_d . Accordingly, as shown in FIG. 4, the lowest resonance frequency on the whole of the acoustic circuit of the earphone is decreased by the inductance (mass) L_d of the duct 7 so as to become a frequency f_0 lower than the lowest resonance frequency f_0 of the speaker unit 1 itself. Similarly, as shown in FIG. 4, the acoustic resistance R_b , which is in parallel to the acoustic resistance L_d , is made small, the frequency f_0 becomes high, whereas if the acoustic resistance R_b is made large, the middle frequency range becomes low. Consequently, it is necessary to select the acoustic resistance R_b to be a proper value relative to the acoustic resistance L_d .

15 With respect to the high frequency range, if the acoustic resistance R_b is made large, the level in a high frequency range necessary for the reproduction by the headphone can be increased in view of the auditory sense.

As will be clear from the above-described results, 20 if the length of the duct 7, and/or the member 11 made of urethane resin as the damping material are varied, it is possible to carry out the acoustic control.

FIG. 5 is a graph showing results of comparing the response vs. frequency characteristic a of the prior art 25 earphone and the response vs. frequency characteristic b of the earphone having the duct of 2mm (in diameter) x 6mm



(in length) according to this invention. From this graph of FIG. 5, it will be seen that the lowest resonance frequency f_0 is lowered from 220Hz to 160Hz and also it will be seen that the level in the high frequency range near 2 to 6kHz necessary for the headphone reproduction is increased. In this case, the speaker unit 1 is 16mm in diameter.

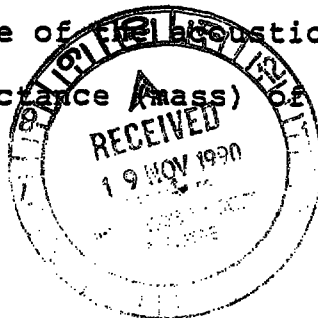
Further, after the earphone was submerged into the water, for example at 15cm deep for one minute, the water in the earphone was wiped out by a cloth and the acoustic characteristic thereof was measured. The measured results are shown on a graph of FIG. 6. As shown in the graph of FIG. 6, it can be understood that the original acoustic characteristic of the earphone is recovered after about 5 to 10 minutes following removal from the water. In the graph of FIG. 6, a curve b indicates the acoustic characteristic presented before the earphone is submerged into the water, a curve c the acoustic characteristic presented when the water in the earphone was wiped out by the cloth, a curve d the acoustic characteristic presented 5 minutes after the water in the earphone was wiped out and a curve e the acoustic characteristic presented 10 minutes after the water in the earphone was wiped out.

Furthermore, the earphone of this invention was set in an ear model and was subjected to the water shower for thirty seconds. Then, the water in the earphone was wiped out by the cloth and the acoustic characteristic thereof was

measured. The measured results are shown on a graph of FIG. 7. As shown in FIG. 7, the original acoustic characteristic of the earphone is substantially recovered after about thirty minutes to one hour from the wiping of the water. In the graph of FIG. 7, a curve b indicates the original acoustic characteristic and the acoustic characteristic presented just after one hour, a curve f the characteristic presented when the water in the earphone is wiped out by the cloth, a curve g the acoustic characteristic presented after 10 10 minutes since the water in the earphone was wiped out and a curve b the acoustic characteristic presented 30 minutes after the water in the earphone was wiped out by the cloth.

As set forth above, according to the earphone of this invention, since the opening portion 7a of the duct 7, the member 11, the urethane resin 13 provided in the front of the grille 12 and the grille screen 14 are subjected to the water repellent treatment, there is then an advantage that when the earphone of the present invention is submerged into water, its original acoustic characteristic 20 will be recovered rapidly.

As described above, according to the present invention, since the duct 7 is provided in connection with the housing 2 to pass therethrough the sound emanated from the rear surface of the speaker unit 1, the lowest resonance 25 frequency on the whole of the acoustic equivalent circuit is decreased by the inductance (mass) of the duct to the



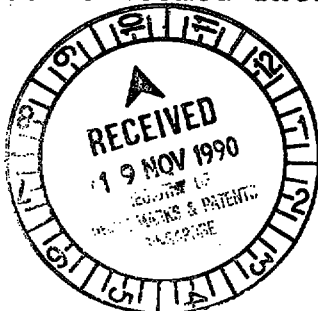
frequency lower than the lowest resonance frequency of the speaker unit 1 itself, while with the respect to the high frequency range, the level in the high frequency range is increased by the resonance of the compliance by the back
5 cavity 8 and the equivalent mass of the vibration system so that the response in the low frequency range and the response in the high frequency range can both be improved.

Furthermore, since the duct 7 and the like are subjected to the water repellent treatment, the water can be
10 prevented from entering through the duct 7 and the like so that even when this earphone is submerged into water, the original acoustic characteristic of the earphone will be recovered rapidly.

The above description relates to a preferred
15 embodiment of the invention but it will be apparent that many modifications and variations can be effected by one skilled in the art without departing from the scope of the invention as defined by the appended claims.

CLAIMS

1. An earphone comprising :
a housing having a front opening;
a speaker unit having front and rear portions
mounted in said housing with the front of the
5 speaker positioned in said opening; a cavity in said
housing formed between a rear portion of said
speaker unit and said housing; and
a duct acoustically coupled to said cavity to lower
the lowest resonance frequency, said duct comprising
10 an opening through said housing by which said cavity
and the rear outside of said housing communicate
with each other, said duct being provided with a
mesh thereacross which is acoustically transmissive
while preventing the ingress of water into the
15 cavity.
2. An earphone according to claim 1, in which said
mesh is treated with a water repellent.
3. An earphone according to claim 1 or 2, in which
said mesh is of 100 to 200 meshes.
- 20 4. An earphone according to claim 1, 2 or 3, in
which said duct is formed integrally with said housing.



5. An earphone according to claim 4, in which said duct has an opening and said opening is terminated with a cap having a through-hole.

6. An earphone according to claim 5, in which the 5 mesh is accommodated in said cap.

7. An earphone according to any preceding claim, further including a plurality of rear facing openings in said housing adjacent the periphery of the speaker unit communicating with the rear outside of the housing, each of 10 said rear facing openings having acoustics damping means positioned therein, and being treated with a water repellent.

8. An earphone constructed and arranged to operate substantially as hereinbefore described with reference to 15 and as illustrated in the accompanying drawings.

9. A stereo or monaural headset comprising a pair of earphones according to any one of the preceding claims.

