ABSTRACT: A dynamic acoustic transducer which is worn in the vicinity of the ear, with sound outlets on both sides of the diaphragm, one of them acting directly on the auditory canal, while one or more others reach the entrance to the auditory canal only via detours is shown. The resonant frequency of the diaphragm lies in the lower transmission range. Means in the form of a spacer are provided which prevent a sealing off of the entrance to the auditory canal with respect to the air space surrounding the head and the acoustic transducer. The spacer is made of acoustically damping material and may be in the form of an acoustic foam cushion. The spacer may be provided with one or more openings on its surface between the diaphragm and the auditory canal. The sound outlet or outlets from the side of the diaphragm facing away from the ear to the air space surrounding the acoustic transducer and the head are conducted via acoustic conduits which are terminated with their characteristic impedance on the end discharging into the air space. The acoustic conduits are so dimensioned that their characteristic impedance coupled to the diaphragm damps the diaphragm.
The invention relates to acoustic transducers and, in particular, to acoustic transducers suitable for use as earphones. It is known that earphones, despite the use of dynamic systems, are frequently only of limited quality, particularly at low frequencies. In order to obtain a dependable, reproducible frequency response, it is known to apply earphones in such a manner to the ear or ears that the ears are sealed off well (cf. High Fidelity Yearbook 1967/68, pages 87 and 88). The necessary good closing off of the ears can, however, only be obtained by a relatively strong pressure of the earphone against the ear. This results in discomfort which makes the wearing of earphones for a long time troublesome. As a result of this, the headband is often bent apart so that the earphone rests loosely against the ear. There are thus produced uncontrollable openings between the ear and the earphone which affect the frequency response in uncontrolled and unpredictable fashion.

In German Pat. Nos. 888,113 and 952,358 there are shown methods of reducing this undesirable effect on this frequency response. The basic principle of these solutions contemplates coupling the side of the diaphragm facing away from the ear to the air space surrounding the earphone and the head and then applying the earphone only loosely to the ear. In this way, some improvement is obtained in the low frequency transmission.

U.S. Pat. No. 3,157,750 discloses a similar proposal in which openings are provided to the rear of an earphone. The openings present an impedance which is more dependent on mass than friction down to the base range. An unidentified opening is provided between the earphone and the auricle of the ear.

These solutions, however, all have the disadvantage that the space defined by the earphone, the auricle and the auditory canal form a Helmholtz resonator with undefined openings formed by the application of the earphone to the ear. It has varying resonance frequencies, depending on the size of the volume and the size of the openings. The frequency response of the earphone is, therefore, once again undefined. The variations in the frequency response produced by the resonator are very disturbing. They greatly falsify the acoustic sound to be transmitted.

It is an object of the present invention to provide a dynamic acoustic transducer which has a predictable frequency response.

It is another object of the present invention to provide a dynamic acoustic transducer which may be worn comfortably against the ear.

The present invention eliminates the undesirable and unpredictable frequency response caused by the undefined application of an earphone against the ear as provided by the prior art. The application is made more specific by mechanical means while the earphone nevertheless rests only loosely against the ear. A deformation of the auricle and change in the size of the auditory canal is practically entirely avoided. The mechanical means which define the position of the earphone against the ear at the same time, in accordance with the present invention, determines the size of the coupling opening of the Helmholtz resonator and, by the acoustic impedance of the material forming the mechanical means, dampen the effect of the resonator. As a further development, the invention improves the transfer constant of the earphone.

The present invention is a dynamic acoustic transducer which is worn in the vicinity of the ear, with sound outlets on both sides of the diaphragm, one of them acting directly on the auditory canal, while the other receives the entrance to the auditory canal only via detours, and in connection with which the resonant frequency of the diaphragm lies in the lower transmission range. Mechanical means are provided which prevent a sealing off of the entrance to the auditory canal with respect to the air space surrounding the head and the acoustic transducer.

The mechanical means is made of acoustic damping material and preferably is an acoustic foam cushion. The advantages and features of the present invention will become readily apparent as the following detailed description of a preferred embodiment of the invention is read with reference to the accompanying drawing.

The sole FIGURE in the drawing shows one embodiment of an earphone constructed in accordance with the present invention. A plastic housing 10 which consists of the cylinder 11, rear cover 12 and front cover 13 is provided. The housing 10 holds within it a magnet system consisting of the core magnet 20, ferromagnetic bottom member 21, core pole shoe 22, annular pole shoe 23 and yoke member 24. A nonmagnetic insert 25 which may be made of plastic forms, in known manner, together with the inner wall of yoke member 24, channel 26 which may be, for instance, approximately round or square in cross section. The channels 26 are conducted through the ferromagnetic bottom member 21 and the rear cover 12 into the air space surrounding the earphone. They are connected at their end with the acoustic impedance members 27. The channels 26 form acoustic conduits which are terminated at their end with their characteristic impedance by the acoustic impedance members 27. Their opposite end opens in known manner in flat bottomed space 28 below airgap 29. The moving coil, not shown, of diaphragm 30 is located in the airgap. Between the diaphragm 30 and the front cover 13 there is a resonator volume 40 which, via the openings 14 in the cover 13 and spacer 50, in accordance with the present invention, leads the sound into the auditory canal 61 of the ear. The spacer 50 consists, in this example, of a very soft acoustic resistance material, for instance an acoustic foam cushion made of cellular foam plastic. The resonator volume of the Helmholtz resonator defined by the auditory canal 61, the auricle 60 and the front cover 13 is coupled in a strongly damped manner, in accordance with the concept of the invention, by the sound-permeable thin cross section of the spacer 50 to the space surrounding the earphone and the ear. In this way, the resonant frequency of the resonator is damped.

The sound coming from the rear side of the diaphragm passes through the airgap to the acoustic conduits 26 which may be, for instance, four in number. The conduits 26 are distributed substantially uniformly over a circle. They form a path for the rearward sound to the air space surrounding the earphone. The rearward sound emerging through the characteristic-impedance termination provided by impedance members 27 is damped greatly in amplitude by the great distance from impedances 27 around the housing 10 to the spacer 50. It then, again damped by the spacer 50, reaches the inlet to the auditory canal 61. In this way, as a result of the invention, the undesirable attenuation of low frequencies otherwise present in the case of transducers which are open at the rear is substantially reduced.

The acoustic conduits 26 and their characteristic impedance terminations provided by members 27 are so dimensioned that they serve as damping for the diaphragm. Extensive tests with earphones constructed in accordance with the present invention using a large number of test subjects have shown that the damping of the Helmholtz resonator and the strong damping of the rear sound of the diaphragm before its entrance into the auditory canal brought about a decisive advance in the state of the art. The previously known disturbances in resonance by Helmholtz resonators practically completely eliminated and the phones show substantially improved transmission of low frequencies as compared with the previously known prior art.

Among possible modifications of the earphone are the addition of a treble resonator between the diaphragm and the spacer means formed of acoustic damping material. The resonator could be substituted for front cover 13. Such an arrangement with a diaphragm cap would define an annular horn space between the diaphragm and the spacer means. The acoustic damping material used for resistive impedance members 27 and for forming the spacer means 50 can advantageously be made removable from the earphone. Various
types of acoustic damping material can be utilized. Ordinary plastic foam material, foam material such as disclosed in U.S. Pat. No. 3,236,328, and felt, as well as other textile materials, would be suitable. The acoustic damping impedance members 27 can, if desired, be combined into a single member held against the back of channels 26 by a portion of the housing and one or more slots provided in the housing for coupling the single member to the air.

The above described acoustic transducer is a preferred specific embodiment of the present invention, and many modifications may be made thereto without departing from the spirit and scope of the invention which is defined in the claims.

I claim:

1. A dynamic acoustic transducer, suitable for being used as an earphone, comprising
   a. a diaphragm having a resonant frequency in the lower transmission range,
   b. at least one front sound outlet on one side of said diaphragm suitable for acting directly on the entrance to the auditory canal,
   c. at least one year sound outlet on the other side of said diaphragm which provides a detour path for sound, and
   d. acoustically damping spacer means for preventing the sealing off of the entrance to the auditory canal with respect to the air space surrounding the acoustic transducer, sound reaching said auditory canal by a first path comprising said front sound outlet and acoustically damping spacer means, and by a second path comprising said rear sound outlet and said acoustically damping means.

2. A dynamic acoustic transducer according to claim 1, wherein the acoustic damping material is a foam material.

3. A dynamic acoustic transducer according to claim 2, wherein the acoustic damping material is an acoustic foam cushion.

4. A dynamic acoustic transducer according to claim 1, wherein the acoustically damping spacer means has at least one opening on its surface between the diaphragm and the entrance to the auditory canal.

5. A dynamic acoustic transducer according to claim 1, wherein at least one rear sound outlet extends from the side of the diaphragm away from the ear to the air space surrounding the acoustic transducer via acoustic conduits which are terminated with their characteristic impedance on the end discharging into the air space.

6. A dynamic acoustic transducer according to claim 5, wherein the acoustic conduits are so dimensioned that their characteristic impedance coupled to the diaphragm damps the diaphragm.

7. A dynamic acoustic transducer according to claim 1, comprising a plurality of rear sound outlets.

8. A dynamic acoustic transducer according to claim 7, wherein the plurality of rear sound outlets comprise four sound outlets.

9. A dynamic acoustic transducer according to claim 7, wherein the plurality of rear sound outlets are distributed substantially uniformly over a circle.

10. A dynamic acoustic transducer according to claim 1, wherein said acoustically damping spacer means covers the outward facing surface of a cover member.

11. A dynamic acoustic transducer according to claim 1, wherein a treble resonator is positioned between said diaphragm and said acoustically damping spacer means.

12. A dynamic acoustic transducer according to claim 1, wherein the acoustically damping spacer means is removable from the earphone.