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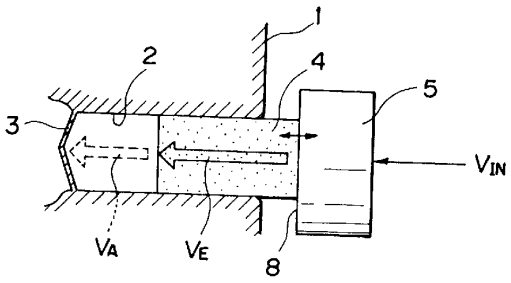
(54) **Earphone.**

(57) An earphone includes an earplug (4) of sound insulating material which is insertable in the external auditory meatus of an ear, and an elastic vibration generator (5) responsive to an electric signal supplied thereto for generating and applying an elastic wave corresponding to the supplied electric signal to an outer end (9) of the earplug (4) inserted in the external auditory meatus. The elastic vibration generator (5) may be held in or out of contact with the earplug, so that the elastic wave generated by the elastic vibration generator can be applied directly or indirectly to the earplug (4). The earphone may be combined with a helmet (46) or a headband (52). The earplug (4) is effective to prevent external noise from being transmitted to the ear drum of the ear, and also allows desired sound to be transmitted in the form of an elastic wave reliably and clearly to the ear drum.

F I G. 1



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BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to an earphone, and more particularly to an earphone suitable for use with a radio receiver in a noisy environment such as an automobile racing circuit, a construction site, or the like.

Description of the Prior Art:

In automobile racing, conversations between the drivers of racing automobiles and pit members or directors are usually transmitted and received typically through transceivers. The driver hears transmitted conversations with a small-size loudspeaker, a headset, or an earphone which is incorporated in a helmet that the driver wears to protect his head. The noise produced by a racing car while it is running has a very high level of up to 100 through 120 dB. While the helmet has a certain noise insulating capability as it covers the driver's ears, such a high racing noise level is excessive enough to make the helmet ineffective as a noise insulation. Conventional earphones are designed for use with audio systems or in low-noise environments, and cannot be used in noisy environments as the transmitted information that is reproduced by the earphones is masked by the noise.

In view of the aforesaid problems, there have been developed earphones with a noise insulating capability as disclosed in Japanese laid-open utility model publications Nos. 2-21891 and 2-75890, for example.

The earphone disclosed in Japanese laid-open utility model publication No. 2-21891 has an acoustic passage extending from an electroacoustic transducer toward an end to be inserted in an external auditory meatus of the user, the acoustic passage being in the form of an air vibratory system. Since sound produced by the electroacoustic transducer is propagated through the air in the acoustic passage by means of wave motion, external noise may leak through a vibratory plate of the electroacoustic transducer and the acoustic passage into the external auditory meatus.

Japanese laid-open utility model publication No. 2-75890 discloses a headset having a vibration damping material for insulating sound. The headset includes pads for covering the user's ears. When the pads are not properly held against the ears, external noise tends to leak through the headset into the external auditory meatus.

Inasmuch as the conventional earphone or headset is designed to propagate sound waves through air, its noise insulating capability is not sufficient in noisy environments such as automobile racing circuits, construction sites, engine compartments on ships, or the like.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an earphone which is capable of reliably insulating noise when used in noisy environments, and also of clearly transmitting desired information to the user of the earphone.

According to the present invention, there is provided an earphone including an earplug of sound insulating material which is insertable in the external auditory meatus of an ear, and an elastic vibration generator responsive to an electric signal supplied thereto for generating and applying an elastic wave corresponding to the supplied electric signal to an outer end of the earplug inserted in the external auditory meatus.

According to the present invention, there is also provided an earphone including an earplug of sound insulating material which is insertable in the external auditory meatus of an ear, and an elastic vibration generator held in contact with the earplug and responsive to an electric signal supplied thereto for generating and applying an elastic wave corresponding to the supplied electric signal directly to an outer end of the earplug inserted in the external auditory meatus.

According to the present invention, there is further provided an earphone including an earplug of sound insulating material which is insertable in the external auditory meatus of an ear, and an elastic vibration generator held out of contact with the earplug and responsive to an electric signal supplied thereto for generating and applying an elastic wave corresponding to the supplied electric signal indirectly to an outer end of the earplug inserted in the external auditory meatus.

According to the present invention, there is further provided an earphone and helmet assembly including an earplug of sound insulating material which is insertable in the external auditory meatus of an ear, an elastic vibration generator responsive to an electric signal supplied thereto for generating and applying an elastic wave corresponding to the supplied electric signal to an outer end of the earplug inserted in the external auditory meatus, and a helmet shell, the elastic vibration generator being attached to an inner surface of the helmet shell at a position corresponding to the external auditory meatus.

According to the present invention, there is further provided an earphone and headband assembly including an earplug of sound insulating material which is insertable in the external auditory meatus of an ear, an elastic vibration generator responsive to an electric signal supplied thereto for generating and applying an elastic wave corresponding to the supplied electric signal to an outer end of the earplug inserted in the external auditory meatus, and a headband, the elastic vibration generator being attached to the headband at a position corresponding to the external audi-

tory meatus.

The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which preferred embodiments of the present invention shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view, partly in cross section, showing the principles of an earphone according to the present invention;

FIG. 2 is an exploded perspective view of an earphone according to a first embodiment of the present invention;

FIG. 3 is a side elevational view showing the manner in which the user uses the earphone according to the first embodiment;

FIG. 4 is a cross-sectional view of a dynamic exciter;

FIG. 5 is a cross-sectional view of a magnetic exciter;

FIG. 6 is a view showing the manner in which the user uses an earphone according to a second embodiment of the present invention;

FIG. 7 is an exploded side elevational view, partly in cross section, of an earphone according to a third embodiment of the present invention;

FIG. 8 is an exploded side elevational view of an earphone according to a fourth embodiment of the present invention;

FIG. 9 is a side elevational view, partly in cross section, showing the manner in which the user uses an earphone according to a fifth embodiment of the present invention;

FIG. 10 is a side elevational view, partly in cross section, showing the manner in which the user uses an earphone according to a sixth embodiment of the present invention;

FIG. 11 is a side elevational view showing the manner in which the user uses an earphone according to a seventh embodiment of the present invention;

FIG. 12 is a side elevational view of an earphone according to an eighth embodiment of the present invention;

FIG. 13 is a side elevational view of an earphone according to a ninth embodiment of the present invention;

FIG. 14 is a side elevational view, partly in cross section, showing the manner in which the user uses the earphone according to the ninth embodiment of the present invention;

FIG. 15 is a side elevational view of an earplug according to a first modification;

FIG. 16 is a side elevational view, partly in cross section, of an earplug according to a second modification;

FIG. 17 is a side elevational view of an earplug according to a third modification;

FIG. 18A is a side elevational view, partly in cross section, of an earplug according to a fourth modification;

FIG. 18B is a cross-sectional view taken along line A - A of FIG. 18A;

FIG. 19 is a view showing an acoustic transmission spectrum of an earplug made of a single material;

FIG. 20 is a view showing an acoustic transmission spectrum of an earplug made of complex materials;

FIG. 21A is a side elevational view, partly in cross section, of an earplug according to a fifth modification;

FIG. 21B is a cross-sectional view taken along line B - B of FIG. 21A;

FIG. 22A is a side elevational view, partly in cross section, of an earplug according to a sixth modification;

FIG. 22B is a cross-sectional view taken along line C - C of FIG. 22 A;

FIG. 23A is a side elevational view, partly in cross section, of an earplug according to a seventh modification;

FIG. 23B is a cross-sectional view taken along line D - D of FIG. 23A;

FIG. 24A is a side elevational view, partly in cross section, of an earplug according to a eighth modification;

FIG. 24B is a cross-sectional view taken along line E - E of FIG. 24A;

FIG. 25A is a side elevational view, partly in cross section, of an earplug according to a ninth modification;

FIG. 25B is a cross-sectional view taken along line F - F of FIG. 25A;

FIG. 26 is a side elevational view, partly in cross section, of an earplug according to a tenth modification;

FIG. 27 is an exploded perspective view of an earphone according to a tenth embodiment of the present invention;

FIG. 28 is a side elevational view, partly in cross section, showing the principles of another earphone according to the present invention;

FIG. 29 is an exploded side elevational view of an earphone according to an eleventh embodiment of the present invention;

FIG. 30 is a cross-sectional view of an exciter in the earphone according to the eleventh embodiment;

FIG. 31 is a fragmentary cross-sectional view of an earphone according to a twelfth embodiment of the present invention, as it is used by the user;

FIG. 32 is a fragmentary cross-sectional view of

an earphone according to a thirteenth embodiment of the present invention, as it is used by the user;

FIG. 33 is a side elevational view of an earplug for an earphone according to a fourteenth embodiment of the present invention; and

FIG. 34 is a fragmentary cross-sectional view of an earphone according to the fourteenth embodiment, as it is used by the user.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Like or corresponding parts are denoted by like or corresponding reference characters throughout views.

FIG. 1 illustrates the principles of an earphone according to the present invention.

As shown in FIG. 1, an earphone according to the present invention has an earplug 4 insertable into the external auditory meatus 2 of an ear 1, the earplug 4 being made of a sound insulating material, and an elastic vibration generator 5 responsive to an electric signal V_{IN} applied thereto for generating and transmitting an elastic wave V_E directly to an outer end of the earplug 4 remote from the inner end thereof to be inserted in the external auditory meatus 2. The elastic vibration generator 5 is held in contact with the outer end of the earplug 4 for transmitting the elastic wave V_E directly to the earplug 4.

Since the earplug 4 is made of a sound insulating material and inserted in the external auditory meatus 2 of the ear 1, external noise is prevented from entering the external auditory meatus 2 through the earplug 4. The earplug 4 inserted in the external auditory meatus 2 also serves as a medium for propagating sound, i.e., the elastic wave V_E produced by the elastic vibration generator 5. Therefore, sound, typically voice, from the elastic vibration generator 5 can reliably and clearly be transmitted through the earplug 4 to an ear drum 3. The earplug 4, which serves as an elastic wave propagation medium, is effective to block external noise, and also to propagate the elastic wave V_E efficiently.

The elastic wave V_E generated by the elastic vibration generator 5 can be transmitted highly efficiently to the earplug 4 because the elastic vibration generator 5 is held in contact with the earplug 4 for direct transmission of the elastic wave V_E to the earplug 4.

1ST EMBODIMENT:

FIGS. 2 through 5 show an earphone according to a first embodiment of the present invention. As shown in FIGS. 2 and 3, the earphone according to the first embodiment comprises a cylindrical or rod-shaped earplug 4 that can be inserted into the external auditory meatus 2 of an ear 1, and a cylindrical exciter 5 (elastic vibration generator) coupled to an outer end of the earplug 4 for generating and applying an elastic wave V_E directly to the earplug 4.

The earplug 4 has an outside diameter slightly larger than the inside diameter of the external auditory meatus 2, and is made of a sound insulating material such as an elastic foamed polymer, e.g., urethane foam, which should preferably have a very high internal loss. When compressed, the earplug 4 is elastically restorable to its original shape. The earplug 4 is as hard as an ear lobe, and has such a degree of elasticity that when in use, it can be compressed by fingers, and after being inserted in the external auditory meatus 2, it will elastically be restored to its original cylindrical shape within an appropriate period of time. When the earplug 4 is restored to its original cylindrical shape after being inserted in the external auditory meatus 2, the earplug 4 has its outer circumferential surface held in intimate contact with the inner wall surface of the external auditory meatus 2 under pressure. Therefore, the earplug 4 is placed in the external auditory meatus 2 tightly enough to acoustically isolate the external auditory meatus 2 from outside of the ear 1 for the prevention of entry of external noise into the external auditory meatus 2. The earplug 4 may also be made of silicone resin, clay, or the like.

The exciter 5 is in the form of a vibrator for generating elastic vibration on a vibratory surface 8. The exciter 5 may comprise a dynamic exciter 5 as shown in FIG. 4 or a magnetic exciter 5 as shown in FIG. 5.

The dynamic exciter 5 shown in FIG. 4 has a bottomed cylindrical casing 10 of synthetic resin with one axial end open, and a circular vibratory plate 8 of metal or magnetic material such as iron mounted on the open axial end, closing the casing 10. The casing 10 houses a bottomed cylindrical yoke 11 suspended therein with a suitable degree of stiffness by dampers 12. The yoke 11 has an open axial end direction in the same direction as the open axial end of the casing 10. An axially extending cylindrical magnet 14 is disposed centrally in the yoke 11, with a circular center pole 13 mounted on the tip of the magnet 14. The inner circumferential surface of the yoke 11 and the outer circumferential surfaces of the magnet 14 and the center pole 13 define a ring-shaped gap therebetween. In the gap there is disposed a ring-shaped voice coil 15 out of contact with the yoke 11, the magnet 14, and the center pole 13, the ring-shaped voice coil 15 having an axial end fixed to the vibratory plate 8. The voice coil 15 is electrically connected to leads 7 (see FIGS. 2 and 3) that extend from a transceiver (not shown). When an electric signal V_{IN} is applied over the leads 7 to the voice coil 15, the yoke 11 vibrates at a frequency corresponding to the frequency of the applied electric signal V_{IN} through the interaction between a magnetic field produced in the gap by a magnetic circuit composed of the yoke 11, the magnet 14, and the center pole 13 and an alternating magnetic field in-

duced by the voice coil 15. The vibration of the yoke 11 appears as elastic vibration on the vibratory plate 8. The outer end of the earplug 4, which is remote from the inner end thereof inserted in the external auditory meatus 2, is held in mechanical contact with the vibratory plate 8, so that an elastic wave V_E is propagated from the vibratory plate 8 through the earplug 4, thereby vibrating the inner end thereof inserted in the external auditory meatus 2.

The dynamic exciter 5 shown in FIG. 5 has a bottomed cylindrical casing 16 of synthetic resin with one axial end open, and a circular vibratory plate 21 having an outer circumferential edge fitted in a ring groove 23 defined in the open axial end, closing the casing 16. The casing 16 houses a bottomed cylindrical yoke 17 fixedly mounted on the bottom thereof and has an open axial end directed in the same direction as the open axial end of the casing 16. A cylindrical magnet 18 and a cylindrical center pole 19 which extend axially are disposed centrally on the bottom of the yoke 17. A ring-shaped voice coil 20 is disposed coaxially with and around the center pole 19 out of contact therewith, the ring-shaped voice coil 20 having an axial end fixed to the vibratory plate 21. The voice coil 20 is electrically connected to leads 7 (see FIGS. 2 and 3). When an electric signal V_{IN} is applied over the leads 7 to the voice coil 20, the vibratory plate 21 vibrates at a frequency corresponding to the frequency of the applied electric signal V_{IN} through the interaction between a magnetic field produced in a gap defined by a magnetic circuit composed of the yoke 17, the magnet 18, and the center pole 19 and an alternating magnetic field induced by the voice coil 20. The vibration of the vibratory plate 21 is elastic vibration. The outer end of the earplug 4, which is remote from the inner end thereof inserted in the external auditory meatus 2, is held in mechanical contact with the vibratory plate 21, so that an elastic wave V_E is propagated from the vibratory plate 8 through the earplug 4, thereby vibrating the inner end thereof inserted in the external auditory meatus 2.

The exciter 5 is not limited to the structures shown in FIGS. 4 and 5, but may be of any structures insofar as they can produce elastic vibration.

As shown in FIGS. 2 and 3, the earplug 4 and the exciter 5 are joined to each other through the outer end of the earplug 4, which serves as a vibration receiving surface 9, and the vibratory surface or plate 8 of the exciter 5. The earplug 4 and the exciter 5 may be integrally fixed to each other in advance, but should preferably be separate from each other so that they can easily be joined to each other when in use.

As shown in FIG. 1, the electric signal V_{IN} applied to the exciter 5 is converted into mechanical vibration by the exciter 5. The mechanical vibration produced by the vibratory plate 8 is transmitted as an elastic wave V_E from the vibratory plate 8 through the vibration receiving surface 9 into the earplug 4. The elastic wave V_E is then propagated through the earplug 4 toward the inner end thereof. When the elastic wave V_E reaches the inner end of the earplug 4, the inner end vibrates at the same frequency as the frequency of the applied electric signal V_{IN}, radiating a sound wave V_A into the external auditory meatus 2. Since the external auditory meatus 2 is acoustically isolated from the space outside of the ear 1, at this time, the intensity of external noise which may enter the external auditory meatus 2 is very low. Almost all acoustic energy that reaches the ear drum 3 at this time is the sound wave V_A radiated from the inner end of the earplug 4. Consequently, the user of the earphone can clearly hear or perceive the sound reproduced from the sound wave V_A with a low noise background.

2ND EMBODIMENT:

FIG. 6 shows an earphone according to a second embodiment of the present invention. The earphone according to the second embodiment includes an exciter 5 having such an outer size or profile that it is snugly fitted in the concha 26 of an ear of the user and retained in place against removal by the tragus 25 of the ear.

The outer surface of the exciter 5 is covered with a material having a certain degree of resiliency and a coefficient of friction. Therefore, once placed in the ear of the user, the exciter 5 is securely held in the ear against dislodgement. The material, structure, and shape of the earplug and the internal structure of the exciter 5 are identical to those of the earphone according to the first embodiment.

3RD EMBODIMENT:

FIG. 7 shows an earphone according to a third embodiment of the present invention. The earphone according to the third embodiment has an earplug 4A and an exciter 5A that are detachably coupled to each other.

The exciter 5A has an outwardly extending protrusion 27 on the center of the vibratory plate 8, and the earplug 4A has a recess 28 defined in the center of the outer end or the vibration receiving surface 9 thereof, for receiving the protrusion 27 therein. The inside diameter of the recess 28 may be slightly smaller than the outside diameter of the protrusion 27, or the protrusion 27 may be progressively larger in diameter toward its tip end and the recess 28 may be progressively smaller in diameter toward its open end, so that the protrusion 27 that is received in the recess 28 is securely retained therein against forces tending to separate the earplug 4A and the exciter 5A.

The earplug 4A and the exciter 5A that are detachably coupled to each other make the earphone usable conveniently. More specifically, when the earphone is to be used, the earplug 4A is first inserted

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