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FORM 1

SPRUSON & FERGUSON

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

APPLICATION FOR A STANDARD PATENT

Sony Corporation, of 7-35 Kitashinagawa 6-chome, Shinagawa-ku, Tokyo, JAPAN, hereby apply for the grant of a standard patent for an invention entitled:

Electro-Acoustic Transducer and Sound Reproducing System

which is described in the accompanying complete specification.

Details of basic application(s):-

Basic Applic. No:	Country:	Application Date:
1-255797/89	JP	30 September 1989

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DATED this TWENTY EIGHTH day of SEPTEMBER 1990

Sony Corporation

By:

Registered Patent Attorney

TO: THE COMMISSIONER OF PATENTS
OUR REF: 143148
S&F CODE: 56837

5845/2

COMMONWEALTH OF AUSTRALIA
PATENTS ACT 1952
DECLARATION IN SUPPORT OF A
CONVENTION APPLICATION FOR A PATENT

In support of the Convention Application made for a patent for an invention entitled:
Electro-Acoustic Transducer and Sound Reproducing System

I/~~We~~ SHOJI WAKAYAMA
of c/o Sony Corporation, 7-35, Kitashinagawa 6-chome, Shinagawa-ku, Tokyo, Japan

do solemnly and sincerely declare as follows:

1. I am/~~We are~~ authorised by SONY CORPORATION, the applicant for the patent to make this declaration on its behalf.

2. The basic application(~~s~~) as defined by Section 141 of the Act was/~~were~~ made in Japan on September 30, 1989

(,respectively), by SONY CORPORATION.

3. Makoto Yamagishi
c/o Sony Corporation, 7-35, Kitashinagawa 6-chome, Shinagawa-ku, Tokyo, (respectively) is/~~are~~ the actual inventor(~~s~~) of the invention and the facts upon which the applicant is/~~are~~ entitled to make the application are as follows:

The said applicant is the assignee of the actual inventors~~.~~

4. The basic application refered to in paragraph 2 of this Declaration was the first application made in a Convention country in respect of the invention(~~s~~) the subject of the application.

DECLARED at TOKYO JAPAN this 13 day of Sept. 1990

Signature of Declarant

TO: THE COMMISSIONER OF PATENTS
AUSTRALIA

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ELECTRO-ACOUSTIC TRANSDUCER AND SOUND REPRODUCING SYSTEM

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(56) Prior Art Documents
US 4381830
US 4467145
US 3667569

(57) Claim

1. An electro-acoustic transducer comprising

an electro-acoustic transducer unit having a sound radiating side and a rear side accommodated in a housing, and

a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said housing and into an external auditory meatus of a wearer of said transducer,

said sound guide tube being of a lesser diameter than said external auditory meatus to allow at least the sound radiating end of the sound guide tube to be introduced into said external auditory meatus leaving a space between said sound radiating end and an inner wall of said external auditory meatus so as not to completely close said external auditory meatus.

12. A sound reproducing system comprising

a sound reproducing apparatus supplied with electrical signals, and

an electro-acoustic transducer including an electro-acoustic transducer unit accommodated in a housing, and a sound guide tube for conducting sound from the electro-acoustic transducer unit out of said housing,

.../2

said sound guide tube having at least a sound radiating end of a lesser diameter than the external auditory meatus to permit said sound radiating end to be introduced into the external auditory meatus without completely closing the external auditory meatus,

said electro-acoustic transducer unit being adapted for reproducing at lest a low-frequency component of the frequency range of the electrical signal of the sound reproduced by said sound reproducing apparatus.

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FORM 10

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COMPLETE SPECIFICATION

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Related Art:

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Complete Specification for the invention entitled:

Electro-Acoustic Transducer and Sound Reproducing System

The following statement is a full description of this invention, including the best method of performing it known to me/us

SPECIFICATION

TITLE OF THE INVENTION

Electro-Acoustic Transducer and Sound Reproducing System

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an electro-acoustic transducer for sound reproduction and a sound reproducing system constructed with the use of the electro-acoustic transformer.

Description of the Related Art

Up to now, there is proposed an electro-acoustic transducer or a sound reproducing system supplied with acoustic signals in the form of electrical signals and adapted for converting the acoustic signals into sound to realize sound reproduction, such as a headphone device or an earphone device.

The aforementioned electro-acoustic transducer comprises an electro-acoustic transducer unit for converting the acoustic signals into sound. The electro-acoustic transducer constructed as the headphone device is adapted for supporting a pair of electro-acoustic transducer units in opposition to both auricles of the user.

The sound reproducing system also includes a pair of speaker units as the sound reproducing device arranged for converting the sound signals into sound. The speaker unit includes a speaker unit having a diaphragm and functioning as the sound reproducing unit and a speaker cabinet accommodating the speaker unit with

the sound radiating side facing to outside. With the present sound reproducing system, the speaker device is arranged in front of and for facing to the listener to effect sound reproduction by the speaker device.

Meanwhile, with the above described electro-acoustic transducer, constructed as the headphone device, the electro-acoustic transducer unit constituting the transducer faces to the listener's tympanic membrane, so that standing waves are produced between the transducer unit and the tympanic membrane. The listener using such electro-acoustic transducer feels oppressed due to the standing waves or feels as if the sound source were within his head.

With the above described electro-acoustic transducer, the electro-acoustic transducer unit is supported for substantially closing the listener's external auditory miatus so that the listener using the electro-acoustic transducer feel unable to hear the external sound. Thus the use of the electro-acoustic transducer during walking on the road or driving a vehicle or car endangers safe walking or driving since the user can hardly recognize the outside situation.

With the above sound reproducing system, for optimum sound reproduction over a wide frequency range including the lower frequency range, it becomes necessary to increase the volume of the speaker cabinet constituting the speaker device or to increase the area of the diaphragm of the speaker unit. If the

cabinet volume or diaphragm area are increased, the size of the apparatus in increased.

On the other hand, with a sound reproducing system in which the size of the apparatus is increased to enable sound reproduction over a wide frequency range, it may be occasionally impossible to effect sound reproduction at a sufficient sound pressure in view of the inconveniences to the neighbors under the straitened or congested housing circumstances.

Object and Summary of the Invention

In view of the foregoing, it is a principal object of the present invention to provide an electro-acoustic transducer which, when arranged as a headphone device or an earphone device, does not give rise to oppressed feeling or a feeling as if the sound source were within the user's head.

It is another object of the present invention to provide a sound reproducing system which is capable of satisfactorily reproducing the sound over a wide frequency range including the low frequency range without unnecessary increasing the size of the system or inconveniencing neighbors.

In accordance with one aspect of the present invention, there is provided an electro-acoustic transducer comprising

an electro-acoustic transducer unit accommodated in a housing, and

a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said housing,

said sound guide tube being of a lesser diameter than the external acoustic meatus to allow at least the sound radiating end of the sound guide tube to be introduced into the external auditory meatus leaving a space between said sound radiating end and an inner wall of said external auditory meatus so as not to completely close said external auditory meatus.

In accordance with a second aspect of the present invention, there is provided a sound reproducing system comprising

a sound reproducing apparatus supplied with electrical signals, and

an electro-acoustic transducer including an electro-acoustic transducer unit accommodated in a housing, and a sound guide tube for conducting sound from the electro-acoustic transducer unit out of said housing,

said sound guide tube having at least a sound radiating end of a lesser diameter than the external auditory meatus to permit said sound radiating end to be introduced into the external auditory meatus without completely closing the external auditory meatus,

said electro-acoustic transducer unit being adapted for reproducing at lest a low-frequency component of the frequency range of the electrical signal of the sound reproduced by said sound reproducing apparatus.

With the electro-acoustic transducer of the present invention, the sound guide tube adapted for conducting the sound radiated from the electro-acoustic transducer unit accommodated in the housing towards the outside of the housing has at least its sound radiating end of a lesser diameter than the external auditory meatus so that the sound radiating end may be inserted into the external auditory meatus. Thus the sound may be conducted into the inside of the external auditory meatus without stopping the external auditory meatus.

The sound reproducing system according to the present invention is so arranged and conducted that the sound may be reproduced by the sound reproducing apparatus adapted for being supplied with electrical signals and for converting the electrical signals into sound for reproduction thereof, and that the electro-acoustic transducer adapted for converting at least the low-frequency component of the electrical signals supplied to said sound reproducing apparatus conducts the sound radiated from the electro-acoustic transducer unit accommodated in the housing towards the outside of the unit, while radiating the sound into the external acoustic meatus by way of a sound guide tube having at least its sound radiating end of a lesser diameter than the external auditory meatus to permit the sound radiating end to be inserted into the external auditory meatus without stopping the external auditory meatus. In this manner, both the sound reproduced by the sound reproducing apparatus and the sound reproduced by the electro-acoustic transducer unit of the electro-acoustic transfer may be heard simultaneously.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagrammatic cross-sectional view showing the construction of the electro-acoustic transducer of the present invention.

Fig. 2 is an equivalent acoustic circuit diagram showing acoustic characteristics of the electro-acoustic transducer.

Fig. 3 is a chart showing frequency characteristics of the reproduced sound of the electro-acoustic transducer.

Fig. 4 is a circuit diagram showing the construction of a correction circuit for correcting the frequency characteristics of the electro-acoustic transducer.

Fig. 5A is a side view showing the state in which the electro-acoustic transducer arranged as an earphone device is attached to user's auricles.

Fig. 5B is a cross-sectional view showing the state in which the electro-acoustic transducer arranged as the earphone device is attached to user's auricles.

Fig. 6A is a side view showing another example of the state in which the electro-acoustic transducer arranged as the earphone device is attached to user's auricles.

Fig. 6B is a cross-sectional view showing another example of the state in which the electro-acoustic transducer arranged as the earphone device is attached to user's auricles.

Fig. 7 is a perspective view showing still another example of the state in which the electro acoustic transducer arranged as an earphone device is attached to user's auricles.

Fig. 8 is a perspective view showing the electro-acoustic transducer arranged as the headphone device.

Fig. 9 is a perspective view showing still another example of construction of the electro-acoustic transducer.

Fig. 10 is a diagrammatic perspective view showing the construction of the sound reproducing system of the present invention.

Fig. 11 is a circuit diagram showing the construction in the above sound reproducing system whereby the low frequency component of the acoustic signals may be supplied to the electro-acoustic transducer.

Fig. 12 is a chart showing frequency characteristics of the amplifier supplying the low frequency component of the acoustic signals to the electro-acoustic transducer shown in Fig. 11 and frequency characteristics of the reproduced sound of the transducer.

Fig. 13 is a circuit diagram showing another example of construction of supplying the low frequency component of the acoustic signals to the electro-acoustic transducer.

Fig. 14 is a perspective view showing the construction of supporting the sound reproducing apparatus of the sound reproducing system by the listener's head.

Fig. 15 is a side view showing the construction in which a sound guide tube is provided in the sound reproducing apparatus supported by the listener's head in the sound reproducing system.

Fig. 16 is a cross-sectional view showing another example of construction of the electro-acoustic transducer in the sound reproducing system.

Fig. 17 is an equivalent acoustic circuit diagram showing acoustic characteristics of the electro-acoustic transducer shown in Fig. 16.

Fig. 18 is a cross-sectional view showing still another

example of construction of the electro-acoustic transducer in the sound reproducing system.

Fig. 19 is a side view showing another example of construction of sound guide tube of the electro-acoustic transducers of various types.

Fig. 20 is a cross-sectional view showing the construction using the headphone device attached to the user's auricle as the sound reproducing device in the above sound reproducing system.

Fig. 21 is a cross-sectional view showing the construction of the hermetically sealed headphone device used as the sound reproducing apparatus of the sound reproducing system.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

By referring to the drawings, certain preferred embodiments of the present invention will be explained in detail.

Figs. 1 to 4 illustrate an embodiment of an electro-acoustic transducer which is constructed as an earphone device attached to auricles.

The earphone device shown in Fig. 1 includes a cabinet 1 and a sound reproducing unit 2 which is an electro-acoustic transducer unit housed within the cabinet 1.

The sound reproducing unit 2 includes a diaphragm and a magnetic circuit. A voice coil is mounted on the diaphragm so as to lie in the magnetic path of the magnetic circuit. That is, with the present sound reproducing unit 2, when the sound signal which is the driving signal is supplied to the voice coil via

feeder 2a, the voice coil is driven and offset in the magnetic path of the magnetic circuit. The offsetting of the voice coil is transmitted to the diaphragm which then radiates the reproduced sound towards the front and rear sides.

The cabinet 1 is formed of synthetic resin, for example, and is formed for accommodating and supporting the sound reproducing unit 2. The cabinet 1 has an opening 1a whereby the front side functions as the sound radiating side of the sound reproducing unit 2 is caused to face to outside. The cabinet 1 accommodates and supports the sound reproducing unit 2 with the front side of the sound reproducing unit 2 facing outwards via opening 1a.

The feeder 2a is led out of the cabinet 1 by means of a feeder outlet 1c provided in the cabinet 1.

The cabinet 1 is provides with a sound guide tube 3 establishing communication between the inside and the cutside of the cabinet 1. Thus the cabinet 1 is provided with a sound conducting opening 1b situated at the lateral side of the sound reproducing unit 2, the sound guide tube 3 in the form of a hollow cylinder is provided in alignment with the opening 1b. This sound guide tube 3 is formed integrally with the cabinet 1 with a predetermined length so as to be projected out of the cabinet 1. The terminal end 3a, functioning as the sound radiating end, is opened as the sound radiating opening 3b.

Thus the sound radiated from the rear side of the sound reproducing unit 2 into the inside of the cabinet 1 is propagated

from the inside of the cabinet by way of the sound conducting opening 1b into the inside of the sound guide tube 3 so as to be radiated outwards via sound radiating opening 3b of the sound guide tube 3.

The distal end 3a of the sound guide tube 3 has an outside diameter, as shown by arrow d in Fig. 1, which is lesser than the inside diameter of the external auditory miatus E shown by arrow e in Fig. 1, so that the distal end 3a may be inserted into the external auditory ~~miatus~~ meatus E without stopping the external auditory ~~miatus~~ meatus E to provide an interstice large enough to permit sound propagation between it and the inner wall of the external auditory ~~miatus~~ meatus E. Meanwhile, the inside diameter of the external auditory ~~miatus~~ meatus E of a human is usually 7 to 9 mm. The sound guide tube 3 has its distal portion 3c bent arcuately in about 90° direction, so that. device, to user's auricles, the sound radiating opening 3b is directed to the inside of the external auditory ~~miatus~~ meatus E.

When the above described earphone device is in use, the distal end 3a of the sound guide tube 3 is inserted into the external auditory ~~miatus~~ E, as shown in Fig. 1. That is, this earphone device is supported by a supporting member, as later described, so that the sound radiated from the sound radiating opening 3b at the distal end 3a of the sound guide tube inserted into the external auditory ~~miatus~~ E will reach the tympanic membrane, not shown, after propagation through the inside of the

external auditory meatus ~~miatus~~ E.

This earphone device allows the sound from the sound reproducing unit 2 to reach the tympanic membrane via the external auditory meatus ~~miatus~~ E without stopping the external auditory meatus ~~miatus~~ E. Hence, with the present earphone device, the sound may be reproduced without impeding the hearing of the external sounds.

Fig. 2 shows an equivalent acoustic circuit showing acoustic characteristics of the earphone device. An equivalent mass Md for the sound reproducing unit 2, a compliance Cd and an acoustic resistance Rd are connected in series and a compliance Cb within the cabinet 1 is connected to the series of the equivalent means Md, compliance Cd and the acoustic resistance Rd to form a closed loop. One of the junctions between the compliance Cb on one hand and the equivalent mass Md, compliance Cd and the acoustic resistance Rd, on the other, is connected to an acoustic circuit ϵ within the external acoustic meatus ~~miatus~~ E via an equivalent mass Mb of the air in the sound guide tube 3. The other of the junctions between the compliance Cb on one hand and the equivalent mass Md, acoustic resistance Rd and compliance Cd on the other is connected directly to the acoustic circuit ϵ of the external acoustic meatus ~~miatus~~ E. The acoustic circuit ϵ in the external acoustic meatus ~~miatus~~ E forms a closed loop consisting of the equivalent mass Me within the external auditory meatus ~~miatus~~ E, compliance Ce and acoustic resistance Re. The junction between

the compliance Ce and the acoustic resistance Re is connected to an equivalent mass Mb of the air in the sound guide tube 3. The junction between the compliance Ce and the equivalent mass Me is connected to the other B of the junctions betwee equivalent mass Md, compliance Cd and acoustic resistance Rd on one hand and compliance Cb on the other.

With the above acoustic circuit, the resonant frequency f_0 of the earphone device f_0 is given by

$$f_0 = 1/(2\pi\sqrt{<Md+Mb})Cd \quad \ldots\ldots (1)$$

which is lower than the resonance frequency of the sound reproducing unit 2 alone. Hence, with the above earphone device, optimum sound reproduction may be achieved over a wide frequency range including the low frequency range.

Meanwhile, the frequency response of the reproduced sound by the sound reproducing unit 2 alone exhibits a resonance peak at about 2 kHz, as shown in Fig. 3. For reducing the effects of the resonance peak, the above sound signals are supplied via a correction circuit 5 to the sound reproducing unit 2. As shown in Fig. 4, this correction circuit 5 has a series circuit of first and second capacitors 6 and 7 between one of the output ends 5b of the signal source 5a and the one input end of the sound reproducing unit 2, and first and second resistances 8 and 9 are connected in series so as to be in parallel with the capacitors 6 and 7. A point between the capacitors 6 and 7 is connected via third resistor 10 to the other output end 5c of the

signal source 5a connected to the other input end of the sound reproducing unit 2. A point between the first resistor 8 and the second resistor 9 is connected via third capacitor 11 to the other output end 5c of the signal source 5a.

By supplying the above acoustic signals by way of the above described correction circuit 5 to the sound reproducing unit 2, the sound may be reproduced with the frequency characteristics affected to a lesser extent by the resonance peaks.

The electro-acoustic transducer of the present invention may be constructed so that a pair of the above described earphone devices are adapted to be attached to the user's auricles and are used for left and right ears to perform stereophonic sound reproduction.

On the other hand, the sound reproducing unit of the electro-acoustic transducer of the present invention may be accommodated in and supported by the cabinet 1 with the rear side facing outwards by way of the opening 1a and the front side facing the inner side of the cabinet 1. In this case, the sound radiated from the front side of the sound reproducing unit 2 may be guided by the sound guide tube 3 to reach the external auditory meatus E.

Construction of Supporting Member Supporting Electro-Acoustic Transducer

The electro-acoustic transducer of the present invention, formed as an earphone device attached to user's auricles when in

use, may also be so arranged and constructed that, as shown in Figs. 5A and 5B, a protuberance 4a is provided as the supporting member at the foremost part 3c of the sound guide tube 3 and the forward side 3c of the sound guide tube 3 is supported in a cavity of the D which is a recessed part of the auricle C. That is, with the present earphone device, when the distal side 3c of the sound guide tube 3 is inserted into the cavity of the concha D, with the proximal side of the ear guide tube 3 directing downwards, the projection 4a is supported in abutment with the tragus F and the antitragus J in the lower region of the auricular recess D. The sound guide tube 3 depends from an intertragic notch K between the tragus F and the antitragus J, and is supported in abutment with the outer surface of the otorrhea, a portion of the auricle C, at a position below the intertragic notch K.

With the projection 4a supported in abutment with the tragus F and the antitragus J, and with the sound guide tube 3 supported in abutment with the otorrhea L, the distal side 3c of the sound guide tube 3 is held within the cavity of the concha D, and the distal end 3a of the sound guide tube 3 is introduced into the external auditory ~~miatus~~ meatus E, as shown in Fig. 5B. With the earphone device, since the point of abutment of the sound guide tube 3 by the otorrhea L is below the support point supporting the projection 4a, rotation in the direction shown by arrow X in Fig. 5B, with the abutting support point between the tragus F and

J the antitragus as the center of rotation, which is the direction of falling of the projection 4a from the cavity of the concha D, is inhibited, to guarantee safe and positive support of the earphone device by the auricle C.

With the earphone device, a toroidal member 4b may also be provided as the supporting member at the distal side 3c of the sound guide tube 3, as shown in Figs. 6A and 6B, so that the distal side 3c of the sound guide tube 3 may be maintained in the cavity of the concha D by the toroidal supporting member 4b. That is, with the present earphone device, when the distal side 3c of the sound guide tube 3 is inserted into the cavity of the concha D, with the proximal side of the round guide tube 3 directing downwards the toroidal member 4b is supported in abutment with the tragus and the antitragus J in the cavity of the concha D. The rear peripheral surface of the toroidal member 4b, facing to the outside of the auricle C on introducing the toroidal member 4b into the cavity of the concha D, is formed as a tapered inclined portion 4d to assure optimum abutment by the tragus F and the antitragus J. The sound guide tube 3 is adapted to depend downwards via the intertragic notch K between the tragus F and the antitragus J and is supported in abutment with the outer lateral surface of the otorrhea L.

When the toroidal member 4b is thus supported in abutment with the tragus F and the antitragus, J and the sound guide tube 3 is supported in abutment with the otorrhea L, the distal side

3c of the sound guide tube 3 is held within the cavity of the concha D, as shown in Fig. 6B, and the distal end 3a of the sound guide tube 3 is inserted into the external auditory meatus ~~miatus~~ E, which simultaneously faces outwards by way of a central through-hole 4c in the toroidal member 4b. With the present earphone device, similarly to the earphone device shown in Fig. 5B, the abutting point of the sound guide tube 3 on the otorrhea L and that of the toroidal member 4b on the tragus F and the antitragus J acts to inhibit rotation of the toroidal member 4b in the direction of falling of the toroidal member from the cavity of the concha D as shown by an arrow x in Fig. 6B to guarantee safe and positive holding of the earphone device by the auricle C.

Meanwhile, with the earphone device shown in Figs. 5A, 5B, 6A and 6B, the sound tube 3 is adapted to communicate with the cabinet 1 at the lateral surface on the proximal side, and the feeder outlet 1c is provided on the proximal side.

The earphone device may also be so constructed that, as shown in Fig. 7, an arm-shaped ear hanger 13, bent as a supporting member, is provided at the outward side of the cabinet 1, and the ear hanger 13 is engaged and supported on the upper side of the outer lateral side of the auricle C. With this earphone device, when the ear hanger 13 is engaged with and supported by the auricle C, the distal side 3a of the sound guide tube 3 is inserted into the external auditory meatus ~~miatus~~ E.

The electro-acoustic transducer of the present invention may

also be arranged as to be attached to the user's head. Thus, as shown in Fig. 8, a pair of the above described earphone devices are attached to both sides of a hair band 12 adapted to conform substantially to the user's head. Such headphone device is used with the hairband 12 supported by the user's head and the distal sides of the sound guide tubes 3 of the earphone devices inserted into external auditory ~~miatuses~~ meatuses of the user's left and right ears. The headphone device shown in Fig. 8 has a pair of the sound reproducing units 2 to perform stereophonic reproduction.

The electro-acoustic transducer of the present invention may also be constructed as shown in Fig. 9 wherein the cabinet 1 is provided on the hairband 12 and two sound guide tubes 31, 3r for left and right ears are provided on the cabinet 1. The sound guide tubes 31, 3r are adapted to project on both sides of the hairband 12. This electro-acoustic transducer is used with the hairband 12 being supported on the user's head and the distal sides 3a of the sound guide tubes 31, 3r being inserted into the external auditory ~~miatuses~~ meatuses of the user's left and right ears. With the electro-acoustic transducer, the sound reproduced by the sound reproducing unit accommodated in and supported by the cabinet 1 is propagated through the sound guide tubes 31, 3r to reach the external auditory ~~miatuses~~ meatuses of the left and right ears.

Construction of Sound Reproducing System

The sound reproducing system according to the present

invention shown in Fig. 10 is comprised of a headphone device 14 of the type attached to the user's auricles, which is provided with a pair of the earphone devices shown in Fig. 1 to constitute an electro-acoustic transducer, and left and right speaker devices 151, 15r functioning as sound reproducing devices.

Each of the speaker devices 151, 15r is provided with a speaker unit 15a having a magnetic circuit and a diaphragm and a speaker cabinet 15b accommodating and supporting the speaker unit 15a with the sound radiating side facing outwards. When the sound signals are supplied to the speaker devices 151, 15r, these devices 151, 15r convert the sound signals into vibrations of the diaphragm of the speaker unit 15a to reproduce the sound. The speaker units 151, 15r are positioned on the left and right forward sides of the listener 17 with the sound radiating side facing the listener 17.

In order that only the low frequency component of the acoustic signals supplied to the speaker devices 151, 15r will be supplied to the headphone device 14, the above mentioned acoustic signals are supplied to the headphone device 14 via amplifier 16, as shown in Fig. 11. The amplification factor-frequency characteristics of the amplifier 16 are approximately zero at an area higher than about 1 kHz, as shown at G in Fig. 12 and, in the area lower than about 1 kHz, the amplification factor becomes the higher for the lower frequency range.

The headphone device 14, supplied with the acoustic signals

by way of the amplifier 16 having such amplification factor-frequency characteristics, performs sound reproduction with the frequency characteristics in which the sound pressure is raised in the frequency range of 20 to 100 Hz.

With the above described sound reproducing system of the present invention, the acoustic signals are reproduced as the sound by the speaker devices 151, 15r, while the low frequency component of the sound signals is reproduced by the headphone device. Since the headphone device 14 causes the reproduced sound to reach the tympanic membrane of the listener 17 without obstructing the external acoustic ~~miatus~~ meatus of the listener 17, the listener 17 may hear the sound reproduced by the speaker device 151, 15r and the sound reproduced by the headphone device 14 simultaneously.

Hence, with the above described sound reproducing system, when the size of the speaker cabinet 15b or the speaker unit 15a constituting the speaker devices 151, 15r is reduced and the sound reproduction by these speaker devices 151, 15r in the low frequency range cannot be realized at a sufficient sound pressure, the sound reproduction in the low frequency range can be realized by the headphone device 14. That is, with the present sound reproducing system, the sound from the speaker device 151, 15r and the sound from the headphone device 14 cooperate to realize satisfactory sound reproduction over a wide frequency range including the low frequency range.

Meanwhile, with the present sound reproducing system, the fixed position feel of the reproduced sound is approximately formed by the sound of the low to high frequency range reproduced by the speaker devices 15l, 15r. The sound of the low frequency range which is reproduced by the headphone device 14 does not essentially affect the fixed position feeling of the reproduced sound.

The amplifier 16 may also be so constructed that switching may be made between the amplification frequency characteristics emphasizing the above mentioned low frequency range and frequency characteristics substantially flatly amplifying the entire frequency range. When the amplification frequency characteristics of the amplifier 16 are substantially flat over the entire frequency range, the headphone device 14 reproduces the sound over the entire frequency range, so that satisfactory sound reproduction may be achieved without using the speaker devices 15l, 15r.

In order that only the low frequency component of the sound signal will be supplied to the headphone device 14, the sound signal may be supplied to the headphone device 14 via so-called passive network type electrical circuit 18, as shown in Fig. 13. This passive network type electrical circuit 18 includes a plurality of coils 20a, 20b, 20c interposed between one output 19a of a signal source 19 and an input of the sound reproducing unit 2 of the headphone device 14. These coils 20a, 20b, 20c are

connected in series with one another. Capacitors 21a, 21b, 21c are interposed between points between the coils 20a, 20b, 20c and the other output 19b of the signal source 19 connected to the other input of the sound reproducing unit 2.

The sound signals supplied to the headphone device 14 via passive network type electrical circuit 18 are supplied to the headphone device 14 after damping which works more strongly for the higher frequency component. The degree of damping may be determined by suitably setting the inductance values of the coils 20a, 20b, 20c and the reactance values of the capacitors 21a, 21b, 21c, and may be represented by how much the level of the sound signal of the double frequency is damped with respect to the sound signals of a given frequency, as 6 dB/Oct or 12 dB/Oct.

The acoustic circuit for the headphone device 14 is shown in Fig. 2 wherein the equivalent mass Mb of the air in the sound guide tube 3 is connected to the acoustic circuit for the sound reproducing unit 2. Therefore, the larger the equivalent mass Mb of the air within the sound guide tube 3, the lower is the resonance frequency f_0 of the headphone device 14, so that more satisfactory reproduction of the sound signal of the low frequency range may be realized by the headphone device 14.

The sound reproducing system according to the present invention is not limited to the construction in which sound reproduction for only the low frequency range may be made by the headphone device 14 but the so-called surround sound may be

reproduced by the headphone device 14. That is, the sound signals supplied to the speaker devices 151, 15r are supplied via so-called surround circuit to the headphone device 14. This surround circuit outputs the sound signal after predetermined delaying and damping.

With the above described sound reproducing system, the sound reproduced by the speaker devices 151, 15r and the sound reproduced by the headphone device 14 cooperate to reproduce the sound with so-called concert-hall presence, that is, simultaneously with the reverberating and residual sound components.

The sound reproducing system of the present invention may be constructed as shown in Fig. 14 wherein the speaker devices 151, 15r may be supported by the listener's head 17.

With the sound reproducing system, shown in Fig. 14 the speaker devices 151, 15r are supported at the forward left and forward right sides of the listener 17, by the hairband 12 and a pair of speaker supporting arms 22 projectingly supported by the hairband 12, with the sound radiating side facing the listener 17. The headphone device 14 is worn by the listener 17 as is the above mentioned sound reproducing system.

With the present sound reproducing system, since the speaker devices 151, 15r governing the stationary position feeling of the reproduced sound are supported by the listener's head 17 and the speaker devices 151, 15r are moved to follow the listener's head

when the listener 17 moves his head, sound reproduction may be performed satisfactorily without changing the stationary position feeling.

On the other hand, with the above described sound reproducing system in which the speaker devices 151, 15r are supported by the listener's head, the sound guide tube 3 may be provided on the speaker cabinet 15b of the speaker devices 151, 15r, without using the headphone device 14, as shown in Fig. 15.

That is, with the present sound reproducing system, the sound guide tube 3 similar to that provided on the cabinet 1 of the headphone device 14 is provided on the speaker cabinet 15b. This sound guide tube 3 is so constructed that the sound radiated from the rear surface of the speaker cabinet 15b towards the inner side of the speaker cabinet 15b will be conducted outwards via sound guide opening 15c provided in the speaker cabinet 15b and radiated via sound radiating opening 3b at the distal end 3a so as to reach the external auditory ~~miatus~~ meatus E of the listener 17. That is, with the present sound reproducing system, the sound radiated by the speaker unit 15a towards the front side proves to be the sound reproduced by the sound reproducing device, while the sound radiated by the speaker unit 15a is equivalent to the sound reproduced by the electro-acoustic transducer.

The above described sound reproducing system is so designed that the resonance frequency in the speaker cabinet 15b and in

the sound guide tube 3 becomes lower than the resonance frequency in the speaker unit 15a, and that the low frequency component of the sound radiated by the speaker unit 15a is conducted more efficiently in the sound guide tube 3. Thus, with the present sound reproducing system, even if the sound pressure of the low frequency component of the reproduced sound radiated by the speaker devices 15l, 15r towards the front side is insufficient, the low range frequency component of the sound radiated towards the rear side of the speaker unit 15a are conducted by the sound guide tube 3 to the external auditory ~~miatus~~ meatus of the listener 17 to realize satisfactory sound reproduction.

In the sound reproducing system of the present invention, when the reproduction of the low frequency component only of the sound is to be performed by the headphone device 14 the headphone device 14 may be replaced by a headphone device or an earphone device shown in Figs 5A to 9. Since the sound of the low frequency range does not affect the fixed position feeling of the reproduced sound, sound reproduction may be achieved satisfactorily when the sound of the low frequency range is supplied only to one ear.

Another Construction of Electro-Acoustic Transducer of sound Reproducing System

As the electro-acoustic transducer constituting the sound reproducing system of the present invention, a variety of transducers constructed for satisfactorily reproducing the sound

of the low frequency range may be used, in addition to the above described headphone device 14, headphone device or earphone devices shown in Figs. 5A to 9.

That is, as the earphone device constituting the headphone device 14, such device in which, as shown in Fig. 16, a partition wall 24 having a duct 23 in the cabinet 1 of the earphone device shown in Fig. 1 may be provided and this earphone device may be constructed as the so-called double bus ref type. With this earphone device, the inside of the cabinet 1 is divided by the partition wall 24 into a first air chamber 25 on the side of the sound reproducing unit 2 and a second air chamber 26 on the side of the sound guide opening 1b. These first and second air chambers 25, 26 communicate with each other by the above duct 23 provided in the partition wall 24.

With the above described earphone device, the sound radiated towards the rear side of the sound reproducing unit 2 is radiated into the first air chamber 25 so as to be guided via duct 23 into the second air chamber 26. The sound guided into the second air chamber 26 is guided outwards via sound conducting opening 1b and the sound guide tube 3.

In an equivalent acoustic circuit showing acoustic characteristics of the above described earphone device, shown in Fig. 17, the equivalent mass Md, compliance Cd and the acoustic resistance Rd of the sound reproducing unit 2 are connected in series and a compliance C_1 in the first air chamber 25 is

connected to the series circuit to form a closed loop. One of the junctions between the equivalent mass Md, compliance Cd and the acoustic resistance Rd shown in Fig. 17A is connected to an acoustic circuit ϵ of the external auditory miatus E by way of the air equivalent mass M_1 in the duct 23 and the air equivalent mass Mb in the sound guide tube 3. The equivalent mass M_1 and the equivalent mass Mb are connected in series with each other. The other junction between the equivalent mass Md, compliance Cd and the acoustic resistance Rd on one hand and the compliance C_1 on the other, shown at B in Fig. 17, is connected to the acoustic circuit ϵ of the external auditory miatus E. A compliance C_2 in the second air chamber 26 is interposed and connected between the junction between the equivalent mass M_1 of the air in the duct 23 and the equivalent mass Mb of the air in the sound guide tube 3 and the other junction between the compliance C_1 on one hand and the equivalent mass Md, compliance Cd and the acoustic resistance Rd on the other, shown at B in Fig. 17.

In the acoustic circuit ϵ of the external auditory miatus E, the equivalent mass Me in the external auditory miatus E, compliance Ce and the acoustic resistance Re constitute a closed loop. The junction between the compliance Ce and the acoustic resistance Re is connected to the equivalent mass Mb in the sound guide tube 3. The junction between the compliance Ce and the equivalent mass Me is connected to the other junction between the equivalent mass Md, compliance Cd and the acoustic resistance Rd,

shown at B in Fig. 17.

With the above described earphone device, by the acoustic circuit shown in Fig. 17, the resonance frequency f_0 of the earphone device may become the lower, the larger the sum of the equivalent mass M_1 of the air in the duct 23 and the equivalent mass Mb of the air in the sound guide tube 3. That is, with the present earphone device, the resonance frequency f_0 may be made lower by an amount corresponding to the equivalent mass M_1 of the air in the duct 23, as compared to the earphone device shown in Fig. 1, so that sound reproduction of the low frequency range may be performed satisfactorily.

As the earphone device constituting the headphone device 14, such transducer may be employed in which, as shown in Fig. 18, the sound guide tube 3 or of the earphone device shown in Fig. 1 is divided into plural sound guide sections 28a, 28b by a partition wall 27 formed along the axis of the sound guide tube 3.

That is, with the sound guide tube 3 of the present earphone device, the sound guide sections 28a, 28b defined by the partition wall 27 may have different inside diameters or lengths, while they are so adapted that the equivalent masses in the sound guide sections 28a, 28b are approximately equal to one another. Hence, with the present earphone device, it becomes possible to prevent resonance from being produced along the length of the sound guide tube 3 to realize optimum sound reproduction in the

low frequency range.

In the earphone device constituting the headphone device 14, a hermetic sealing member 29 formed of an air permeable material such as urethane may be provided for surrounding the outer peripheral surface of the distal side 3c of the sound guide tube 3, as shown in Fig. 19.

In such earphone device in which the sealing member 29 is provided on the outer peripheral surface at the distal end 3c of the sound guide tube 3, the extent of hermetic sealing extent in the sound guide tube 3 and the external auditory ~~miatus~~ meatus is improved to increase the sound pressure of the reproduced sound in the low frequency range.

Meanwhile, since the sealing member 29 exhibits air permeability, it does not obstruct the hearing of the sound reproduced by the speaker devices 151, 15r or the exterior sound. The sealing member 29 may be made detachable with respect to the sound guide tube 3.

Another Construction of Sound Reproducing Device of Sound Reproducing system

As the sound reproducing system constituting the sound reproducing system of the present invention, headphone devices designed for performing sound reproduction over the entire frequency range from the low to the high range may also be used besides the above mentioned speaker devices 151, 15r.

Thus, as shown in Fig. 20, this sound reproducing system is

comprised of a headphone device of the type attached to the user's auricle, which is supplied with acoustic signals to reproduce the sound, and an electro-acoustic transducer 34 adapted for reproducing at least the low frequency component of the acoustic signals supplied by means of the amplifier 16 or the passive network 18. As the electro-acoustic transducer 34, the earphone devices shown in Figs. 1, 5A to 9, 16 or 18, or a headphone device making use of a pair of such earphone devices, are used.

The headphone device attached to the user's auricles 30 is adapted for supporting a pair of sound reproducing units 31, adapted for converting acoustic signals into sound, in a confronting relation at the inlets to both external auditory ~~miatuses~~ meatuses E. That is, the sound reproducing units 31 are accommodated in and supported by a headphone cabinet 32, as shown in Fig. 20, with the sound radiating side facing outwards by means of the sound radiating opening 32a. This headphone cabinet 32 is accommodated in the cavity of the concha D, which is the recess in the auricle C, with the sound radiating side of the sound reproducing unit 31 facing the inlet to the external auditory ~~miatus~~ meatus E, and is supported by the tragus and the antitragus. A feeder 31a supplying the sound signal to the sound reproducing unit 31 is taken out by way of a cord guide section 32c extended from the headphone cabinet 32 and by way of a feeder outlet 32c provided at the foremost part of the cord guide

section 32c.

The headphone cabinet 32 is provided with a sound guide extension tube 33 for establishing communication between the vicinity of the periphery of the sound reproducing unit 31, which is the sound radiating side of the sound reproducing unit 31, and the back side of the headphone cabinet 32 facing the sound radiating side. That is, the sound guide extension tube 33 is formed as a tube opened at both ends and made integral with the headphone cabinet 32, within this headphone cabinet 32, so that one opening end 33a faces to the front side from the vicinity of the periphery of the sound reproducing unit 31 and the other opening end 33b faces the rear side from the vicinity of the center on the rear surface of the headphone cabinet 32.

The distal end 3a of the sound guide tube 3 of the electro-acoustic transducer 34 may be detachably inserted and engaged into the other opening end 33b of the sound guide extension tube 33. That is, the sound radiated from the rear surface of the sound reproducing unit 2 of the electro-acoustic transducer 34 into the inside of the cabinet 1 of the electro-acoustic transducer 34 is conducted into the inside of the sound guide extension tube 33 by way of the sound guide tube 3, the sound radiating opening 3b and the other opening end 33b of the sound guide extension tube 33. The sound thus conducted into the sound guide extension tube 33 is propagated in the extension tube 33 so as to be radiated at one opening end 33a facing the front

side. The one opening end 33a of the sound guide extension tube 33 faces the inlet of the external auditory miatus E, as does the acoustic transducer unit 31 of the headphone device 30 attached to the user's auricle, so that the sound radiated from the opening end 33a reaches the inside of the external auditory ~~miatus~~ meatus E.

With the above described sound reproducing system, the sound is reproduced by the headphone device attached to the user's auricle 30 over the entire frequency range. Even if the low frequency component of the sound reproduced by the headphone device attached to the user's auricle 30 has an insufficient sound pressure, the sound of the low frequency range is reproduced by the electro-acoustic transducer 34 to reach the external auditory ~~miatus~~ meatus E. That is, the sound reproduced by the headphone device attached to the user's auricle 30 and the sound reproduced by the electro-acoustic transducer 34 cooperate with each other to effect satisfactory sound reproduction.

On the other hand, when employing the headphone device as the sound reproducing apparatus constituting the sound reproducing system of the present invention, the headphone device attached to the user's head, that is the so-called hermetically sealed headphone device, may be employed.

The head attachment type headphone device 35 is so constructed that a pair of sound reproducing units 36 for converting acoustic signals into sound are supported in a

confronting relation to the entrance to both external acoustic meatuses ~~miatuses~~ E. That is, as shown in Fig. 21, the sound reproducing unit 36 is accommodated in the associated headphone cabinet 37, with the sound radiating surface facing outwards by way of the sound radiating opening 37a. These headphone cabinets 37 are attached to both ends of the headband 38 and, with the headband 38 supported by the listener's head, the headphone cabinets 37 are supported in abutment with the auricles C so that the sound radiating surface of the sound reproducing unit 36 faces the inlet to the external acoustic meatus ~~miatus~~ E. On the perimeter of the headphone cabinet 37 abutting on the auricle C is mounted an annular buffer member 39 of urethane or rubber. The feeder 36a for supplying acoustic signals to the sound reproducing unit 36 is extracted outwards by a feeder outlet 37b provided at the headphone cabinet 37.

The headphone cabinet 37 is provided with a sound guide extension tube 40 for establishing communication between the vicinity of the perimeter of the sound reproducing unit 36 on the front side or the sound radiating side of the sound reproducing unit 36 and the rear surface of the headphone cabinet 37 facing the sound radiating side, as in the case of the above mentioned headphone attached to the user's auricle 30. The sound guide extension tube 40 is formed in the headphone cabinet 37 as a tube which is opened on both sides and formed integrally with the headphone cabinet 37, with the one opening end 40a facing

forwards from the vicinity of the periphery of the sound reproducing unit 36 and with the other opening end 40b facing rearwards from about the center of the rear surface of the headphone cabinet 37.

The other opening end 40b of the sound guide extension tube 40 is so formed that the distal end 3a of the sound guide end 3 of the electro-acoustic transducer 34 may be detachably inserted and engaged therein. That is, the sound radiated from the rear side of the sound reproducing unit 2 of the electro-acoustic transducer 34 is adapted to be transmitted into the sound guide extension tube 40 by way of the sound guide tube 3, the sound radiating opening 3b and the other opening end 40b of the sound guide extension tube 40. The sound transmitted into the sound guide extension tube 40 is propagated within the sound guide extension tube 40 so as to be radiated at the one opening end 40a facing the front side. The one opening end 33a of the sound guide extension tube 40 faces the inlet to the external auditory miatus E, as does the acoustic transducer unit 36 of the hermetically sealed headphone device 35, so that the sound radiated from one opening end 40a may reach the external acoustic miatus E.

With the above described sound reproducing system, the sound may be reproduced over the full frequency range by the above mentioned hermetically sealed headphone device 35. Even if the low frequency component of the sound reproduced by this

hermetically sealed headphone device 35 has only an insufficient sound pressure, the sound of the low frequency range is reproduced by the electro-acoustic transducer 34 so as to reach the external auditory ~~miatus~~ meatus E. That is, the sound reproduced by the hermetically sealed headphone device 35 and the sound reproduced by the electro-acoustic transducer 34 cooperate with each other to effect satisfactory sound reproduction.

H. Effect of the Invention

With the above described electro-acoustic transducer of the present invention, the sound guide tube by which the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet is conducted out of the cabinet is of a lesser diameter than the external auditory ~~miatus~~ meatus, at least at the sound radiating end, so as to be inserted into the external auditory ~~miatus~~ meatus. For this reason, it becomes possible for the electro-acoustic transducer to conduct the sound through the external auditory ~~miatus~~ meatus without obstructing the external auditory ~~miatus~~ meatus.

Hence, with the present electro-acoustic transducer, no standing waves are produced in the space between the tympanic membrane of the listener and the transducer unit, while the extraneous sound may be propagated into the external auditory ~~miatus~~ meatus by way of the space between the inner wall of the external auditory ~~miatus~~ meatus and the outer periphery of the sound guide tube.

Thus the present invention may provide an electro-acoustic transducer which may be applied advantageously to, for example,

an earphone device or a headphone device, and which may reproduce the sound without oppressed feeling or a stationary position feeling.

In addition, with the sound reproducing system of the present invention, the electro-acoustic transducer is supplied with acoustic signals and transducer the acoustic signals into sound to reproduce the sound by a sound reproducing device, and at least the low frequency component of the acoustic signal supplied to the sound reproducing device is converted into sound. Thus the sound is radiated into the external auditory meatus ~~miatus~~, without stopping the external auditory meatus ~~miatus~~, by means of a sound guide tube of a lesser diameter than the external auditory meatus ~~miatus~~, so that the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet may be conducted towards outside of the cabinet and at least the sound radiating side may be inserted into the external auditory meatus ~~miatus~~.

Hence, with the present sound reproducing system, both the sound reproduced by the sound reproducing device and the sound reproduced by the sound reproducing unit of the headphone device may be heard simultaneously.

Thus, even if the low frequency component of the sound reproduced by the sound reproducing device has an insufficient sound pressure, this sound may reach the external auditory meatus ~~miatus~~ E. Thus the sound reproduced by the hermetically sealed headphone device 35 and the sound reproduced by the electro-

acoustic transducer cooperate to effect satisfactory sound reproduction.

With the above described electro-acoustic transducer of the present invention, the sound guide tube for conducting the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet has at least its sound radiating end of a lesser diameter than the external auditory miatus so that the sound radiating end may be inserted into the external auditory meatus ~~miatus~~. Thus it is possible with the present electric-acoustic transducer to conduct the sound into the external auditory meatus ~~miatus~~ without occluding it.

Thus, with the present electro-acoustic transducer, no standing waves are produced between the listener's tympanic membrane and the electro-acoustic transducer unit, while extraneous sound may be propagated between the inner wall of the external auditory meatus ~~miatus~~ and the outer peripheral surface of the sound guide tube.

Thus the present invention provides an electro-acoustic transducer which may be advantageously applied to, for example, an earphone device or a headphone device and with which the sound may be reproduced without causing an oppressed feeling or a stationary position feeling, that is a feeling as if the sound source were situated stationarily within the listener's head.

With the sound reproducing system according to the present invention, the sound reproducing device is adapted to be supplied

with acoustic signals and to transduce the acoustic signals into sound for reproduction thereof, while the electro-acoustic transducer is adapted to transduce at least the low frequency component of the acoustic signals supplied into the sound reproducing device into sound. The electro-acoustic transducer radiates the sound into the external auditory miatus without stopping it by means of a sound guide tube which is of a lesser diameter than the external auditory ~~miatus~~ meatus in order to conduct the sound radiated from the electro-acoustic unit accommodated in the cabinet towards the outside of the cabinet and to permit at least the sound radiating end to be inserted into the external auditory ~~miatus~~ meatus.

Hence, with the present sound reproducing system both the sound reproduced by the sound reproducing device and the sound reproduced by the sound reproducing unit of the headphone device may be heard simultaneously.

Therefore, even if the low frequency component of the sound reproduced by the sound reproducing device has an insufficient sound pressure, this sound cooperates with the sound reproduced by the electro-acoustic transducer to achieve satisfactory sound reproduction.

It is noted that, since the stationary position feeling of the reproduced sound is formed by the sound of the medium to high frequency range reproduced by the sound reproducing device, the stationary position feeling is hardly affected by the sound in

the low frequency range even if the sound in the low frequency range is radiated into the external auditory meatus ~~miatus~~.

Thus the present invention provides a sound reproducing system in which the sound may be reproduced satisfactorily over a wide frequency range, encompassing the low frequency range, without increasing the size of the system or inconveniencing the neighbors.

The claims defining the invention are as follows:

1. An electro-acoustic transducer comprising

an electro-acoustic transducer unit having a sound radiating side and a rear side accommodated in a housing, and

a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said housing and into an external auditory meatus of a wearer of said transducer,

said sound guide tube being of a lesser diameter than said external auditory meatus to allow at least the sound radiating end of the sound guide tube to be introduced into said external auditory meatus leaving a space between said sound radiating end and an inner wall of said external auditory meatus so as not to completely close said external auditory meatus.

2. The electro-acoustic transducer according to claim 1 wherein said housing is formed for covering said rear side of said electro-acoustic transducer unit.

3. The electro-acoustic transducer according to claim 2 wherein said sound guide tube is substantially L-shaped and has its end opposite to said sound radiating end connected to a sound conducting opening provided on a side of said housing.

4. The electro-acoustic transducer according to any preceding claim further comprising supporting means for supporting one of said transducer unit or said sound guide tube so that the sound radiating end of said sound guide tube is at a predetermined position within said external auditory meatus.

5. The electro-acoustic transducer according to claim 4 wherein said supporting means comprises at least one projection provided on a side of said sound guide tube and adapted to be engaged with an auricular recess of said wearer.

6. The electro-acoustic transducer according to claim 4 wherein said supporting means comprises a toroidal member provided at the sound radiating end of said sound guide tube and adapted for being held in the cavity of the concha of said wearer.

7. The electro-acoustic transducer according to claim 4 wherein said supporting means comprises an ear hanger provided outside the housing and engaged with the upper side of the outer periphery of said housing.

8. The electro-acoustic transducer according to claim 4 wherein said supporting means comprises a head band.

9. The electro-acoustic transducer according to claim 8 wherein said housing is provided at a central portion of said head band and a pair of said sound guide tubes are provided extending from said housing in opposite directions.

10. The electro-acoustic transducer according to claim 1 wherein a sealing member formed of an air permeable material is provided at the sound radiating end of said sound guide tube to provide a seal between said sound guide tube and the external auditory meatus.

11. The electro-acoustic transducer according to claim 1 wherein electrical signals supplied to said transducer unit are supplied thereto by way of a compensation circuit for compensating frequency resonance peaks generated in said transducer unit.

12. A sound reproducing system comprising

a sound reproducing apparatus supplied with electrical signals, and

an electro-acoustic transducer including an electro-acoustic transducer unit accommodated in a housing, and a sound guide tube for conducting sound from the electro-acoustic transducer unit out of said housing,

said sound guide tube having at least a sound radiating end of a lesser diameter than the external auditory meatus to permit said sound radiating end to be introduced into the external auditory meatus without completely closing the external auditory meatus,

said electro-acoustic transducer unit being adapted for reproducing at lest a low-frequency component of the frequency range of the electrical signal of the sound reproduced by said sound reproducing apparatus.

13. The system according to claim 12 wherein at least the low frequency component of the electrical signals supplied to said sound reproducing apparatus is supplied to said electro-acoustic transducer.

14. The system according to claim 12 further comprising amplifier means for amplifying the low frequency component of the electrical signal supplied to said sound reproducing apparatus.

15. The system according to claim 14 wherein said amplifier means comprises a passive network electric circuit.

16. An electro-acoustic transducer substantially as hereinbefore described with reference to the accompanying drawings.

17. A sound reproducing system substantially as hereinbefore described with reference to the accompanying drawings.

DATED this THIRD day of JULY 1992

Sony Corporation

Patent Attorneys for the Applicant
SPRUSON & FERGUSON

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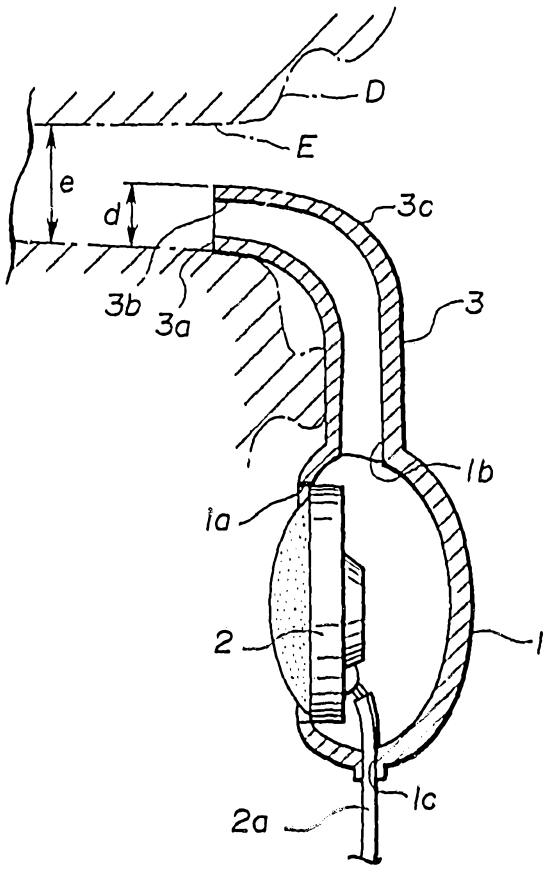

FIG.1

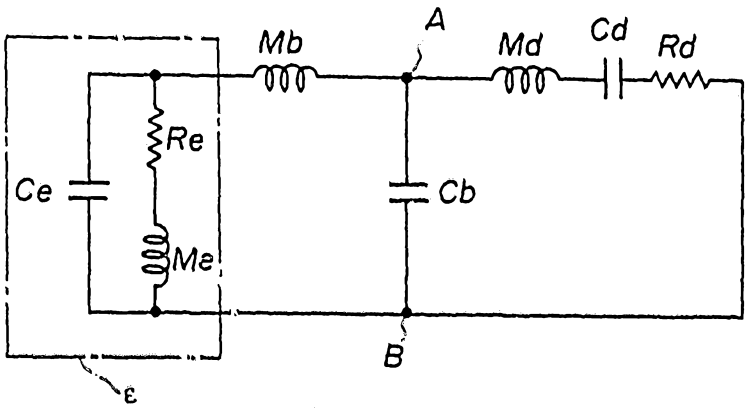

FIG.2

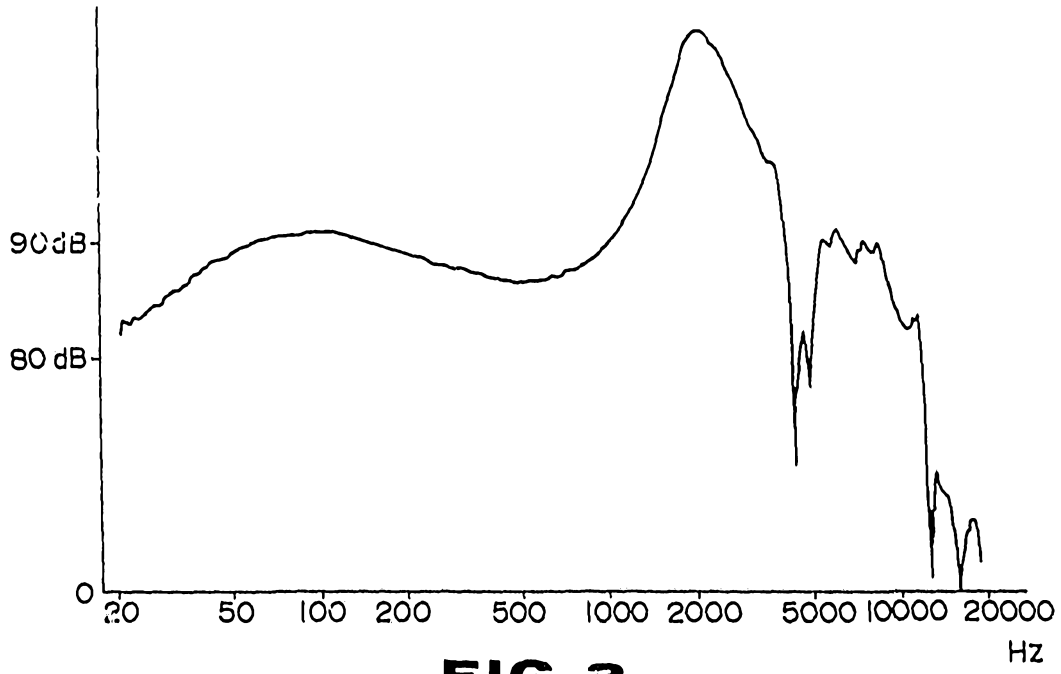
90dB
80 dB
0
20
50
100
200
500
1000
2000
5000
10000
20000
Hz

FIG. 3

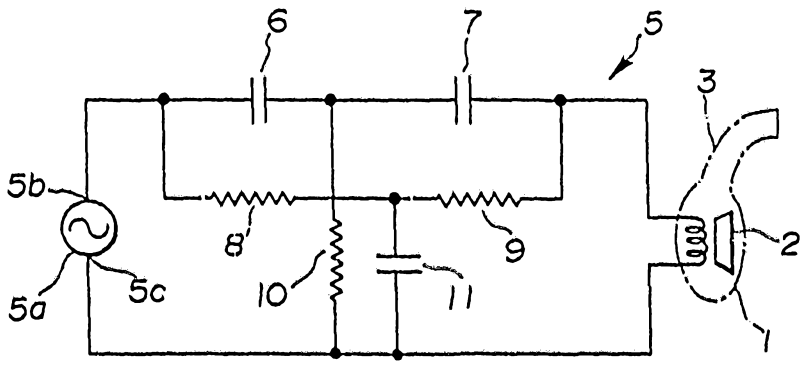
6
7
5
3
5b
8
9
2
10
11
5a
5c
1

FIG. 4

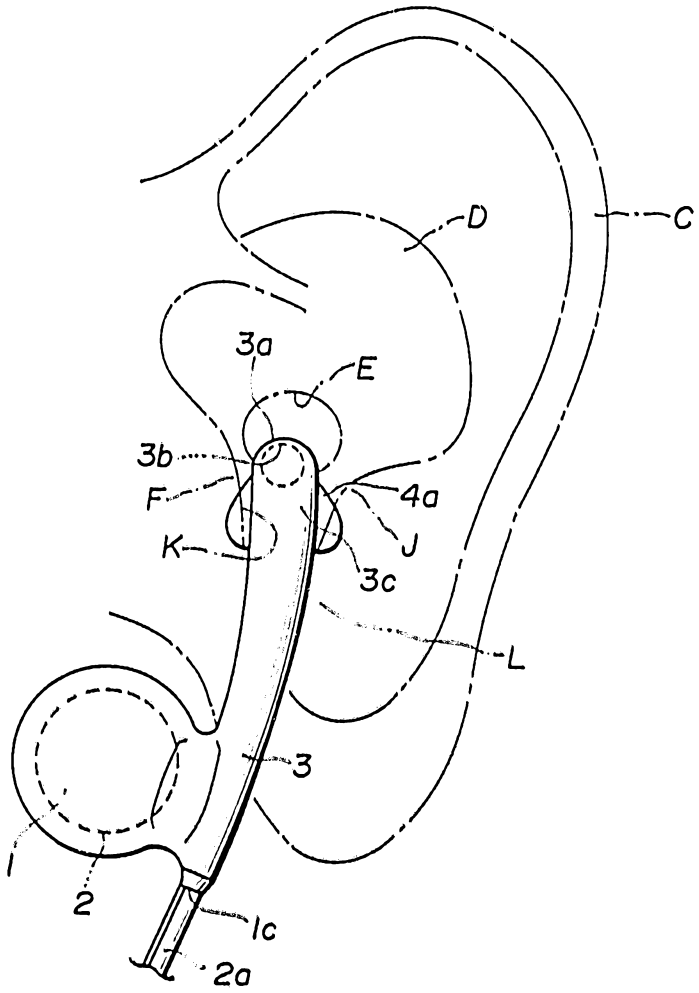

FIG. 5A

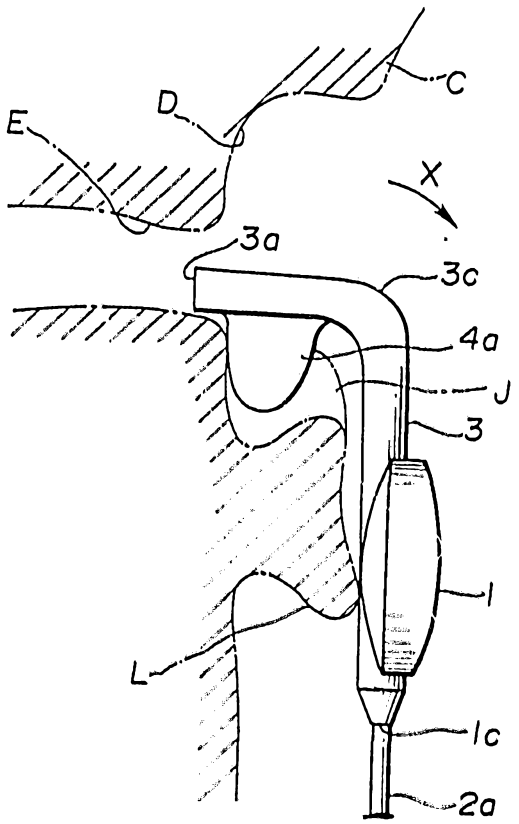

FIG. 5B

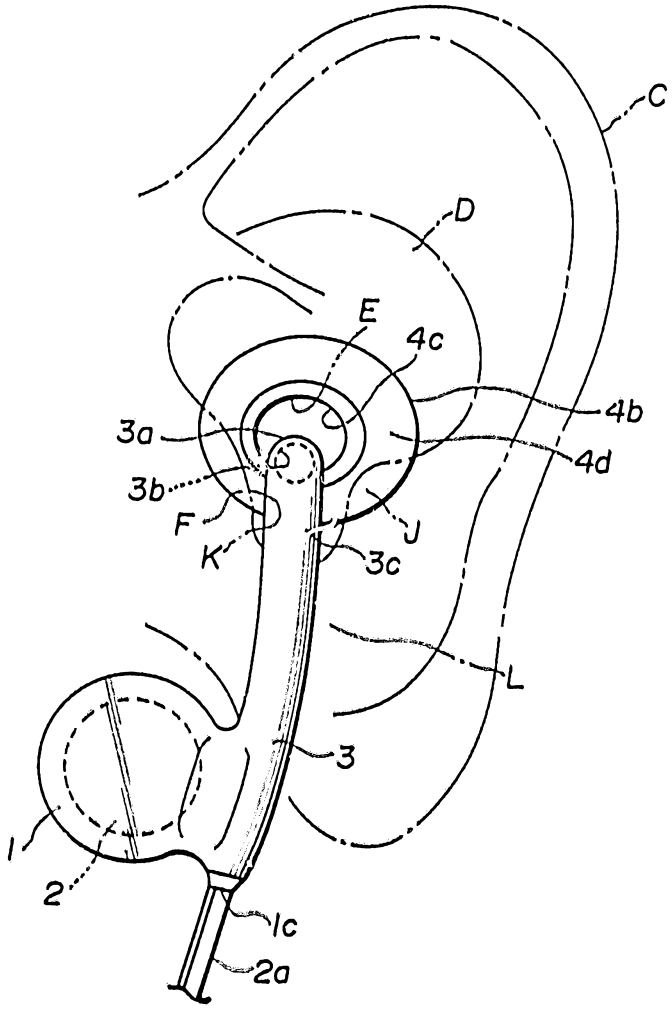

FIG. 6A

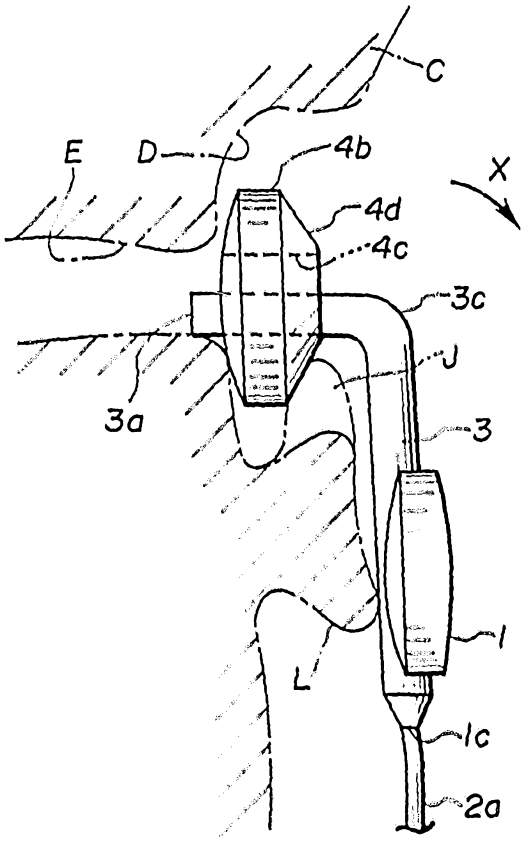

FIG.6B

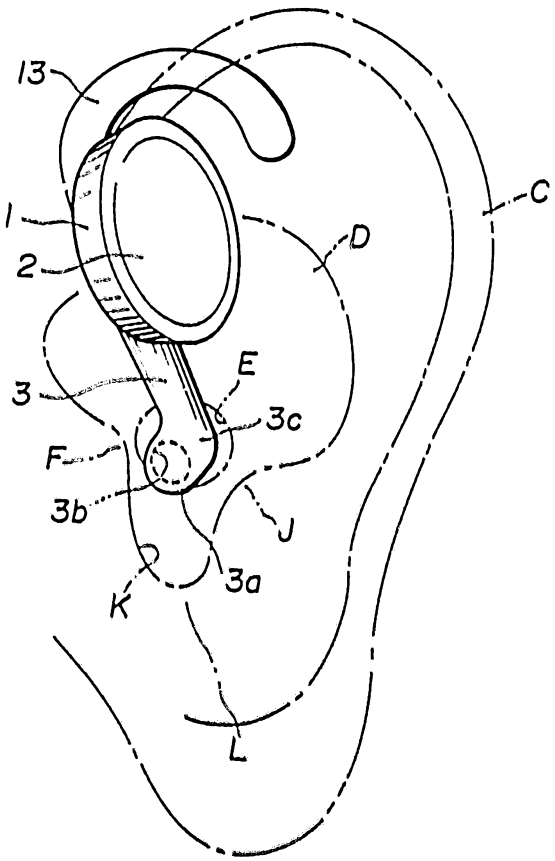

FIG. 7

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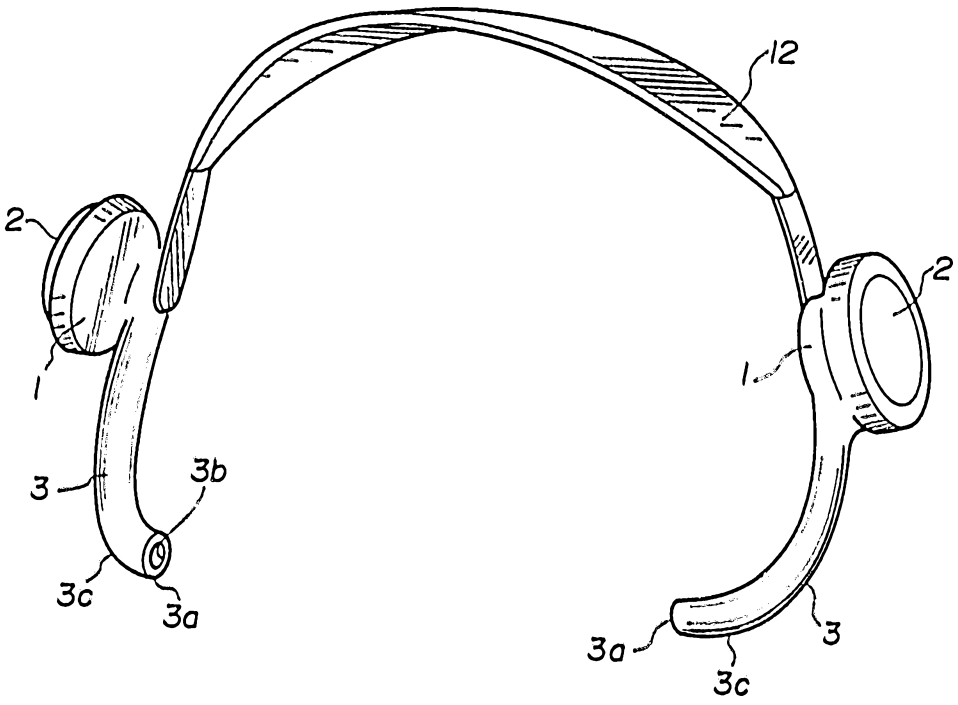

FIG. 8

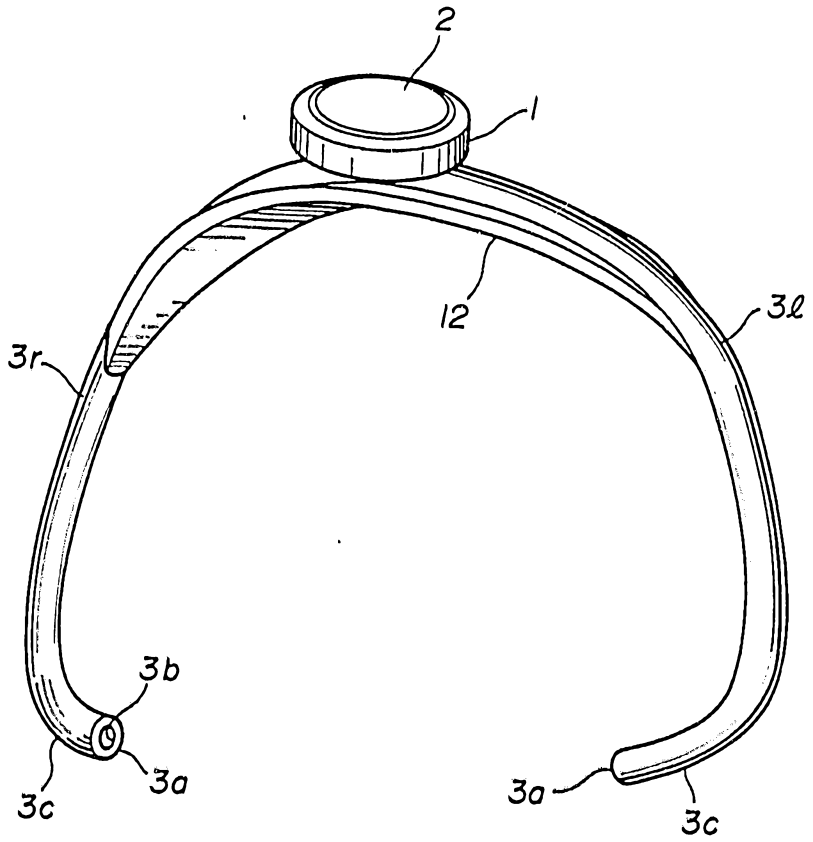

FIG. 9

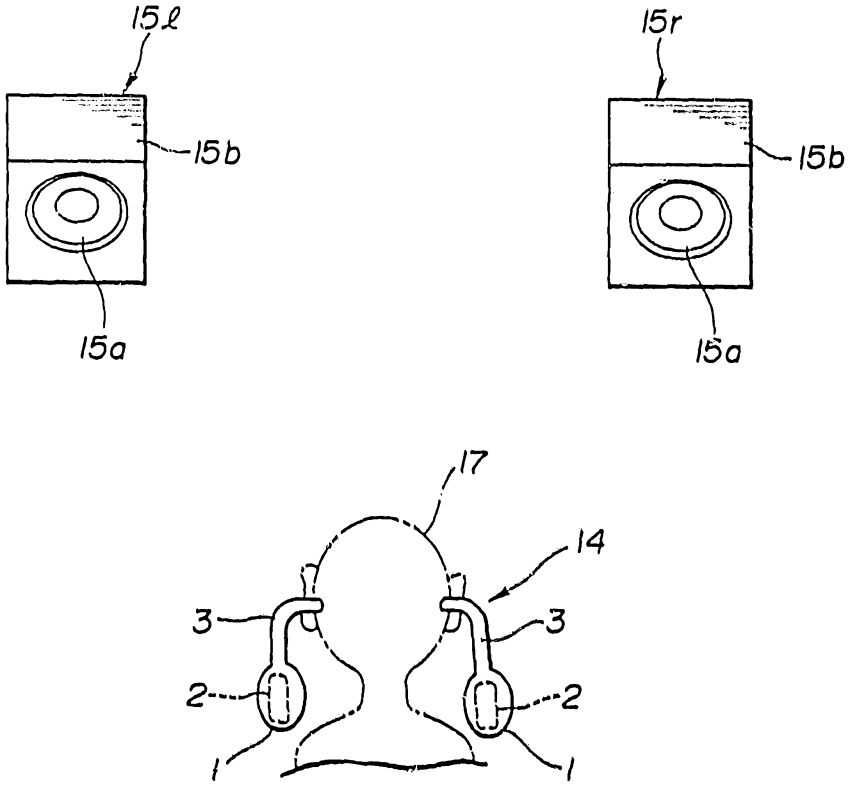

FIG.10

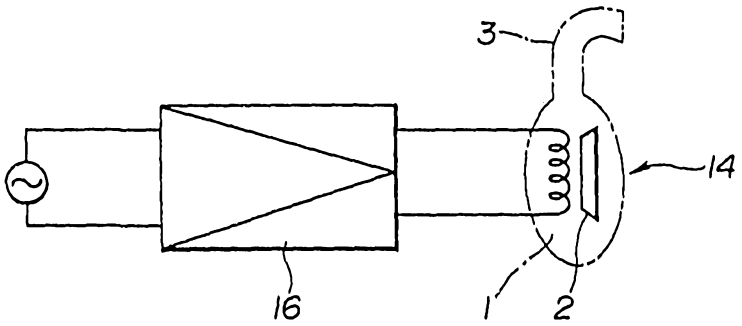
3
14
16
1
2

FIG.11

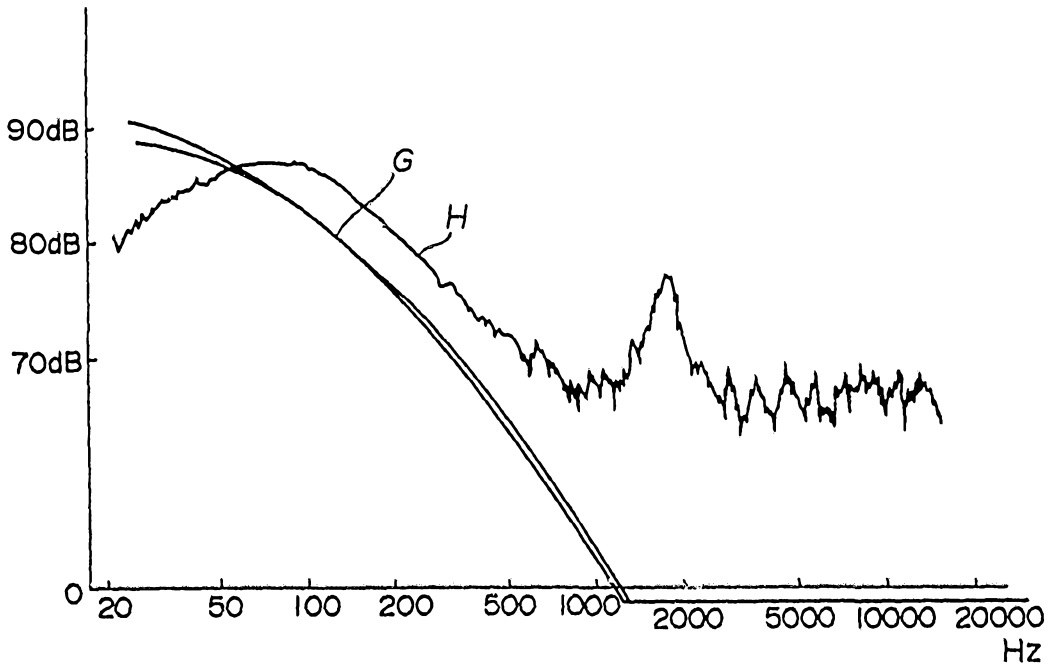
90dB
80dB
70dB
0
G
H
20
50
100
200
500
1000
2000
5000
10000
20000
Hz

FIG.12

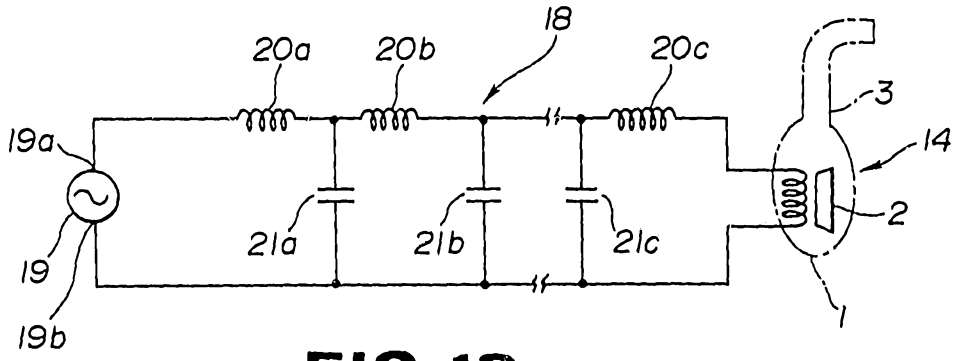
18
20a
20b
20c
3
19a
14
2
21a
21b
21c
19
19b
1

FIG. 13

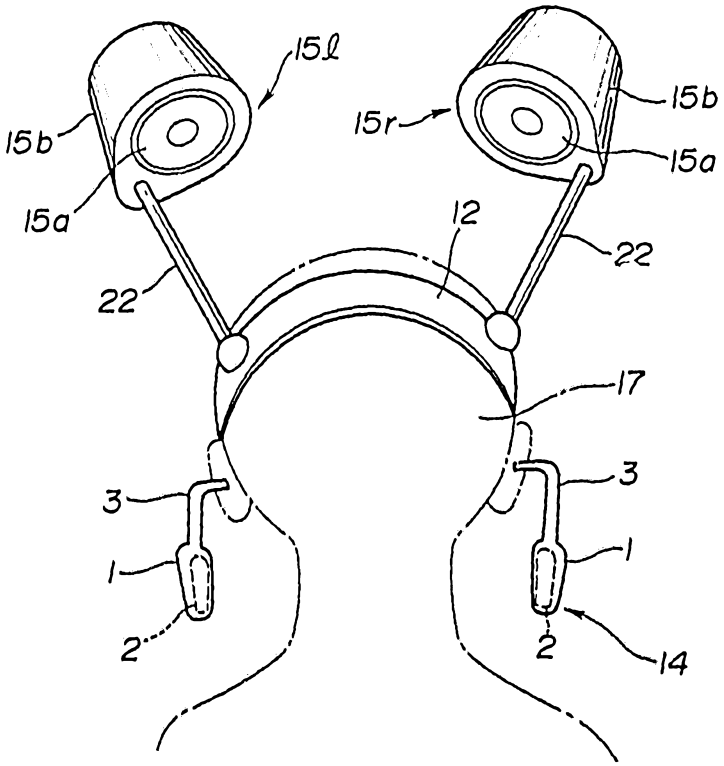
15ℓ
15b
15r
15b
15a
15a
12
22
22
17
3
3
1
1
2
2
14

FIG. 14

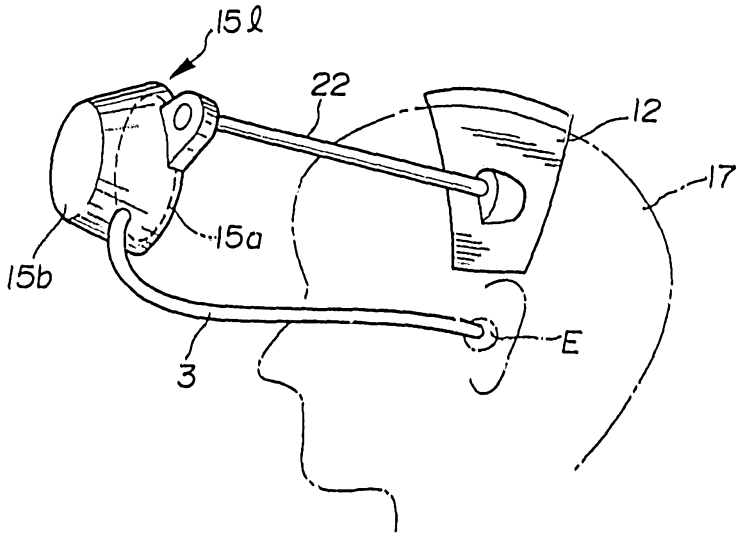

FIG.15

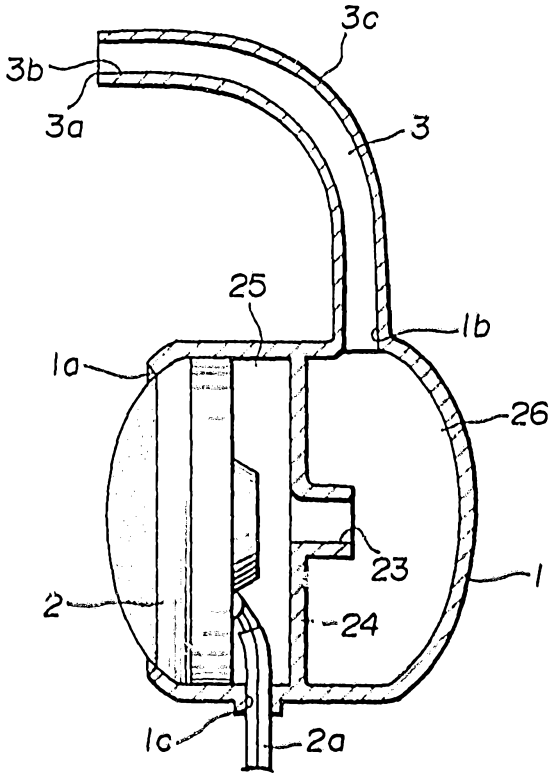

FIG.16

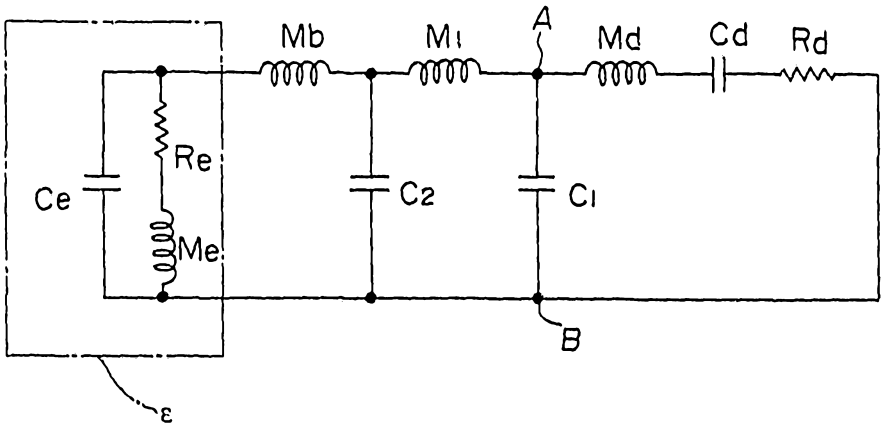
Mb
M1
A
Md
Cd
Rd
Re
Ce
C2
C1
Me
B
ε

FIG.17

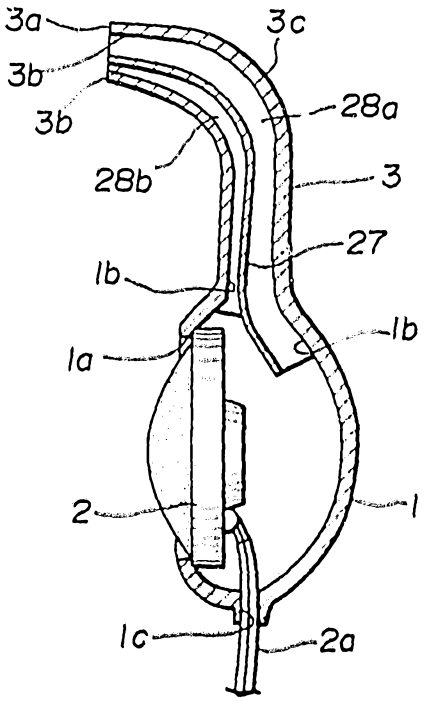
3a
3c
3b
28a
3b
28b
3
27
1b
1b
1a
2
1
1c
2a

FIG.18

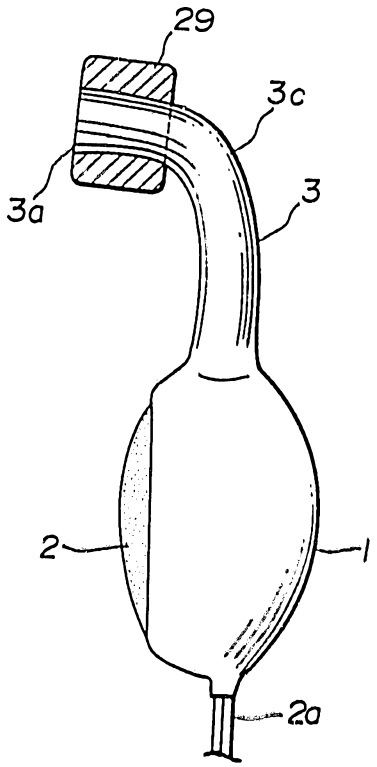

FIG.19

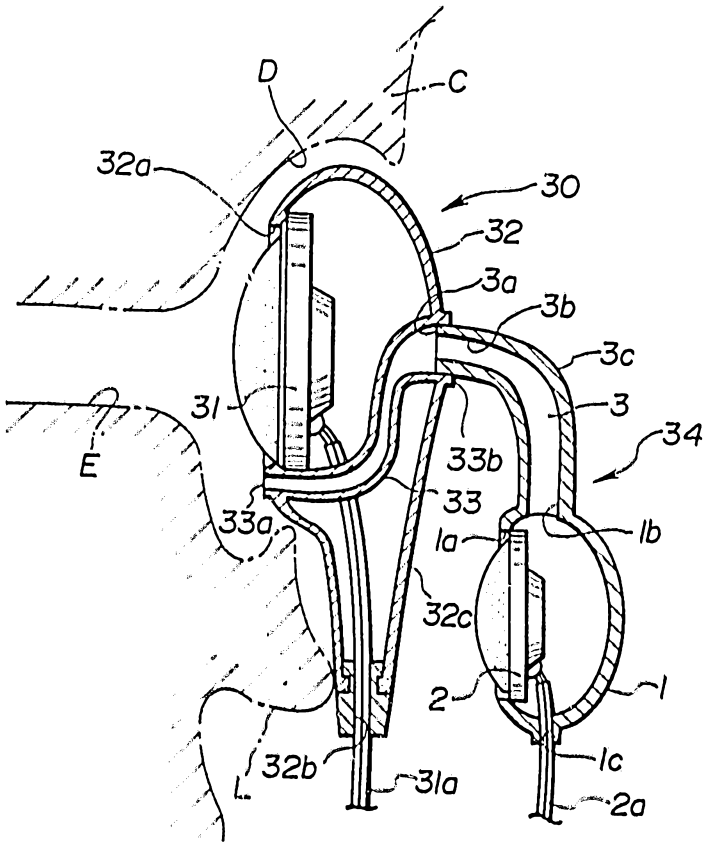

FIG.20

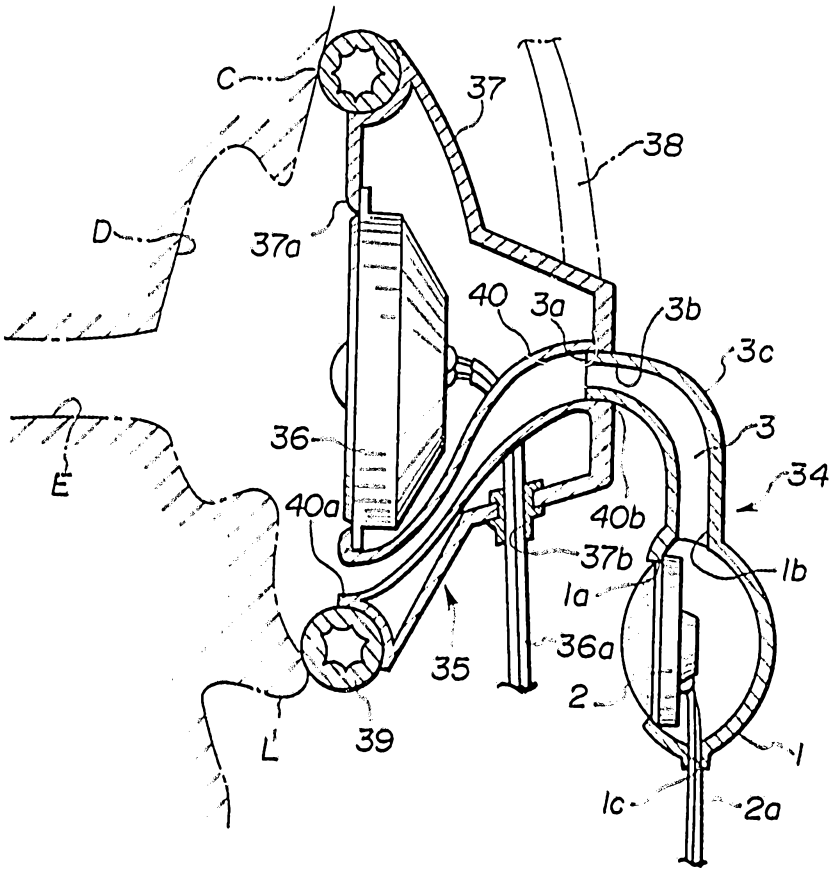
C
37
38
D
37a
40
3a
3b
3c
3
34
36
E
40a
40b
37b
1b
1a
36a
35
2
39
L
1
1c
2a

FIG. 21