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(71) Applicants: THIJS-JAMIN, Anneliesje (heiress of the deceased inventor) [NL/NL]; THIJS, Alexander, Victor, Marie, Anne (heir of the deceased inventor) [NL/NL]; Sartonlaan 8, NL-6132 BD Sittard (NL).

(72) Inventor: THIJS, Victor, Marie, Joseph (deceased).

(74) Agent: DE BRUIJN, Leendert C.; Nederlandsch Octrooibureau, Scheveningseweg 82, P.O. Box 29720, NL-2505 LS The Hague (NL).

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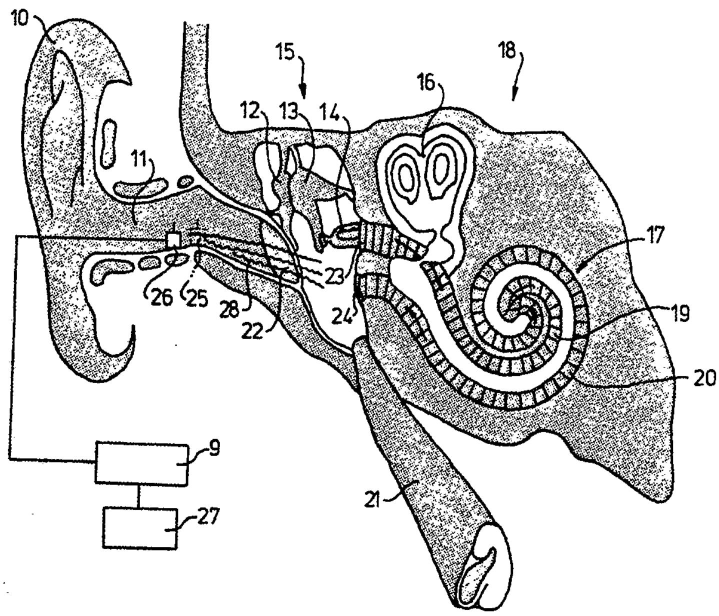

(57) Abstract

Hearing aid, comprising at least one microwave generator (9) which receives an electrical signal from, for example, a microphone (27) and generates a frequency-modulated electrical signal composed of bursts, the burst frequency depending on the sounds picked up by the microphone, which frequency-modulated signal is fed to a radiator (25, 26) which generates microwave radiation (28) made up of bursts, at least the radiator (25, 26) of the hearing aid being situated in the ear canal (11) of a hearing organ and the microwave generator (9) being designed in such a way that the burst frequencies are at least virtually equal to the sound frequencies of the sounds picked up by the microphone.

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Hearing aid based on microwaves

The present invention relates to a hearing aid, comprising at least one microwave generator which receives an electrical signal from a sound transducing unit, for example a microphone, and generates a frequency-modulated electrical signal composed of bursts, the burst frequency depending on the sounds picked up by the sound transducing unit, which frequency-modulated signal is fed to a radiator which generates microwave radiation made up of bursts.

Such a hearing aid is disclosed by US Patent Specification US-A-4,877,027. A device is described therein in which a deaf person is irradiated with microwaves having a pattern which is such that when they arrive at the brain of said deaf person, they excite a hearing sensation. The device is composed of a microphone or the like for converting sound waves into an electrical audio signal. Said audio signal is fed to a pulse generator which excites bursts of microwave pulses. The microwaves are in the region between 100 MHz and 10,000 MHz, the neutral spacing of the bursts depending on the intensity of the electrical audio signal. In this connection, only intensity values of the electrical audio signal above a predetermined threshold value are taken into consideration. In this way, a frequency modulation of the electrical audio signal takes place. With the aid of a microwave generator, the frequency-modulated signal is converted into microwaves which are transmitted via an aerial in the direction of the head of the deaf person. The microwaves generated reach the brain through the skull of the person and excite electrical signals therein which are perceived as sound sensation. The known device has several disadvantages. First of all, it is difficult to keep the microwave bundle which is radiated directed at the head of the deaf person, which is generally in continuous movement. Secondly, the spacing between the aerial and the person concerned is not constant, with the result that the operation of the known device will depend on the position which the person concerned assumes. Moreover, it is unclear how the demodulation of the frequency-modulated signal takes place in the known device: the frequency of the bursts of microwave pulses is between 1 kHz and 100 kHz, which does not directly correspond to the frequencies of the sound waves perceived, which are, after all, primarily in the region of a few tens of Hz to approximately 20 kHz. The quality of the sound perception of the deaf person is therefore mediocre in the case of the known device. Because the microwave generator plus the associated aerial are situated at a distance from the deaf person, microwaves of an appreciable level have, moreover, to be generated, as a result of which various counter-measures are necessary to prevent the person at whom the microwaves are directed becoming excessively heated internally as a consequence of a sort of "magnetron effect".

The object of the present invention is therefore to provide a hearing aid which is safe and whose quality does not depend on the spacing between the device concerned and the deaf person. In addition, the objective of the present invention is to provide a hearing aid which gives a correct reproduction of the ambient noises and which does more than excite a "sound sensation".

For this reason, a hearing aid of the type mentioned at the outset has the characteristic that at least the radiator of the hearing aid is situated in the ear canal of a hearing organ and the microwave generator is so designed that the burst frequencies are substantially equal to the sound frequencies of the sounds picked up by the sound transducing unit.

Such a hearing aid is suitable for eliminating both middle-ear deafness and inner-ear deafness. In addition, such a hearing aid requires only a minimum amount of energy because the hearing aid can be placed in the ear canal of a deaf person and thus a small amount of radiated microwave energy will suffice. As a result, the chance of damage as a consequence of the microwave energy is minimum and independent of the spacing between the hearing device and the deaf person. In addition, with such a hearing aid, a 1:1 relationship exists between the frequency spectrum of the ambient noise and the vibration excited in the cochlea of the hearing organ, as a result of which the quality of the sound perceived in the brain is appreciably improved. Finally, such a hearing aid is to be placed at least partly in the ear canal of a deaf person.

The invention will be explained in greater detail below by reference to the drawings, wherein:

Figure 1 shows a diagrammatic reproduction of a known device for detecting gas species, with which the present invention is explained in greater detail;

Figure 2 shows a cross section through a hearing organ in which a hearing aid according to the invention is fitted in the ear canal.

The present invention is partly based on the so-called photoacoustic effect which was discovered by Alexander Graham Bell as long ago as 1880 but which has only found a small number of applications. The most known application of the photoacoustic effect relates to a gas detector. The principle of the gas detector is explained in greater detail below by reference to Figure 1.

In Figure 1, the reference numeral 1 indicates a sealed space in which an unknown gas is situated. Directed at the sealed space 1 is a monochromatic beam 2 which is interrupted by a rotating disc 3 provided with holes 4. Bursts of monochromatic light therefore radiate into the unknown gas, the burst frequency being dependent on the rotary speed of the disc and the number of holes 4, and also on the mutual spacing of the holes. The frequency of the monochromatic light is adjustable. It is found that photons of one or more specific frequencies can be absorbed by the unknown gas, in which process electrons in the gas molecules enter an excited state. These frequencies, to which said excited state belongs, are characteristic of the gas which is situated in the sealed casing 1. This excited state of the gas molecules can be perceived acoustically. It is found, in particular, that gas whose molecules are excited by the incident monochromatic light beam exerts a somewhat greater pressure on the sealed space 1 than gas molecules which are not in the excited state. Because the monochromatic light beam radiates into the gas in the form of bursts, there will occur, provided the monochromatic light beam 2 contains photons having the excitation frequency of the gas, pressure differences in the sealed casing 1, the frequency of said pressure differences being related to the interruption frequency of the monochromatic light beam. These pressure differences can be detected by a microphone 6 which feeds a corresponding electrical signal, optionally amplified, to a loudspeaker 8 via a cable 7. The consequence is that, if the monochromatic beam contains light having the excitation frequency of the unknown gas, the loudspeaker emits sound whose frequency corresponds to the interruption speed of the light beam. In this way, the gas species in the sealed space 1 can be detected.

Figure 2 shows diagrammatically a cross section through a hearing organ. The auricle of the ear is indicated by reference numeral 10, while reference numeral 11 indicates the ear canal of the ear. At least one ear radiator 25 or 26 is accommodated in the ear canal. In some cases, the use of two ear radiators in each ear canal may be beneficial, and this will be explained in greater detail below. The ear radiator(s) 25, 26 is/are connected to a microwave generator 9 which can be fitted in or near the ear. If ambient sound is to be fed to the hearing organ, a microphone 27 is coupled to the microwave generator 9, which microphone can also be fitted in or near the ear. The precise position of the microwave generator 9 and of the microphone 27 is not material to the present invention, although they are preferably situated in, or as much as possible in, the ear. The ear radiator(s) 25, 26 excite pulsed microwaves 28 which are transmitted in the direction of the eardrum 22. The microwaves 28 reach the cavity of the middle ear 15, in which the malleus 12, the incus 13 and the stapes 14 are situated, unattenuated or virtually unattenuated by the eardrum 22. The middle ear is connected to the cochlea 17 of the inner ear 18, the oval window 23 situated near the stapes and the round window drum 24 situated thereunder. Normally, sound vibrations transmitted via the eardrum 22 are transmitted via the malleus 12, the incus 13, the stapes 14 and the oval window 23 to the cochlea 17. In the cochlea 17, sound vibrations are mechanically converted into nerve impulses which can be sensed in the hearing cortex. The energy supplied to the cochlea 17 via the malleus 12, the incus 13, the stapes 14 and the oval window 23 travels in the direction indicated with the aid of an arrow into the uppermost cochlea canal 19 and leaves the cochlea 17 via the lowermost cochlea canal 20. The reference numeral 16 indicates semicircular canals in the hearing organ. The reference numeral 21 indicates the Eustachian tube, which connects the middle ear cavity 15 to the cavity of the larynx (which is not shown). The semicircular canal 16 and the cochlea 17 form together the inner ear 18.

The hearing aid shown operates as follows. Ambient noise is picked up by the microphone 27 and converted into corresponding electrical signals, which are fed to the microwave generator 9. The microwave generator 9 is designed in such a way that it generates bursts of microwaves, whose burst frequency is directly related to the noise frequencies of the ambient sound perceived. If, for example, there were a noise source producing a constant 50 Hz sound in the surroundings, the burst frequency would also be 50 Hz. The electrical signal originating from the microwave generator 9 is converted into electromagnetic microwave radiation 28 with the aid of the ear radiator(s) 25, 26. Said microwave radiation 28 is therefore also emitted in the form of bursts, the burst frequency being determined by the frequency of the ambient noise. The microwaves 28 transmitted in bursts reach the middle ear 15, which contains, normally, a gas mixture composed of oxygen and water vapour molecules. If, by analogy with the gas detection device according to Figure 1, the frequency of the microwaves present in the bursts now corresponds to one or more excitation frequencies of said gas mixture in the middle ear, pressure changes will consequently occur in said gas mixture in the middle ear 15, just as in the gas in the sealed space 1 in Figure 1. The frequencies with which said pressure changes are associated correspond to the burst frequencies of the pulsed microwaves. The pressure changes in the middle ear 15 are transmitted directly to the round window drum 24, which registers said pressure changes. As a result, sound vibrations occur in the round window drum 24 which correspond to the original vibrations of the ambient noise. These sound vibrations occurring in the round window drum 24 are converted into nerve impulses in the cochlea 17. It is pointed out that the energy presented to the hearing organ via the pulsed microwaves therefore travels, in fact, the reverse path to the direction indicated by the arrows in the canals 19 and 20. This nevertheless results in the original sound vibrations from the surroundings being perceived. To convert the original sound vibrations from the surroundings into nerve impulses in the cochlea 17, the eardrum 22, the malleus 12, the incus 13 and the stapes 14 are therefore, as it were, skipped. Middle ear deafness resulting from otosclerosis is therefore eliminated. (Otosclerosis is increasing deafness as a result of a disorder in the hearing organ which results in the stapes becoming immobile and it no longer being able to pass sound vibrations to the inner ear.)

Using the present hearing aid, however, inner ear deafness can also be eliminated, and this can be explained as follows. A microwave frequency can be imparted to pulsed microwaves emitted by the ear radiator(s) 25, 26 which is such that the pulsed microwaves reach the round window drum 24 virtually unattenuated by the eardrum 22 and the middle ear. Such bursts of microwaves will also radiate virtually unimpeded through the round window drum 24. By adjusting the frequency of the microwaves to a suitable value, a photoelectric effect can be excited in the fluid in the canals 19, 20 of the cochlea 17, as a result of which the nerve filaments situated therein excite electrical signals which can be heard by the brain. An important advantage of this is that a so-called cochlea implantation can be avoided. Complex operations undertaken for this purpose can therefore be dispensed with.

The microwave energy generated can be kept to a very low level in a simple way using the present hearing aid, enough energy nevertheless being generated to stimulate the nerve filaments in the cochlea 17. The intensity of the microwaves emitted may, for example, be 50 mW per mm^2, which is so low that the eardrum 22 is certainly not damaged. In addition, certainly no damaging heat is generated thereby in the hearing organ.

The frequency of the microwaves emitted in bursts depends on the intended application. If middle ear deafness is to be eliminated, the selected frequency of the microwaves should be such that the photoacoustic effect can occur in the middle ear 15, this being related to the precise composition of the gas situated therein. The microwave frequency may therefore vary to some extent from person to person. If, on the other hand, inner ear deafness is to be remedied, the selected frequency of the microwaves should be such that the photoelectric effect is able to occur in the canals of the cochlea, and this may also vary to some extent from person to person. Of course, it is also possible to design the ear radiator(s) 25, 26 in such a way that both microwaves 28 for eliminating middle ear deafness and microwaves 28 for eliminating inner ear deafness are emitted.

It is found that the present hearing aid can also be used to combat auditory hallucinations in psychosis patients (psychotic voices). For this purpose, the signal generated by the microwave generator 9 is fed to two ear radiators 25, 26. The two ear radiators 25, 26 emit microwaves which are directed at the eardrum 22. The microwaves 28 radiate virtually unimpeded through the eardrum 22 and reach the oval window 23. In this way, the microwaves 28 reach the endolymphatic fluid of the cochlea. The electric field of the microwaves is able to cause the fluid molecules in the cochlea 17 to vibrate, for example, at a frequency of 3.2 MHz, as a result of which fluid vibrations will occur. Said fluid vibrations correspond to the frequency of 3.2 MHz mentioned, or to a microwave length of approximately 9.5 cm. The microwave photons cause the concomitantly vibrating fluid molecules in the endolymph or perilymph to vibrate concomitantly, as a result of which specific hair cells in the cochlea 17 exceed a certain potential threshold value which results in action potentials. The action potentials of the hair cells secrete transmitter substances which block the postsynaptic receptors of the membrane dendrites of the ganglion spirale in a similar way to the neuroleptic blockers. Each hair cell has a specific threshold value coupled to a certain sound stimulus, with the result that each pitch is converted into a specific fluid vibration which stimulates a specific hair cell. Microwaves, on the other hand, directly cause the fluid to vibrate with the corresponding hair cells which block the receptors on the dendrites. The receptors can then no longer cause psychotic voices and these therefore disappear.

The eardrum 22 may have an interfering effect on the operation of the hearing aid. The eardrum 22 may, in fact, partly reflect incident microwaves 28, as a result of which reflected microwaves interfere with microwaves 28 radiating inwards. This can be avoided by polarising the microwaves so that, with a certain angle of incidence, reflection no longer occurs. In a vertically polarised microwave, the electrical force acts vertically and the magnetic force horizontally, both being perpendicular to the propagation direction. The microwaves thus pass unimpeded through the eardrum and reach and also irradiate the cochlea together with the ganglion spirale. The intended effect on the receptors of the dendrites in the ganglion spirale close to the cochlea will remain the same since the electric field and the magnetic field will move the receptors of the dendrites of the ganglion cells to a different absorption spectrum, which was also the purpose of the microwave application. To avoid nerve tissue damage or hyperthermia, 5 mW or higher per mm^2 is permissible. Heat is also removed via the blood flowing in the capillaries when the microwaves irradiate the cochlea.

Claims

1. Hearing aid, comprising at least one microwave generator which receives an electrical signal from a sound transducing unit, for example a microphone, and generates a frequency-modulated electrical signal composed of bursts, the burst frequency depending on the sounds picked up by the sound transducing unit, which frequency-modulated signal is fed to a radiator which generates microwave radiation made up of bursts, <u>characterized in that</u> at least the radiator (25, 26) of the hearing aid is situated in the ear canal (11) of a hearing organ and the microwave generator (9) is so designed that the burst frequencies are substantially equal to the sound frequencies of the sounds picked up by the sound transducing unit (27).

2. Hearing aid according to Claim 1, <u>characterized in that</u> the microwave frequency within the bursts is selected on the basis of the precise composition of the gas mixture in the middle-ear cavity (15) of the hearing organ in such a way that a photoacoustic effect occurs in the middle ear.

3. Hearing aid according to Claim 1, <u>characterized in that</u> the microwave frequency within the bursts is selected on the basis of the precise composition of the fluid in the cochlea (17) of the hearing organ in such a way that a photoelectric effect occurs therein.

4. Hearing aid according to Claim 1, <u>characterized in that</u> the microwaves within the bursts comprise two frequency components, one of which excites a photoacoustic effect in the middle ear and the other a photoelectric effect in the inner ear.

5. Hearing aid according to Claim 1, <u>characterized in that</u> two radiators (25, 26) are situated in the ear canal (11) and excite microwave radiation (28) having a wavelength of approximately 9.5 cm which is directed into the hearing organ in such a way that it is able to reach the cochlea (17) via the oval window in order to remedy auditory hallucinations.

Fig-1

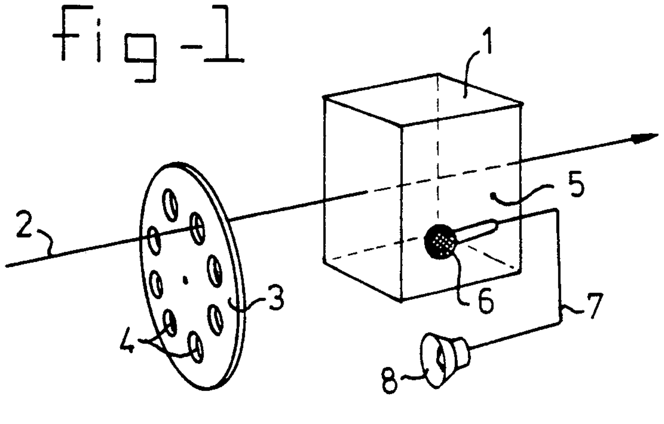
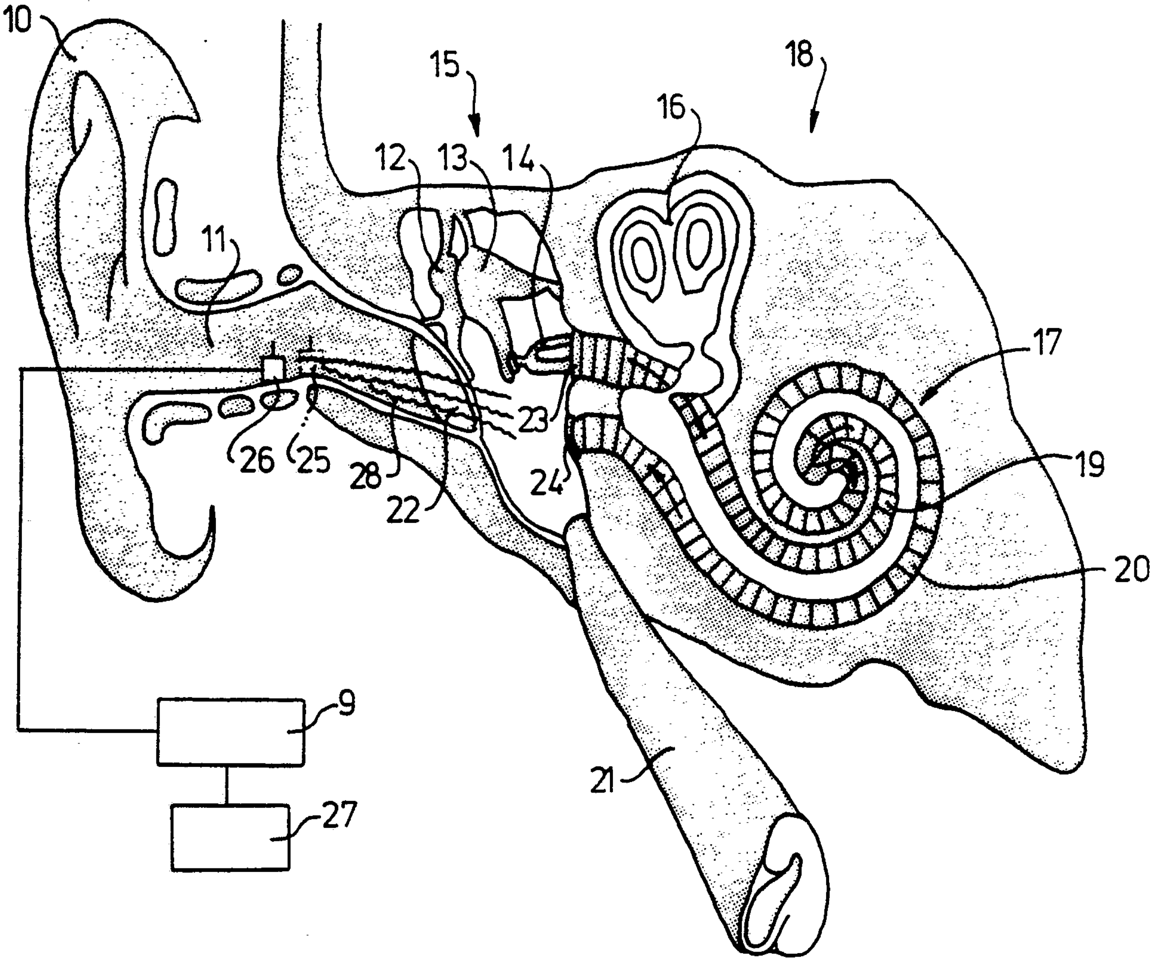


Fig-2



INTERNATIONAL SEARCH REPORT

International Application No PCT/NL 92/00216

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 A61F11/04

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	A61F ; A61N ; A61B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
A	US,A,4 877 027 (BRUNKAN) 31 October 1989 cited in the application see column 2, line 28 - line 39; figures	1
A	DATABASE WPIL Week 9223, 15 July 1991 Derwent Publications Ltd., London, GB; AN 89-653906 & SU,A,1 662 496 (KOSYAKOV ET AL.) see abstract	1
A	US,A,4 858 612 (STOCKLIN) 22 August 1989 see claims; figures	1

° Special categories of cited documents : [10]

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IV. CERTIFICATION

3

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
18 FEBRUARY 1993	02. 03. 93
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

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SA 68287

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-4877027	31-10-89	None	
US-A-4858612	22-08-89	None	

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