



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
29.12.2010 Bulletin 2010/52

(51) Int Cl.:
H04R 25/00 (2006.01) G06F 17/50 (2006.01)

(21) Application number: **09163861.9**

(22) Date of filing: **26.06.2009**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA RS

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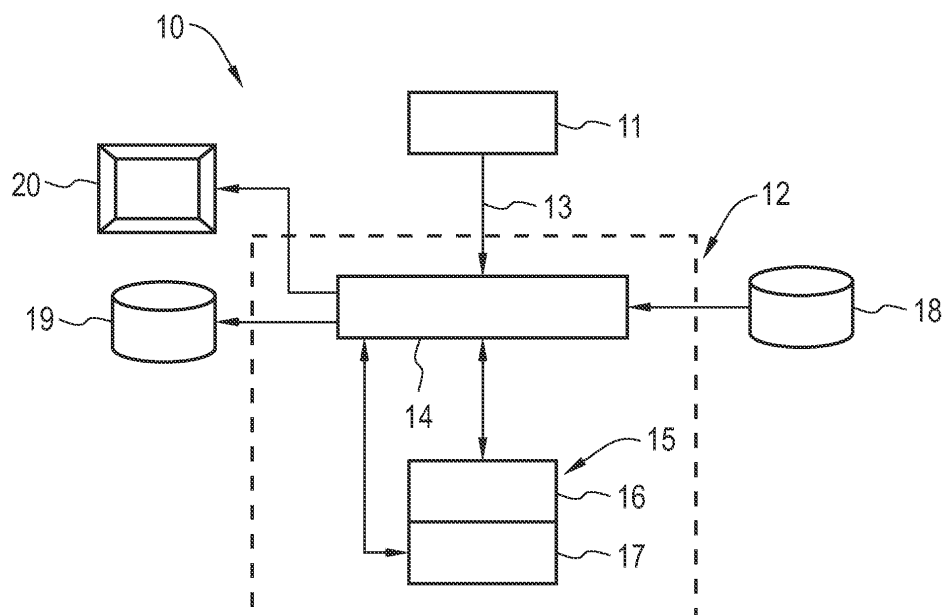
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(54) **System and method for customizing a hearing aid device**

(57) The present invention relates to a system and method for customizing a hearing aid device to a user. The proposed system (10) comprises means (16) for computing a three-dimensional geometric model of an external auditory canal of a user's ear based upon scan data corresponding to at least a portion of said external auditory canal. The proposed system (10) also includes means (16) for computing a three-dimensional geometric model of a hearing aid shell in-situ said computed three-

dimensional geometric model of said external auditory canal and for designating a position within said three-dimensional model of said hearing aid shell. The proposed system (10) further comprises means (17) for computing an acoustic frequency response of a simulated acoustic signal incident on said designated position, said acoustic frequency response being computed taking into account said geometric model of said external auditory canal.

FIG 2



Description

[0001] The present invention relates generally to a system and method for customizing a hearing aid device having at least one microphone. In particular the present system and method relate to hearing aid devices of the types in-the-ear (ITE), in-the-canal (ITC), or completely-in-canal (CIC).

[0002] Hearing aids are used for one or both ears in order to compensate for hearing loss in humans. Hearing aids are typically custom-made because most humans have different levels of hearing loss and different structures ear canal, meatus and/or concha. Depending on where they are worn by the user, hearing aids may be of several types, including behind-the-ear (BTE), in-the-ear (ITE), in-the-canal (ITC), and completely-in-canal (CIC), among others. A hearing aid typically comprises a shell or earmold that snugly fits into a portion of subject's ear and houses electronic and acoustic components. Such components include one or more microphones that receive input acoustic (sound) signals from the environment of the user. The microphones are connected to an amplifying unit arranged within the shell of the hearing aid. This amplifying unit drives a receiver which is acoustically coupled to the subject's ear canal via an acoustically conducting channel.

[0003] The input acoustic signal spectrum can be distorted by the position of the microphone of the hearing aid device at the head or near the ear, in the auditory canal. In the case of (ITE), in-the-canal (ITC), and completely-in-canal (CIC) devices, the frequency response of the input acoustic signal shows a resonance peak, which may, for example, assume values up to 15 dB, depending on the position of the microphone inside the ear. This acoustic effect is well known, and is known as the Microphone Location Effect (MLE). MLE is less pronounced for devices worn outside the ear, such as behind-the-ear (BTE) devices, where the frequency response of the input signal is comparatively flatter.

[0004] MLE is thus a function of the shape/structure of the user's ear and the position of the microphone inside the ear. For a given user, it is desirable to know the individual MLE so that its effect can also be taken into account for the settings of the hearing aid, especially where large individual variances can occur in ITE, ITC, and CIC devices. The measurement of the MLE is however tedious and cannot normally be done by the audiologist who does the adjustments. Therefore, in practice, the average statistical MLE curves are stored in a database. The individual MLE for a user may, for example, be determined based on a look up table, which includes a set of 'n' predefined MLE-shapes as a function of insertion depth of the hearing device's microphone. However, such statistical graphs provide approximate measurements and are hence not accurate for each individual.

[0005] The object of the present invention is to provide a system and method for customizing a hearing aid device to a user with an improved technique for computing

an acoustic frequency response of the input acoustic signal to the hearing aid device.

[0006] The above object is achieved by the system according to claim 1 and the method according to claim 6.

[0007] The underlying idea of the present invention is to model the acoustic effects on the input side of a hearing aid device based on a three-dimensional geometric scan data of corresponding to portion of the user's ear. Based on the geometric scan data of the ear, and the position of the microphone of the hearing aid device in the ear, an acoustic frequency response is computed for the input-side acoustic signal. For the audiologist or health care professional who does the customizing of the hearing aid device for different users, this gives rise to an advantage input side acoustic response can be modeled for each individual user with reasonable effort, which can be used for customizing the hearing aid device for the individual user.

[0008] In one embodiment, the proposed method further comprises directly scanning at least a portion of said external auditory canal to obtain said scan data. In an alternate embodiment, the proposed method further comprises scanning an impression of at least a portion of said external auditory canal to obtain said scan data

[0009] In a preferred embodiment, computing said three-dimensional geometric model of said hearing aid shell comprises adapting the shape of the three-dimensional geometric model of the hearing shell to conform to a shape of a portion of the computed three-dimensional geometric model of said external auditory canal. With this embodiment, the shape of the hearing aid shell can be customized to ensure proper fitting of the hearing aid shell to the user's external auditory canal to achieve satisfactory wearing comfort, reduction in acoustic feedback and unwanted changes in the electro-acoustic characteristics of the aid.

[0010] In one embodiment, said designated position is an intended microphone location and the computing of said acoustic frequency response comprises computing a microphone location effect. The individual MLE can be advantageously taken into account in the basic setting of the hearing aid device.

[0011] In an exemplary embodiment, computing said three-dimensional geometric model of said external auditory canal comprises geometrically measuring a scanned portion corresponding to said external auditory canal and for extrapolating the geometry of the remaining part of said external auditory canal. This eliminates the need for scanning the entire external ear canal of the user which is a cumbersome process.

[0012] In a preferred embodiment, to visually depict the acoustic transmission of the hearing device, the proposed method further comprises displaying a graphical representation of said acoustic frequency response corresponding to said hearing aid device in-situ said user's ear.

[0013] In a further embodiment, the proposed method further comprises storing the acoustic frequency re-

sponse computed for multiple users in a patient database.

[0014] In a still further embodiment, the hearing aid device is customized by pre-setting an amplification unit of a hearing aid device based on said computed acoustic frequency response. This embodiment reduces the number of steps in the fine tuning of hearing aid devices that are pre-set with special microphone measurements.

[0015] In a still further embodiment, the proposed method further comprises storing of said computed acoustic frequency response in said hearing aid device during manufacturing of said hearing aid device. This embodiment advantageously facilitates readout of individual MLE data for follow up fittings on a site other than where the user's ear was scanned originally.

[0016] In a further aspect of the present invention, computer program product is provided comprising computer readable media having computer readable program code embodied therein adapted for executing the actions of any of the methods mentioned above.

[0017] In yet another aspect of the present invention, a hearing aid device is provided that is customized by the any of the methods mentioned above.

[0018] The present invention is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawings, in which:

FIG 1 schematically shows a partial cross-section of the external ear with a hearing instrument partially inserted into the ear canal,

FIG 2 is a schematic diagram of a system for adapting a hearing aid device to a user according to one embodiment of the present invention, and

FIG 3 is a flowchart illustrating an exemplary method for making a hearing aid device customized to a user.

[0019] Referring to FIG 1 is shown a schematic drawing of a hearing aid device 1, wherein the present invention is applicable, the hearing aid device 1 at least partially inserted into an external auditory canal 2 (also referred to as "ear canal") of a user. The illustrated hearing aid device 1 is of the in-the-ear (ITE) type. However, the present invention also applies to devices of in-the-canal (ITC), or completely-in-canal (CIC) types. The hearing aid device 1 includes a shell or ear mold 2 that fits into a portion of the external ear canal 2. The hearing aid device 1 is provided with a microphone 4 located on the front side of the hearing aid shell for receiving input acoustic signals from the environment of the user and converting the acoustic signals into electrical signals. In certain cases, the device 1 may include multiple microphones in order to provide directional information of the sound to the user. The microphone 4 is connected to an amplifying unit 5 arranged within the hearing aid shell 3. The amplifying unit 5 increases the strength of the electrical signal from the microphone 4 and also filters and modifies the

response of the hearing aid device 1 to match the hearing loss of the user. A receiver 6 converts the amplified electrical signal from the amplifier unit 5 back into an acoustic signal. An acoustic conduct 7 couples the acoustic output of the receiver 6 to the user's ear canal 2. The present invention may be employed to customize the exemplary hearing aid device 1 by conveniently computing for an individual user, a frequency response of the input acoustic signal incident on the microphone 4 depending on the position of the microphone 4 inside the ear. Using this, the settings of the hearing aid device 1 can be customized for the user as described hereinafter.

[0020] FIG 2 shows a system for adapting/customizing a hearing aid device to a user according one embodiment of the present invention, which system is designated in entirety by reference numeral 10. The system 10 includes a scanning device 11 which digitizes the shape of a user's external ear canal and a computation device 12 that uses the digitized scan data from the scanning device 11 for computing a three-dimensional geometric model of the user's external ear canal with the hearing aid device in-situ and for subsequently computing an acoustic response of the user's ear with the hearing aid device.

[0021] In one embodiment, the scanning device 11 is adapted for performing a direct three-dimensional scan of the user's external ear canal or a portion thereof. In an alternate embodiment, the scanning device 11 may be adapted to perform a three-dimensional scan of an impression of at least a portion of the user's external ear canal. Thus scan data corresponding to the user's external ear canal can be obtained either by direct scan of a portion of the user's external ear canal or by scanning of an impression of a portion the user's external ear canal or by any other suitable means. The scan may be based, for example, on laser triangulation or light based computed tomography or any other known technique. The scanning device 11 may be operated, at the location of a dispenser. The term "dispenser" is in this context to be construed as a hearing care professional, such as a medical doctor, audiologist, or a hearing care trained person.

[0022] The digitized scan data corresponding to the user's external ear canal is communicated to the computation device 12 via communication link 13. The computation device 12 may be present at the location of the dispenser or at the location of manufacturing of the hearing aid device. In the latter case, the communication link 13 may include, for example, a computer network, television network, telecommunication network, or any combination thereof. The computation device 12 comprises processing means 15 and associated input/output (I/O) circuitry 14 for receiving the scan data from the scanning device 11. The processing means 15 may include, for example, a computer, a microcontroller, a field programmable gate array (FPGA), or a general purpose microprocessor, among others. The processing means 15 comprises functional subsystems, namely a geometric modeling subsystem 16 and an acoustic modeling subsystem. These subsystems 16 and 17 may, for example,

be implemented by software that is executable by the processing means 15.

[0023] The geometric modeling subsystem 16 is adapted for reconstructing the digitized scan data 12 and computing a three-dimensional geometric model of the user's external ear canal. Obtaining scan data of the entire external ear canal of a user may be a difficult and cumbersome process. Hence in one embodiment, the geometric modeling subsystem 16 may be adapted for computing the geometry of the entire external ear canal by geometrically measuring a scanned portion of the ear canal of the user and for extrapolating the geometry of the rest part of the external ear canal. This would advantageously eliminate the need for scanning the entire external ear canal. The geometric modeling subsystem 16 is also adapted for computing a three-dimensional geometric model of the shell of the hearing aid device in-situ (i.e., positioned within) the computed geometric model of the user's external ear canal, i.e., a composite three-dimensional geometric model of the hearing aid shell inserted into a portion of the user's external ear canal. Computation of the composite model of the hearing aid shell in-situ the ear canal thus involves computation of the geometric shape of the hearing aid shell as well the position of fit of the hearing aid shell within the ear canal. The position of fit of the hearing aid shell within the ear canal may be computed so as to achieve satisfactory wearing comfort, reduction in acoustic feedback and unwanted changes in the electro-acoustic characteristics of the aid. In one embodiment, the shape of the hearing aid shell is adapted to conform to the shape of a portion the user's external ear canal where the hearing device is to be fitted. This makes it possible to customize the shape of the hearing aid shell to ensure proper fitting of the hearing aid shell to the user's external ear canal.

[0024] In an alternate embodiment, the user may select a desired hearing aid product from a list of available hearing aid products contained in a database 18, which is fed to the processing means 15 via I/O circuitry 14. The geometric modeling subsystem 16 is in this case adapted to compute a composite geometric model of the shell of the selected hearing aid product in-situ the user's external ear canal. The digital representation or model of the hearing aid that is computed by the geometric modeling subsystem 16 may be based on a photograph or scan of the hearing aid product or may be based on a computer aided design or manufacturing (CAD/CAM) file of the hearing aid product.

[0025] Subsequent to computing the composite three-dimensional model of the hearing aid shell inserted within the user's ear canal, a position is designated within this composite three-dimensional model. In the illustrated example, this designated position is an intended microphone location. The acoustic modeling subsystem 17 then computes an acoustic frequency response of a simulated acoustic signal incident on this position of the microphone within the composite three-dimensional model, taking into account the computed geometry of the user's

external ear canal. The numerical computation by the acoustic modeling subsystem 17 may be based on a simulated acoustic signal comprising one or more frequencies propagating against the outer ear. The acoustic modeling subsystem 17 may be adapted, for example, to calculate a sound pressure level for a three-dimensional geometrical element corresponding to the location of the microphone, which may be normalized relative to the input acoustic signal. The acoustic modeling subsystem 17 thus calculates the frequency response of the input acoustic signal, which may include, for example, a graph of sound pressure level plotted as a function of frequency and angle of incidence. From the computed frequency response, the microphone location effect (MLE) be computed by determining resonance peak of the graph.

[0026] For hearing aid devices with multiple microphones, the individual MLE for each microphone can be computed as described above. The individual MLE/acoustic frequency response thus computed may be made available in suitable form to hearing aid device customization software. The computed MLE/acoustic frequency response for individual users may be stored in a patient database 18 of the customizing audiologist/dispenser or of the hearing aid device manufacturer and may also be displayed as a graphical representation to the customizing audiologist/dispenser or manufacturing personnel via display means 20 (such as a monitor). The present invention thus allows the customizing audiologist/dispenser or the hearing aid manufacturer to obtain individual MLEs with reasonable effort, for customizing the hearing device. The simulation curves in the software of the hearing device will then be able to simulate the acoustic transmission of the hearing device with that much more accuracy. The settings of the hearing aid device, for example, the amplifying unit, can then be pre-set or adjusted based on the computed MLE/acoustic frequency response. That is, the location effect of the microphone can be advantageously used to adjust the setting of the amplification unit. For example, the larger the individual MLE is per frequency, the lesser the amplification that needs to be provided by the hearing aid per frequency in order to compensate for the individual hearing loss. Especially in markets where the hearing devices are pre-set with special microphone measurements, the present invention reduces the number of steps in the fine tuning of the device, since the individual MLE is already taken into account in the basic setting of the hearing aid device.

[0027] FIG 3 is a flowchart illustrating an exemplary method S1 for making a hearing aid device customized to a user. The method S1 begins at step S2, by three-dimensional scanning of at least a portion of a user's external ear canal (or an impression thereof). This may be performed, for example, by a dispenser at a clinic. At step S3, the digitized scan data is utilized to re-construct a three-dimensional geometric model of the user's external ear canal. Step S3 may include, for example, geo-

metrically measuring a scanned portion corresponding to the external ear canal and for extrapolating the geometry of the remaining part of the external ear canal. Next, at step S4, a three-dimensional model of the shell of the hearing aid device is computed. In one embodiment, the shape of the hearing aid shell is adapted to a shape of a portion the user's external ear canal. In an alternate embodiment, the three-dimensional geometric model of the hearing aid shell is computed based on a selected hearing aid product by a user from a list of already available hearing aid products. At step S5, the position of the hearing aid device inside the user's ear is determined and a composite model is computed of the hearing aid shell positioned within the user's external ear canal. Within this composite model, the a position is designated, which may be, as mentioned earlier, an intended location for a microphone. Step S6 involves computation of an acoustic frequency response of a simulated acoustic signal incident on the position of the microphone taking into account the geometry of the external ear canal. In one embodiment, step S6 involves computing a microphone location effect (MLE) corresponding to the position of the microphone in the computed composite model. The computed frequency response/MLE may be stored in a patient database (step S7) and may also be displayed graphically to the audiologist/dispenser (step S8).

[0028] At step S9, the computed frequency response is communicated to the manufacturing center, along with the geometric model of the shell computed at step 4. At step S10, the shell of the hearing device is manufactured at the hearing aid device manufacturing center based on the computed geometric model of the shell, for example, using a direct manufacturing process such as selective-laser sintering, stereo lithography or digital light processing or using rapid prototyping equipment such as dedicated CAD 3D printing machines. Step S11 involves pre-setting or adjusting the settings of the components of the hearing aid device, such as the amplifying unit based on the MLE/acoustic frequency response computed at step S6. In a further embodiment, method S1 further comprises the step (S12) of storing the individual MLE in the individual hearing aid device during manufacturing process. This embodiment advantageously facilitates read-out of individual MLE data for follow up fittings on a site other than where the user's ear was scanned originally. Finally, at step S13, the electronic and acoustic/mechanical components of the hearing aid device are installed into the hearing aid shell manufactured at step S9, thus completing the manufacturing process of the hearing aid device.

[0029] As described earlier, aspects of the above described method may take the form of computer or controller implemented processes and apparatuses for practicing those processes. Aspects of the proposed method may also be embodied in the form of computer program code containing instructions embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, DVDs, or any other computer-readable storage medium, where-

in, when the computer program code is loaded into and executed by a computer or controller, the computer becomes an apparatus for practicing the invention. The techniques described may further be embodied in the form of computer program code or signal, for example, whether stored in a storage medium, loaded into and/or executed by a computer or controller, or transmitted over some transmission medium, such as over electrical wiring or cabling, through fiber optics, or via electromagnetic radiation, wherein, when the computer program code is loaded into and executed by a computer, the computer becomes an apparatus for practicing the invention.

[0030] When implemented on a general-purpose microprocessor, the computer program code segments configure the microprocessor to create specific logic circuits.

[0031] Summarizing, the present invention relates to a system and method for customizing a hearing aid device to a user. The proposed system comprises means for computing a three-dimensional geometric model of an external auditory canal of a user's ear based upon scan data corresponding to at least a portion of said external auditory canal. The proposed system also includes means for computing a three-dimensional geometric model of a hearing aid shell in-situ said computed three-dimensional geometric model of said external auditory canal and for designating a position within said three-dimensional model of said hearing aid shell. The proposed system further comprises means for computing an acoustic frequency response of a simulated acoustic signal incident on said designated position, said acoustic frequency response being computed taking into account said geometric model of said external auditory canal.

[0032] Although the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternate embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the spirit or scope of the present invention as defined by the below-mentioned patent claims.

Claims

1. A system (10) for customizing a hearing aid device, comprising:

- means (16) for computing a three-dimensional geometric model of an external auditory canal of a user's ear based upon scan data corresponding to at least a portion of said external auditory canal,
- means (16) for computing a three-dimensional geometric model of a hearing aid shell in-situ said computed three-dimensional geometric

- model of said external auditory canal and for designating a position within said three-dimensional model of said hearing aid shell, and
 - means (17) for computing an acoustic frequency response to a simulated acoustic signal incident on said designated position, said acoustic frequency response being computed taking into account said geometric model of said external auditory canal.
2. The system (10) according to claim 1, wherein said means (16) for computing said three-dimensional geometric model of said hearing aid shell is configured to adapt the shape of the three-dimensional geometric model of the hearing shell to conform to a shape of a portion of the computed three-dimensional geometric model of said external auditory canal.
 3. The system (10) according any of the preceding claims, wherein said designated position is an intended microphone location and said computed acoustic frequency response includes a microphone location effect.
 4. The system (10) according to any of the preceding claims, wherein said means (16) for computing said three-dimensional geometric model of said external auditory canal is adapted for geometrically measuring a scanned portion corresponding to said external auditory canal and for extrapolating the geometry of the remaining part of said external auditory canal.
 5. The system (10) according to any of the preceding claims, further comprising means (20) for displaying a graphical representation of said acoustic frequency response corresponding to said hearing aid device in-situ said user's ear.
 6. A method (S1) for customizing a hearing aid device, comprising:
 - computing (S3) a three-dimensional geometric model of an external auditory canal of a user's ear based upon scan data corresponding to at least a portion of said external auditory canal,
 - computing (S5) a three-dimensional geometric model of a hearing aid shell in-situ said computed three-dimensional geometric model of said external auditory canal and designating a position within said three-dimensional model of said hearing aid shell, and
 - computing (S6) an acoustic frequency response to a simulated acoustic signal incident on said position taking into account said geometric model of said external auditory canal.
 7. The method (S1) according to claim 6, further comprising directly scanning (S2) at least a portion of said external auditory canal to obtain said scan data.
 8. The method (S1) according to claim 6, further comprising scanning (S2) an impression of at least a portion of said external auditory canal to obtain said scan data.
 9. The method (S1) according to any of claims 6 to 8, wherein computing (S5) said of three-dimensional geometric model of said hearing aid shell comprises adapting (S4) the shape of the three-dimensional geometric model of the hearing shell to conform to a shape of a portion of the computed three-dimensional geometric model of said external auditory canal.
 10. The method (S1) according to any of claims 6 to 9, wherein said designated position is an intended microphone location and computing (S6) of said acoustic frequency response comprises computing a microphone location effect.
 11. The method (S1) according to any of claims 6 to 10, wherein said computing (S3) of said three-dimensional geometric model of said external auditory canal comprises geometrically measuring a scanned portion corresponding to said external auditory canal and for extrapolating the geometry of the remaining part of said external auditory canal.
 12. The method (S1) according to any of claims 6 to 11, further comprising displaying (S7) a graphical representation of said acoustic frequency response corresponding to said hearing aid device in-situ said user's ear.
 13. The method (S1) according to any of claims 6 to 12, further comprising storing (S8) the acoustic frequency response computed for multiple users in a patient database.
 14. The method (S1) according to any of claims 6 to 13, further comprising pre-setting or adjusting (S11) an amplification unit of said hearing aid device based on said computed acoustic frequency response.
 15. The method (S1) according to any of claims 6 to 14, further comprising storing (S12) of said computed acoustic frequency response in said hearing aid device during manufacturing of said hearing aid device.
 16. A computer program product comprising computer readable media having computer readable program code embodied therein adapted for executing the actions of the method according to any of claims 6 to 13.
 17. A hearing aid device (1) customized by a method according to any of claims 6 to 15.

FIG 1

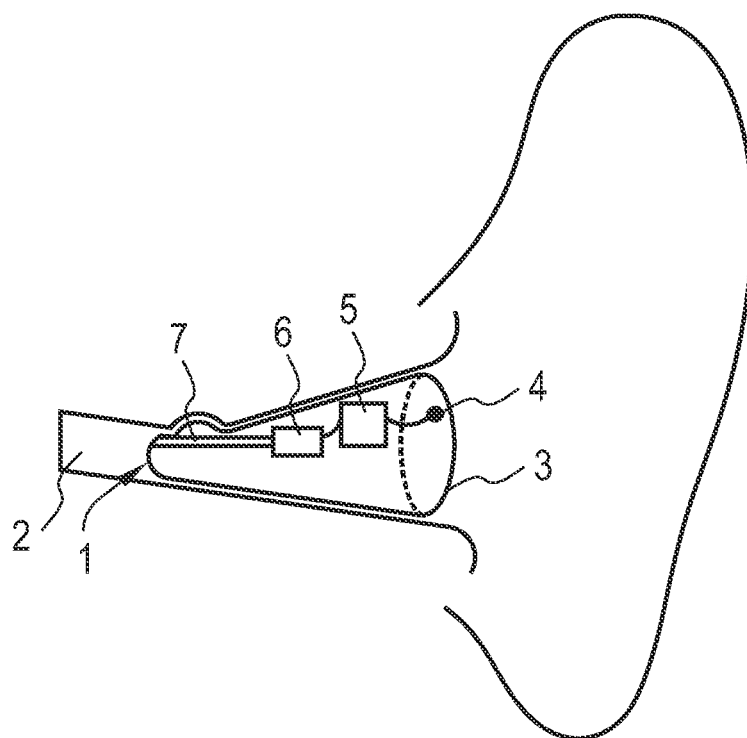


FIG 2

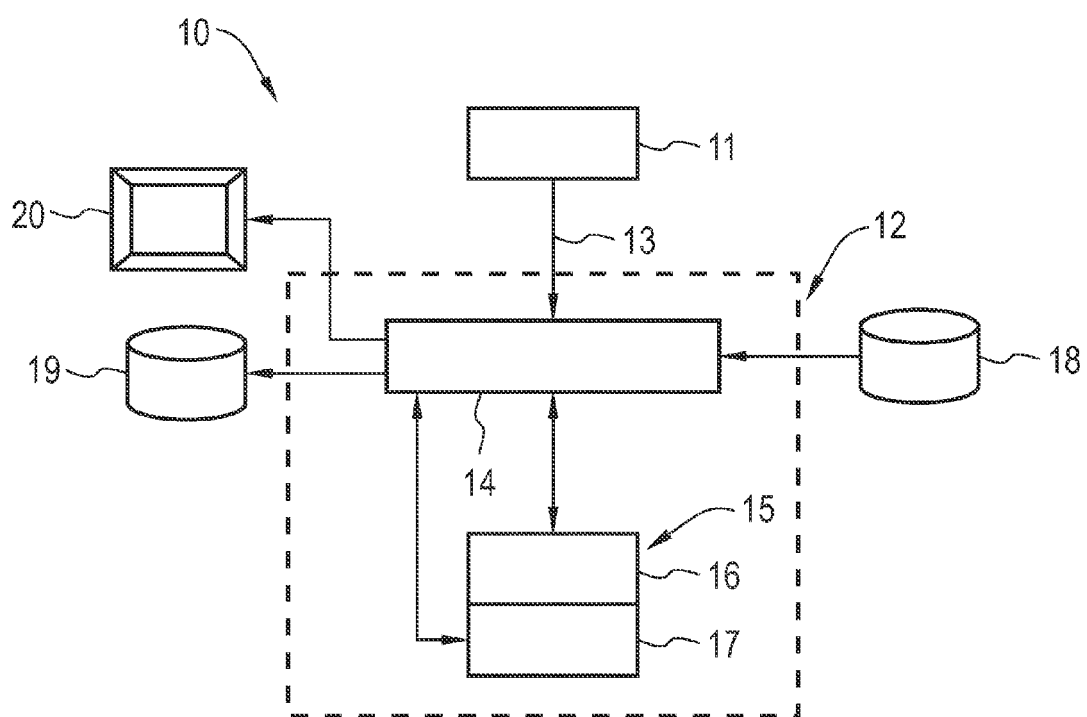
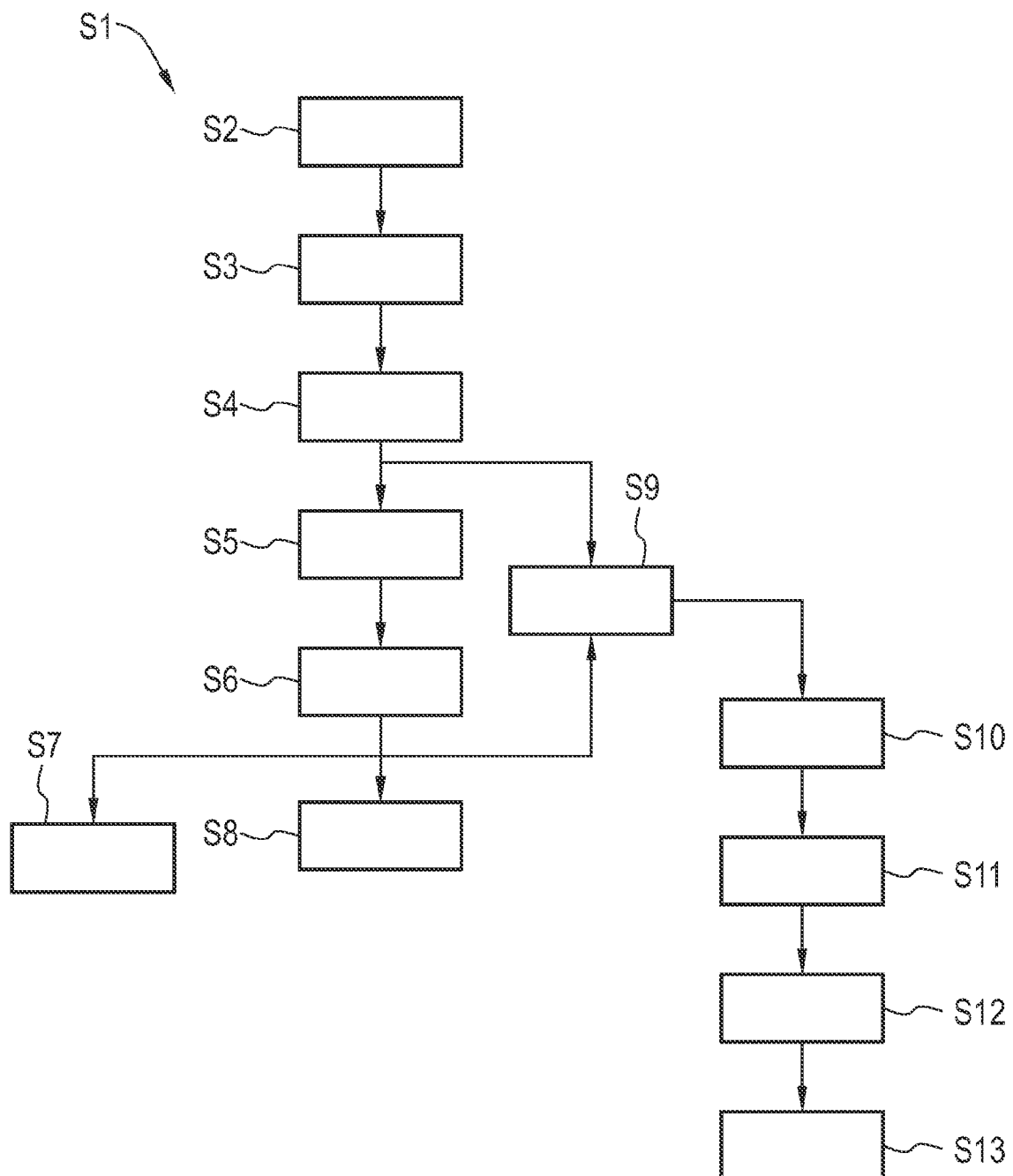


FIG 3





EUROPEAN SEARCH REPORT

Application Number
EP 09 16 3861

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 October 2009	Examiner Duffner, Orla
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 09 16 3861

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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