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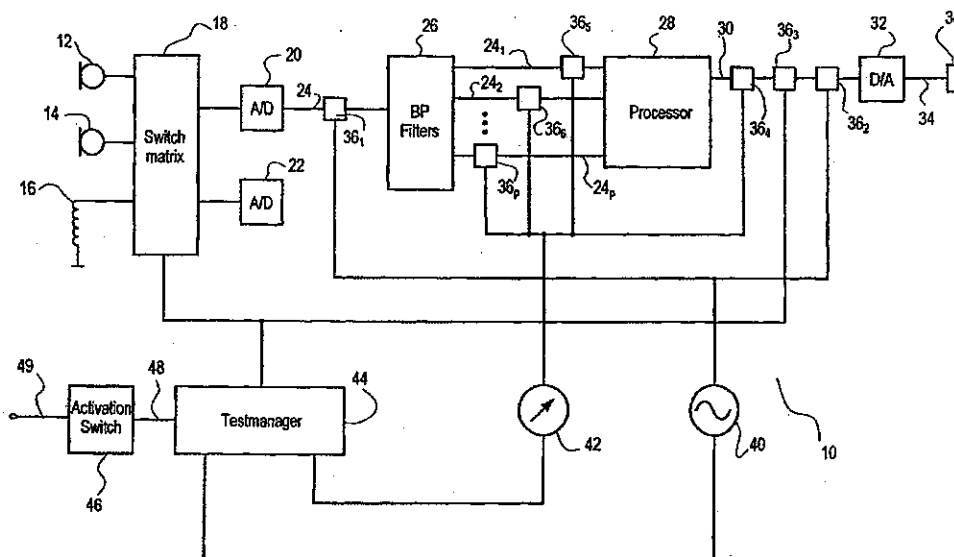
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(54) Title: HEARING AID AND A METHOD FOR TESTING A HEARING AID



(57) Abstract: A hearing aid (10) with a test manager (44) for detection of a defect in the signal path of the hearing aid is provided. The test manager controls a test stimulus generator (40) and a probe (42) for determination of a signal parameter, such as signal level, frequency spectrum, phase characteristic, auto-correlation, cross-correlation, etc. A set of signal switches 36₁, 36₂, ..., 36_p controlled by the test manager is provided for connecting a selected test stimulus generator or a selected probe to a selected point in the signal path for testing of a selected part of the hearing aid. Signal switches (18) are provided for coupling hearing aid components into and out of the signal path of the hearing aid.

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HEARING AID AND A METHOD FOR TESTING A HEARING AID

The present invention relates to hearing aids and to the testing of hearing aids. The invention more specifically relates to a hearing aid having a self-test capability.

It is well-known in the art of hearing aids that a large fraction of hearing aids turned in for
5 repair later prove to operate correctly. Thus in many cases, a perceived problem with a hearing aid does not relate to a defect in the hearing aid, rather it relates to the adjustment and use of the hearing aid. A lot of time and other resources are wasted in shipping and diagnosing hearing aids that are not defect.

It is therefore desirable to provide a hearing aid with a self-test capability, permitting an
10 operator of the hearing aid to verify the proper functioning of the hearing aid. The operator of the hearing aid may be the hearing impaired user of the hearing aid or an audiologist engaged in fitting, fine tuning or otherwise working with the hearing aid.

According to the present invention in a first aspect, the above-mentioned and other objects are fulfilled by a hearing aid having an input transducer for transforming an acoustic input signal
15 into a first electrical signal, a signal processor for compensating a hearing deficiency by generation of a second electrical signal based on the first electrical signal, an output transducer for conversion of the second electrical signal into sound, a probe for determination of a signal parameter, a plurality of signal switches at respective points in a signal path of the hearing aid extending through the input transducer, the signal processor and the output transducer, and a
20 test manager adapted to control the settings of the signal switches to connect the probe to a selected first point of the signal path in order to conduct a test procedure of a selected section of the signal path.

According to the invention in a second aspect, the above-mentioned and other objects are fulfilled by a method for verifying the functioning of a hearing aid, the hearing aid having an
25 input transducer for transforming an acoustic input signal into a first electrical signal, a signal processor for compensating a hearing deficiency by generation of a second electrical signal based on the first electrical signal, an output transducer for conversion of the second electrical signal into sound, and a probe for determination of a signal parameter, the method comprising providing a plurality of signal switches at respective points in a signal path of the hearing aid
30 extending through the input transducer, the signal processor and the output transducer, and using a test manager to control the settings of the signal switches to connect the probe to a

selected first point of the signal path in order to conduct a test procedure of a selected section of the signal path.

- Further the hearing aid may comprise a test controller or a test manager for detection of a state of malfunction in a hearing aid. The test manager may be connected with a test stimulus
- 5 generator, such as a tone generator, a noise generator, a digital word generator, etc, with a probe means for determination of a signal parameter, such as signal level, frequency spectrum, phase characteristic, auto-correlation, cross-correlation, etc, and with a signal switch provided in the hearing aid. The signal switch is provided for connecting a test stimulus generator or a probe to a selected point in the signal path for testing of a selected part of the hearing aid.
- 10 Further signal switches may be provided for coupling hearing aid components into or out of the signal path of the hearing aid.

The signal path may comprise components and transmission paths of the hearing aid that receive, process and transmit signals that are derived from the first electrical signal of the hearing aid.

- 15 For example, the test manager may be adapted to operate respective signal path switches to disconnect the input transducer from the signal path at the entry to the hearing aid processor and to activate a probe means for determination of the signal level at a selected or predetermined point at a later stage of the signal path whereby the noise level generated by parts of the hearing aid processor such as the input circuitry may be determined.
- 20 The value of a signal parameter as determined by the probe may be compared to a reference value that may be retrieved from a memory in the hearing aid or from a device external to the hearing aid. If the detected value lies outside a predetermined range comprising the reference value, the test manager may alert the operator of the hearing aid that the hearing aid is malfunctioning. The type of defect may also be signaled. For example, a tone or a sequence of
- 25 tones may be generated by the output transducer to signify to the hearing impaired user that the hearing aid is defective. A specific tone or a specific sequence of tones may correspond to a specific defect.

- If the hearing aid is connected to a hearing aid programming device equipped with a display, the fact that the hearing aid is malfunctioning may be indicated on the display and, further, an
- 30 indication of the type of defect may be displayed. For example, if the noise level is greater than a predetermined reference value, it may be signaled that the hearing aid is malfunctioning.

Typically, hearing deficiency is frequency dependent in a way that is specific for each individual user. It is known in the art to provide a multichannel hearing aid, wherein the processor is divided into a plurality of channels so that individual frequency bands may be processed differently, e.g. amplified with different gains. A multichannel hearing aid may

5 further comprise a filter bank with bandpass filters for dividing the first electrical signal into a set of bandpass filtered first electrical signal derivatives, and the processor may be adapted to

generate the second electrical signal by individual processing of the respective first electrical signal filter derivatives and adding the processed filter derivatives together to provide the second electrical signal. For a multichannel hearing aid, the test manager may be adapted to selectively connect a desired test stimulus generator or a desired probe to the output of a selected bandpass filter. For example, a probe for level detection may be connected to the output of a selected bandpass filter in order to determine the noise level in a respective frequency band.

In one embodiment of the invention, a test stimulus generator is provided that is controlled by the test manager for generation of a predetermined test stimulus that is fed to the output transducer of the hearing aid for conversion into a sound signal. For one type of test, the hearing aid will be placed in a compartment with hard walls, wherein a part of the generated acoustic signal will be reflected to be received by the acoustic input transducer. The test manager is further adapted to operate a signal switch to connect a selected probe, such as a level detector, etc, to the input transducer for determination of a signal parameter, such as the signal level, of the respective generated first electrical signal.

The determined value of the signal parameter may be compared to a reference value that may be retrieved from a memory in the hearing aid, and if the detected value deviates from the reference value, the test manager may, as previously described, alert the operator of the hearing aid that the hearing aid is malfunctioning. The type of defect may also be signaled. For example, the display of a programming device may show a message saying that the port to the input transducer in question should be checked for ear wax.

One of the input transducers connected to the signal path may be the pick-up coil. The pick-up coil in the hearing aid may be tested in a way similar to the one described previously for an acoustic input transducer, since the output transducer typically generates a significant magnetic field that is picked up by the pick-up coil.

In an embodiment with a filter bank, the probe may be connected to the output of a selected bandpass filter to determine the signal level of the first electrical signal filter derivative in the corresponding frequency band. The probe may be sequentially connected to the outputs of more or all of the bandpass filters to determine the signal parameter in question in more or all frequency bands. In this way the frequency spectrum of the generated first electrical signal may be determined, or harmonic distortion may be determined. For example, the test manager may be adapted to connect a selected probe for level detection to the output of a bandpass filter that

picks out a third harmonic of the output of the test stimulus generator for determination of harmonic distortion.

Signal switches may be provided for connecting a test stimulus generator, such as a tone generator to the input of the signal processor, and for connecting a probe to the output of the signal processor whereby the gain of the signal processor may be determined. Further, the gain of the signal processor may be determined as a function of the frequency.

Further, the compression of the signal processor, i.e. gain as a function of input level may be determined, e.g. as a function of frequency.

It is known in the art to include in the hearing aid an adaptive feedback canceller comprising an adaptive filter to compensate for acoustic feedback. Acoustic feedback may occur in case the input transducer of a hearing aid receives and detects the acoustic output signal generated by the output transducer. Amplification of the detected signal may lead to generation of a stronger acoustic output signal, which may loop to the input, and eventually the hearing aid may oscillate. The adaptive filter estimates the transfer function from output to input of the hearing aid including the acoustic propagation path from the output transducer to the input transducer. The input of the adaptive filter is connected to the output of the hearing aid and the adaptive filter works out an appropriate countersignal, which is subtracted from the input transducer signal to cancel out any acoustic feedback. A hearing aid of this type is disclosed in US 5,402,496.

The test manager may be adapted to verify operation of the adaptive feedback canceller, e.g. the test manager may control a signal switch to disconnect the feedback canceller from the signal path and increase the gain of the signal processor until oscillation occurs. During this test, the hearing aid is preferably placed in a compartment with hard walls. The test manager may further be adapted to reconnect the adaptive feedback canceller to the signal path whereby oscillation should cease if the adaptive feedback canceller operates correctly.

In an embodiment, the hearing aid comprises a test stimulus generator for injection of a digital signal at a selected second point in the digital part of the signal path of the hearing aid, e.g. at the input of the signal processor.

In response to the signal injected at the second point, a properly functioning hearing aid will generate a signal with certain parameter values at the selected first point in the signal path. The parameters may relate to frequency, amplitude, spectrum, modulation, phase, etc. These

parameter values may be compared to canonic values obtained by subjecting a known good hearing aid to a similar test. The test manager may further be adapted to compare the parameter values of the actual response signal with the canonic values to determine whether the hearing aid is malfunctioning. If a detected value lies outside a predetermined range comprising the
5 respective canonic value, it may be concluded that the tested hearing aid is malfunctioning. The presence of a defect may be signaled to the operator of the hearing aid as previously described.

A self-test procedure may be initiated upon user activation of a switch positioned on the hearing aid housing, on a hearing aid programming device, on a remote control unit for the hearing aid, or on a fitting system, etc. Preferably two switches must be activated
10 simultaneously or sequentially to avoid accidental activation of the self-test.

Still other objects of the present invention will become apparent to those skilled in the art from the following description wherein the invention will be explained in greater detail. By way of example, there is shown and described a preferred embodiment of this invention. As will be realized, the invention is capable of other embodiments, and its details are capable of
15 modification in various, obvious aspects all without departing from the invention. Accordingly, the drawings and descriptions will be regarded as illustrative in nature and not as restricting the scope of the invention. In the drawing:

Fig. 1 shows a blocked schematic of a hearing aid according to the present invention, and
Figs. 2-5 show respective self-test messages as displayed on a programming device for the
20 hearing aid according to the present invention, and

Fig. 6 shows a test set-up according to an embodiment of the invention.

Fig. 1 shows a hearing aid 10 having as input transducers two acoustic microphones 12, 14 and an electromagnetic pick-up coil 16, also referred to as a telecoil. A signal switch matrix 18 selectively connects each of the input transducers 12, 14, 16 to a selected A/D converter 20, 22.
25 For simplicity, the connections of the output of the second A/D converter 22 are not shown. The output signal 24 from A/D converter 20 is split by a set 26 of bandpass filters into a set of bandpass filtered signal derivatives $24_1, 24_2, \dots, 24_n$. The processor 28 is divided into a plurality of channels so that individual frequency bands may be processed differently, e.g. amplified with different gains. The processor 28 generates the second electrical signal 30 by individual
30 processing of each of the first electrical signal filter derivatives $24_1, 24_2, \dots, 24_n$ and adding together the processed electrical signals to provide the second electrical signal 30. A D/A

converter 32 converts the digital output signal 30 to an analogue signal 34. An output transducer 38 converts the analogue signal 34 into sound.

It will be obvious for the person skilled in the art that the circuits indicated in Fig. 1 may be implemented using digital or analogue circuitry or any combination hereof. In the present embodiment, digital signal processing is employed and thus, the signal processor 28 and the filter bank 26 are digital signal processing circuits. In the present embodiment, all the digital circuitry of the hearing aid 10 may be implemented on a single digital signal processing chip or, the circuitry may be distributed on a plurality of integrated circuit chips in another way.

Signal switches $36_1, 36_2, \dots, 36_p$ are provided at a number of points of the signal path of the hearing aid circuitry for connecting a test stimulus generator 40, e.g., a tone generator 40, or a probe 42, e.g. a level detector 42, to the various points in the signal path of the hearing aid 10. A test manager 44 controls the settings of the signal switches $36_1, 36_2, \dots, 36_p$ for conducting a test procedure in various sections of the signal path of the hearing aid 10. For simplicity, the control lines connecting the test manager 44 with each of the respective signal switches $36_1, 36_2, \dots, 36_p$ are not shown in Fig. 1. The test manager 44 further controls the signal switch matrix 18 for connecting microphones 12, 14 and pick-up coil 16 to and disconnecting them from the signal path of the hearing aid 10. Further, the test manager 44 is adapted to control the test stimulus generator 40, e.g. to generate an electrical signal of a selected frequency, e.g. 1 kHz, e.g. with a selected amplitude and/or frequency modulation, and to control the probe 42 for determination of a selected signal parameter, such as the rms value.

The test manager 44 may comprise a memory for the storage of data such as identification of the type of hearing aid, calibration data of the transducers and canonic values of test parameters.

For example, the noise level in the second frequency band may be determined by the test manager 44 by controlling the signal switch matrix 18 to disconnect all of the input transducers 12, 14, 16 from the A/D converters 20, 22 and connecting the level detector 40 to the output 24_2 of a bandpass filter 26_2 . Then, a first one of the acoustic transducers is connected to the respective input and the output signal level is determined. Subsequently, the first acoustic transducer is disconnected and a second one of the acoustic transducers is connected to the respective input and the output signal level is determined. The levels may be compared. Assuming a steady noise background, the levels should be similar, and thus a difference would signify a calibration error or a malfunction in one of the acoustic input transducers or the respective associated input stage.

In a further test stage, the telecoil is connected to its respective A/D converter and the output signal level detected. As the telecoil will normally be able to pick up electromagnetic background noise, the output signal level may be expected to be different from the level without the telecoil. If no difference is established, it may be assumed that there is a malfunction in the telecoil or the related input stage.

In general, the test manager 44 may control the signal switch 36₁ to connect the test stimulus generator 40 to the input of the signal processing circuitry 26, 28 and simultaneously disconnect the input from other signal sources, and the signal switch 36₄ to connect the probe 42 to the output of the signal processor 28 facilitating test of any of the signal processing algorithms performed in the signal processing circuitry 26, 28. For any particular test stimulus to be generated by the test stimulus generator 40, canonic values of the output signal obtained by applying a similar test stimulus to a known good signal processor may be stored in a memory (not shown) in the hearing aid 10. Thus, during the a test procedure the test manager 44 may compare the parameters of the detected output signal of the signal processor 28 with the corresponding canonic values in order to determine whether the hearing aid 10 is malfunctioning.

A signal switch 36₃ for interrupting the path of the signal 30 before the signal switch 36₂, and controlled by the test manager 44 is further provided. Having intercepted the signal 30, the test manager activates the tone generator 40 to generate a signal of a selected frequency, e.g. 1 kHz, that is fed to the output transducer 38 of the hearing aid 10 for conversion into a sound signal. During this test, the hearing aid 10 will be placed in a compartment with hard walls so that a substantial part of the generated acoustic signal is received by the acoustic input transducers 12, 14. The test manager 44 further controls signal switch 36₁ to connect probe 42 to one of the acoustic input transducers 12, 14 for determination of the signal level of the respective first electrical signal derivative in the respective frequency band i.

Reference is now made to Fig 6 for a description of a test set-up according to an embodiment of the invention. In this set-up, the hearing aid 10 is connected to a programming device 50 by way of a cable 53 and placed in an upwards open compartment 51 with hard walls. The compartment 51 may basically be any compartment with the capability of reflecting at least part of the transducer output signal to the microphone. A cup-like structure of stainless steel in the shape of a cylinder with open top and a flat, closed bottom, with a diameter of 70 mm, a height of 100 mm and a wall thickness of 0.3 mm, has been found well suited. The hearing aid is simply placed in random orientation on the bottom of the cup.

The self-test is initiated upon reception of a signal 48 from the activation means 46. The activation means may be constituted by one or more switches positioned on the housing of the hearing aid 10 or the activation means may comprise interface means that is adapted to receive a command 49 for initiation of the self-test from an external device, such as a remote control unit, a hearing aid programming device 50, a fitting device, a personal computer, etc.

For example, the hearing aid 10 may be connected to a hearing aid programming device 50 with a display 52. The operator may initiate the self-test by pressing a specific key or set of keys 54 on the programming device 50. Then the device 50 displays that it is ready to perform a self-test procedure as shown in Fig. 2. The self-test is then launched upon activation of key 56. The programming device transmits a corresponding command to the activation means 46 of the hearing aid 10 and indicates that the self-test is in progress as shown in Fig. 3.

During the test, messages may be displayed on the display. The messages may call for user interaction. E.g. the test described in the previous section may reveal that the signal picked up by one of the microphones 12, 14 is lacking. A probable cause may be that the input port to the respective microphone has been occluded by ear wax. Thus the operator is asked to check if this is the problem (ref. Fig. 4). If no problems have been revealed during the self-test, a corresponding message is displayed, as shown in Fig. 5.

The input transducer connected to the signal path may be the pick-up coil 16. The pick-up coil 16 in the hearing aid 10 may be tested like an acoustic input transducer 12, 14, since the output transducer 38 typically generates a significant magnetic field that may be picked up by the pick-up coil 16.

The test manager 44 controls the signal switch matrix 18 to disconnect all of the input transducers 12, 14, 16 from the signal path, and connects the test stimulus generator 40 to the signal path through signal switch 36₁. The probe 42 is connected to the output of the signal processor 28 through signal switch 36₄. By controlling the test stimulus generator 40 to generate a sequence of signals with different frequencies, the gain of the signal processor 28 is determined as a function of the frequency.

Further, the compression of the signal processor 28, i.e. gain as a function of input level may be determined, e.g. as a function of frequency.

CLAIMS

1. A hearing aid having an input transducer for transforming an acoustic input signal into a first electrical signal, a signal processor for compensating a hearing deficiency by generation of a second electrical signal based on the first electrical signal, an output
5 transducer for conversion of the second electrical signal into sound, a probe for determination of a signal parameter, a plurality of signal switches at respective points in a signal path of the hearing aid extending through the input transducer, the signal processor and the output transducer, and a test manager adapted to control the settings of the signal switches to connect the probe to a selected first point of the signal path in order to conduct
10 a test procedure of a selected section of the signal path.
2. The hearing aid according to claim 1, wherein the test manager is adapted to disconnect the input transducer from the remaining part of the signal path and to activate the probe for determination of the signal level at the selected first point.
3. The hearing aid according to claim 1 or 2, comprising a test stimulus generator controlled
15 by the test manager for applying a test stimulus at a second point in the signal path.
4. The hearing aid according to claim 3, wherein the test manager is adapted to compare the parameters of the signal generated at the first point with canonic values in order to determine whether the hearing aid is malfunctioning.
5. The hearing aid according to claim 3 or 4, wherein the second point is selected so that the
20 test stimulus is converted into a sound signal, and wherein the test manager is adapted to connect the probe to the input transducer.
6. The hearing aid according to any of the preceding claims, comprising two acoustic input transducers, wherein the test manager is adapted to determine a signal level in respect of each of the acoustic transducers and to compare the respective signal levels.
- 25 7. The hearing aid according to any of the preceding claims, comprising an electromagnetic input transducer.
8. The hearing aid according to any of the preceding claims, comprising a filter bank with bandpass filters for dividing the first electrical signal into a set of bandpass filtered first electrical signal derivatives, wherein the processor is adapted to generate the second
30 electrical signal by individual processing of each of the first electrical signal derivatives

and adding the processed electrical signals together to provide the second electrical signal, and wherein the test manager is adapted to selectively connect the probe to the output of one of the bandpass filters.

- 5 9. The hearing aid according to claim 8, wherein the test manager is adapted to connect the probe to the output of a bandpass filter selected to pick a third harmonic of the output of the test stimulus generator for determination of harmonic distortion.
- 10 10. The hearing aid according to any of the claims 2-9, wherein the test manager is adapted to verify at least one parameter selected from a group comprising the gain of the signal processor, the gain of the signal processor as a function of frequency and the compression of the signal processor.
11. The hearing aid according to any of the claims 2-10, comprising an adaptive feedback canceller for suppression of acoustic feedback, and wherein the test manager is adapted to verify operation of the adaptive feedback canceller.
- 15 12. The hearing aid according to any of the claims 2-11, comprising activation means for activating the test manager to initiate the self test.
13. The hearing aid according to claim 12, wherein the activation means comprises interface means that is adapted to receive commands from a remote control device used to operate the hearing aid, a fitting device or a programming device used to program the hearing aid.
- 20 14. A method for verifying the functioning of a hearing aid, the hearing aid having an input transducer for transforming an acoustic input signal into a first electrical signal, a signal processor for compensating a hearing deficiency by generation of a second electrical signal based on the first electrical signal, an output transducer for conversion of the second electrical signal into sound, and a probe for determination of a signal parameter, the method comprising providing a plurality of signal switches at respective points in a signal path of the hearing aid extending through the input transducer, the signal processor and the output transducer, and using a test manager to control the settings of the signal switches to connect the probe to a selected first point of the signal path in order to conduct a test procedure of a selected section of the signal path.
- 25 15. The method according to claim 14, comprising using the test manager to disconnect the input transducer from the remaining part of the signal path and to activate the probe to determine the signal level at the selected first point.
- 30

16. The method according to claim 14 or 15, comprising using the test manager to control a test stimulus generator for applying a test stimulus at a second point in the signal path.
17. The method according to claim 16, comprising comparing the parameters of the signal generated at the first point with canonic values in order to determine whether the hearing aid is malfunctioning.
18. The method according to claim 16 or 17, comprising selecting the second point to obtain that the test stimulus is converted into a sound signal, connecting the probe to the input transducer, placing the hearing aid in a compartment with hard walls and determining the signal picked up by the input transducer.
19. The method according to claim 18, comprising using the test manager in a hearing aid comprising two acoustic input transducers to determine a signal level in respect of each of the acoustic transducers, and comparing the respective signal levels.
20. The method according to any of the claims 14-19, comprising using a filter bank with bandpass filters for dividing the first electrical signal into a set of bandpass filtered first electrical signal derivatives, processing of each of the first electrical signal derivatives and adding the processed electrical signals together to provide the second electrical signal, and using the test manager to selectively connect the probe to the output of one of the bandpass filters.
21. The method according to claim 20, comprising using the test manager to connect the probe to the output of a bandpass filter selected to pick a third harmonic of the output of the test stimulus generator for determination of harmonic distortion.
22. The method according to any of the claims 15-21, comprising using the test manager to verify a parameter such as the gain of the signal processor, the gain of the signal processor as a function of frequency or the compression of the signal processor.
23. The method according to any of the claims 15-22, comprising using the test manager in a hearing aid with an adaptive feedback canceller to verify operation of the adaptive feedback canceller.