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(54) **Apparatus for testing directionality in hearing instruments**

Vorrichtung zum Testen der Direktionalität in Hörgeräten

Appareil permettant de tester la directivité dans des appareils auditifs

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Description

[0001] The present disclosure relates to apparatus for testing a hearing instrument and method related thereto and in particular to an apparatus for testing directionality of a hearing instrument.

BACKGROUND

[0002] Many modern hearing instruments include signal processing which allows the hearing instrument to amplify the sound arriving from one direction (typically from the front of the hearing instrument user), while attenuating the sound from other directions. A simple test to verify this functionality will present pure tones at various frequencies, from the front of the hearing instrument and from another direction, in two separate measurements.

[0003] This type of test will work well if the hearing instrument is working in a simple mode where the amplification is nearly independent of the type of signals presented to its microphone(s).

[0004] However, with the recent development of advanced hearing instruments, the signal processing functions in the hearing instrument may include adaptation to the received signal. Specifically, one type of algorithm may detect the presence or absence of speech in the microphone signal(s), and process the signal(s) in order to optimize speech perception for the hearing instrument user. Such an algorithm may classify pure tone signals as non-speech or noise and suppress the signals, leading to an incorrect measurement of the directionality characteristics.

[0005] Attempts to avoid the suppression of the directionality test signal have been described in the literature, e.g. by presenting simultaneous tones over a broad spectrum, some hearing instrument algorithms are more likely to detect the test signal as "speech" and thereby allow for a test of directionality.

[0006] Although this method may be effective in some situations, the trend towards more advanced speech processing algorithms in hearing instruments leads to a desire to use natural signals as stimuli.

[0007] US2005053250 AA discloses a method and apparatus for testing a directional acoustic device such as a directional hearing aid having level-dependent non-linear circuitry, in which two or more speakers are placed at desired positions relative to the hearing aid, e.g. in front and behind the hearing aid. The speakers are excited simultaneously with broadband excitation signals formed from components which are orthogonal to each other, e.g. sinusoids, where the bin frequencies of the Direct Fourier Transform ("DFT") of one excitation signal are different from the bin frequencies of the other excitation signal. Thus, the response to each excitation signal can easily be extracted without filtering, allowing the directional characteristics of the hearing aid to be evaluated.

[0008] "A Dual-Channel MLS-Based Test System for Hearing-Aid Characterization" by Schneider et al., Journal of the Audio Engineering Society, Audio Engineering Society, New York, NY, US, vol. 41, no. 7/08, 1 July 1993 (1993-07-01), page 583-594, discloses that a dual-channel maximum-length-sequence test system has been implemented to characterize the electroacoustic performance of hearing aids. The system applies a frequency-shaped maximum-length sequence to a hearing aid as an acoustic stimulus and measures the acoustic response of the aid in an IEC standard occluded-ear simulator. Measurements are completed in one-third the time required for noise-based measurements, and the responses measured by the system compare favorably to those measured via conventional noise-based methods.

SUMMARY

[0009] There is a need for an apparatus and method for testing directionality of a hearing instrument using natural signals, such as speech, traffic noise, cocktail party noise etc. Furthermore, it is desirable to be able to present signals from more directions of the hearing instrument simultaneously to allow the hearing instrument algorithms to perform as intended.

[0010] Accordingly, an apparatus for testing a directional hearing instrument is provided according to claim 1. Also disclosed is a method for testing a directional hearing instrument according to claim 7. It is an advantage of the present disclosure that it provides a high degree of freedom in the choice of test signals, i.e. the first signal and the second signal (e.g. front and back). Hence, with the present invention test signals resembling real life situations may be chosen, and any suppression of artificial test signals may be avoided, and the directionality of the hearing instrument may be tested in situations as will be experienced by the end user.

[0011] The method for testing a directional hearing instrument may be incorporated in the apparatus as also disclosed. Furthermore any elements or procedural steps as described in connection with any one aspect may be used with any other aspects or embodiments, mutatis mutandis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above and other features and advantages of the present disclosure will become readily apparent to those skilled in the art by the following detailed description of exemplary embodiments thereof with reference to the attached

drawings, in which:

Fig. 1 schematically illustrates an exemplary apparatus for testing a directional hearing instrument,

5 Fig. 2 schematically illustrates an exemplary processing unit for an exemplary apparatus for testing a directional hearing instrument,

Fig. 3 shows a flow diagram of an exemplary method for testing a directional hearing instrument,

10 Fig. 4 shows an illustrative example of determining the first cross spectrum function,

Fig. 5 shows an example of power spectrums of an exemplary first signal and an exemplary second signal,

15 Fig. 6 shows an example of exemplary hearing instrument parameters obtained from testing a hearing instrument operating in an omni-directional mode, and

Fig. 7 shows an example of exemplary hearing instrument parameters obtained from testing a hearing instrument operating in a directional mode.

20 DETAILED DESCRIPTION

[0013] The figures are schematic and simplified for clarity, and they merely show details which are essential to the understanding of the invention, while other details have been left out. Throughout, the same reference numerals are used for identical or corresponding parts.

25 **[0014]** The first signal may be directed towards a first input transducer of the hearing instrument, such as a front input transducer of the hearing instrument. The second signal may be directed towards a second input transducer of the hearing instrument, such as a rear input transducer of the hearing instrument. The first speaker may be configured for transmitting the first signal towards the first input transducer of the hearing instrument, such as the front input transducer of the hearing instrument. The second speaker may be configured for transmitting the second signal towards the second input transducer of the hearing instrument, such as the rear input transducer of the hearing instrument.

30 **[0015]** The first signal and/or the second signal may be a speech signal. The first signal and/or the second signal may be a speech signal in a language such as English, Danish, German, French, Arabic, Chinese, Japanese, Spanish. The first signal and/or the second signal may be the International Speech Test Signal (ISTS). ISTS is an internationally recognized test signal based on natural recordings of speech. The ISTS reflects a female speaker for six different mother tongues (American English, Arabic, Chinese, French, German, and Spanish).

35 **[0016]** The first signal and/or the second signal may be a noise signal. The first signal and/or the second signal may be a random noise signal. The first signal and/or the second signal may be a random noise signal with a characteristic power spectrum, e.g. flat, decaying, increasing, and/or variable over a range of frequencies. For example, the first signal and/or the second signal may be white noise, pink noise, Brownian noise, blue noise, violet noise, grey noise.

40 **[0017]** The first and/or the second signal may be a natural sounding noise signal, e.g. a mix of other speech signals, traffic noise. The first signal and/or the second signal may be a noise signal comprising a plurality of speech signals, e.g. the first signal and/or the second signal may be cocktail party noise and/or a babble noise.

[0018] In an exemplary apparatus and/or method, the first signal is a speech signal, e.g. the ISTS, and the second signal is a noise signal, e.g. a random noise signal and/or a natural sounding noise signal.

45 **[0019]** Transmission of the second signal, or transmission of a second part of the second signal, may be simultaneous with transmission of the first signal, or transmission of a first part of the first signal. Simultaneous transmission of the first signal and the second signal may decrease test time and/or increase quality of the test since the hearing instrument is subjected to a situation resembling a real life situation. Accordingly, the first and second signal may have an overlap in time. For example, the first signal and the second signal may overlap in one or more overlap periods. An overlap period, e.g. a first overlap period, may have a duration of at least 2 seconds.

50 **[0020]** The first microphone may be a directional microphone. The first microphone may be shielded to avoid receiving sound transmitted from the first and/or second speakers. The coupling of the first microphone with the output of the hearing instrument may be obtained by providing an acoustic tube between the first microphone and the output of the hearing instrument. Provision of an acoustic tube between the output of the hearing instrument and the first microphone may avoid or decrease reception of sound transmitted from the first speaker and/or second speaker.

55 **[0021]** The processing unit may be connected to the first microphone. The processing unit may be connected to the first speaker. The processing unit may be connected to the second speaker.

[0022] The apparatus may be configured to transmit the first signal with the first speaker and/or transmit the second

signal with the second speaker. The apparatus may be configured to receive an audio output signal from the hearing instrument with the first microphone.

[0023] The apparatus, i.e. the processing unit of the apparatus, is configured to perform a cross spectrum analysis of the first signal and the audio output signal. The apparatus, i.e. the processing unit of the apparatus, is configured to perform a cross spectrum analysis of the second signal and the audio output signal.

[0024] Determining one or more hearing instrument parameters is based on cross spectrum analysis of the second signal and the audio output signal. Determining one or more hearing instrument parameters is based on cross spectrum analysis of the first signal and the audio output signal and cross spectrum analysis of the second signal and the audio output signal.

[0025] The apparatus, i.e. the processing unit of the apparatus, is configured to determine one or more hearing instrument parameters based on cross spectrum analysis of the second signal and the audio output signal. The apparatus, i.e. the processing unit of the apparatus, is configured to determine one or more hearing instrument parameters based on cross spectrum analysis of the first signal and the audio output signal and cross spectrum analysis of the second signal and the audio output signal.

[0026] The apparatus, e.g. the processing unit of the apparatus, may be configured to obtain a power spectrum of the first signal and/or the second signal and/or the audio output signal. The apparatus, e.g. the processing unit of the apparatus, may be configured to obtain a cross spectrum of the first signal and the audio output signal. The apparatus, e.g. the processing unit of the apparatus, may be configured to obtain a cross spectrum of the second signal and the audio output signal.

[0027] Power spectrum and/or cross spectrum of a signal, such as the first signal and/or the second signal and/or the audio output signal and/or any combinations hereof, may be obtained by cross spectrum analysis.

[0028] The first signal has a first frequency component at a first frequency, and the second signal has a second frequency component at a second frequency. The difference between the first frequency and the second frequency may be less than 10 Hz, such as less than 5 Hz, such as less than 1 Hz. The first signal and the second signal may have overlapping frequency components, such as the first frequency component and the second frequency component. The first frequency and the second frequency may be the same frequency, or substantially the same frequency.

[0029] The frequency components, such as the first frequency component and/or the second frequency component, may have a certain magnitude. The frequency components, such as the first frequency component and/or the second frequency component, may have a certain magnitude relative to each other. The magnitude of the frequency components may be measured in units of decibel sound pressure level (dBSPL). A relationship, such as a ratio and/or a difference, between the first frequency component, e.g. measured in dB SPL, and the second frequency component, e.g. measured in dB SPL, may be in the range from 0.2 to 5.

[0030] The one or more hearing instrument parameters may comprise a first hearing instrument parameter and/or a second hearing instrument parameter and/or a third hearing instrument parameter. The one or more hearing instrument parameters may comprise a plurality of hearing instrument parameters comprising the first hearing instrument parameter and/or the second hearing instrument parameter and/or the third hearing instrument parameter.

[0031] The one or more hearing instrument parameters may comprise a first transfer function. The first transfer function may be based on the first signal and the audio output signal.

[0032] The first hearing instrument parameter and/or the second hearing instrument parameter and/or the third hearing instrument parameter may be the first transfer function. The first transfer function may be a front-to-output transfer function of the hearing instrument. A front-to-output frequency response of the hearing instrument may be obtained based on the first transfer function.

[0033] The one or more hearing instrument parameters may comprise a second transfer function. The second transfer function may be based on the second signal and the audio output signal.

[0034] The first hearing instrument parameter and/or the second hearing instrument parameter and/or the third hearing instrument parameter may be the second transfer function. The second transfer function may be a rear-to-output transfer function of the hearing instrument. A rear-to-output frequency response of the hearing instrument may be obtained based on the second transfer function.

[0035] The first transfer function and/or second transfer function may be obtained using dual channel DFT, such as dual channel FFT analysis. Dual channel DFT comprises cross spectrum analysis. The first transfer function may be obtained using dual channel DFT of the first signal and the audio output signal. The second transfer function may be obtained using dual channel DFT of the second signal and the audio output signal. The apparatus, e.g. the processing unit of the apparatus, may be configured to perform a dual channel DFT of the first signal and the audio output signal. Additionally or alternatively, the apparatus, e.g. the processing unit of the apparatus, may be configured to perform a dual channel DFT of the second signal and the audio output signal.

[0036] The one or more hearing instrument parameters may comprise a front-to-back ratio. The front-to-back ratio may be based on the first transfer function and the second transfer function. The front-to-back ratio may be based on the first transfer function and the second transfer function, wherein the first transfer function may be based on the first

signal and the audio output signal and the second transfer function may be based on the second signal and the audio output signal. The front-to-back ratio may be a ratio of the first transfer function and the second transfer function.

[0037] The first hearing instrument parameter and/or the second hearing instrument parameter and/or the third hearing instrument parameter may be the front-to-back ratio.

[0038] The first signal and the second signal may be at least partly separate in time. The first signal and the second signal may have one or more instances during transmission where they are indistinguishable. However, over time the first signal and the second signal are distinguishable, i.e. the first signal and the second signal has one or more instances during transmission where they are distinguishable.

[0039] The first signal and the second signal may be very different, e.g. in contents of frequency components and/or time variation. For example, the cross correlation (time lag =0) between the first signal and the second signal may be less than a first threshold. Thus, determining of one or more hearing instrument parameters may be performed with short test signals and/or short test time.

[0040] The first signal and the second signal may be very similar, e.g. less different, e.g. in contents of frequency components and/or time variation. For example, the cross correlation (time lag =0) between the first signal and the second signal may be larger than a second threshold. Similarity of the first signal and the second signal may follow from using natural signals. However, the first signal and the second signal may be different in at least a plurality of instances during the test duration, such as the complete duration of the first signal and/or second signal. For example, the first signal may be a speech signal and the second signal may be a noise signal, e.g. a noise signal comprising a plurality of speech signals.

[0041] The first signal may be a finite signal with a first duration. The second signal may be a finite signal with a second duration. The first duration and/or the second duration may be between 1-30 seconds, such as between 5-20 seconds, such as between 10-15 seconds. The first duration and the second duration may be the same, or substantially the same. The first duration and the second duration may differ by less than 3 second, such as less than 2 seconds, such as less than 1 second.

[0042] Cross spectrum analysis of the first signal and the audio output signal and/or cross spectrum analysis of the second signal and the audio output signal may comprise segmenting the first signal and/or the second signal and/or the audio output signal in a plurality of segments. The segments, e.g. each of the plurality of the segments or a group of segments may have durations between 10-400 ms, such as between 30-300 ms, such as between 50-200 ms, such as between 70-150 ms. The segments, e.g. each of the plurality of the segments or a group of segments, may have the same duration.

[0043] Cross spectrum analysis of the first signal and the audio output signal and/or cross spectrum analysis of the second signal and the audio output signal may comprise averaging over cross spectrum analysis of a plurality of segments of the first signal and/or the second signal and/or the audio output signal.

[0044] Fig. 1 schematically illustrates an exemplary apparatus 50 for testing a directional hearing instrument 2. The apparatus 50 comprises: a first microphone 52 for coupling with an output 4 of the hearing instrument 2; a first speaker 54 for transmission of a first signal 56; and a second speaker 58 for transmission of a second signal 60.

[0045] A directional hearing instrument, such as the directional hearing instrument 2 as illustrated, comprises a first input transducer 6, a second input transducer 8, an output 4, and a hearing instrument processing unit 10. The first input transducer 6 and the second input transducer 8 is typically positioned to primarily detect acoustic signals from opposite or approximately opposite directions. For example, the first input transducer 6 may be a front input transducer, and the second input transducer 8 may be a rear input transducer. The directional hearing instrument 2 furthermore comprises a hearing instrument housing 12. The first input transducer 6, the second input transducer 8, the output 4, and the hearing instrument processing unit 10 are contained in the hearing instrument housing 12.

[0046] The first speaker 54 transmits the first signal 56 towards the first input transducer 6 of the hearing instrument 2. The second speaker 58 transmits the second signal 60 towards the second input transducer 8 of the hearing instrument 2. The first input transducer 6 may detect the second signal 60, or a fraction of the second signal 60. The second input transducer 8 may detect the first signal 56, or a fraction of the first signal 56.

[0047] The apparatus 50 is configured to: transmit the first signal 56, transmit the second signal 60, and receive an audio output signal 5 from the hearing instrument 2. The first signal 56 and the second signal 60 are acoustic signals. The first signal has a first frequency component at a first frequency, and the second signal has a second frequency component at a second frequency. The first frequency and the second frequency may be the same and/or overlapping, e.g. the difference between the first frequency and the second frequency may be less than 10 Hz. The first signal 56 and the second signal 60 may comprise contents at one or more common frequencies. A relationship, such as a ratio or difference, between the first frequency component and the second frequency component measured in sound pressure, such as dB SPL, may be in the range from 0.1 to 20, such as in the range from 0.1 to 10, such as in the range from 0.2 to 5.

[0048] The apparatus 50 may transmit the first signal 56 from the first speaker 54 simultaneously, or within less than 5 ms, such as within less than 1 ms, of transmitting the second signal 60 from the second speaker 58. The first signal 56 and the second signal 60 may be different over time. For example, the first signal 56 and the second signal 60 may

have one or more instances during transmission where they are indistinguishable, but over time they are distinguishable, i.e. the first signal 56 and the second signal 60 has one or more instances during transmission where they are distinguishable.

[0049] The apparatus 50 is furthermore configured to determine one or more hearing instrument parameters based on cross spectrum analysis of the first signal 56 and the audio output signal 5. The apparatus 50 may furthermore be configured to determine one or more hearing instrument parameters based on cross spectrum analysis of the second signal 60 and the audio output signal 5.

[0050] The apparatus 50 furthermore comprises an apparatus processing unit 64. The apparatus processing unit 64 is connected to the first microphone 52, the first speaker 54, and the second speaker 58. The apparatus processing unit 64 receives, from the first microphone 52 an input signal 66 indicative of the audio output signal 5 of the hearing instrument 2.

[0051] The apparatus processing unit 64 may be configured to determine the one or more hearing instrument parameters. Furthermore, the apparatus processing unit 64 may be configured to control the first speaker 54 to transmit the first signal 56 by transmitting a first speaker signal 68 indicative of the first signal 56, and/or the apparatus processing unit 64 may be configured to control the second speaker 58 to transmit the second signal 60 by transmitting a second speaker signal 70 indicative of the second signal 60.

[0052] The one or more hearing instrument parameters may comprise a first transfer function based on the first signal 56 and the audio output signal 5. The first transfer function may be based on cross spectrum analysis of the first signal 56 and the audio output signal 5.

[0053] The one or more hearing instrument parameters may comprise a second transfer function based on the second signal 60 and the audio output signal 5. The second transfer function may be based on cross spectrum analysis of the second signal 60 and the audio output signal 5.

[0054] The one or more hearing instrument parameters may be a front-to-back ratio (sometimes also referred to as a front-to-rear ratio), e.g. a ratio of the first signal 56 and the second signal 60 in the received audio output signal 5. The front-to-back ratio may be determined from a ratio of a cross spectrum analysis of the first signal 56 and the audio output signal 5 and a cross spectrum analysis of the second signal 60 and the audio output signal 5. The front-to-back ratio may be determined by a ratio between the first transfer function and the second transfer function.

[0055] The apparatus 50 comprises an apparatus housing 62. The housing 62 comprise the first microphone 52, the first speaker 54, and the second speaker 58. In the apparatus 50, as depicted, the apparatus housing comprises the processing unit 64. In other exemplary apparatuses (not shown), the processing unit 64 may be external to the apparatus housing 62, e.g. the processing unit 64 may be a processing unit of a laptop, a smartphone, a tablet computer, or any other device.

[0056] The apparatus 50 further comprises an optional interface 72 for providing an output to a user or an additional device. The interface 72 may be a display, a wireless transmitter unit, an interface speaker, and/or a connector. The wireless transmitter may be a Bluetooth transmitter, a WiFi transmitter, a 3G transmitter, and/or a 4G transmitter. The connector may be a USB connector, a FireWire connector, and/or a custom connector. The interface 72 may connect the apparatus to an external device, such as a laptop, a smart phone, a tablet computer, and/or a PC.

[0057] Fig. 2 schematically illustrates an exemplary processing unit 64 for an exemplary apparatus 50 for testing a directional hearing instrument 2. The processing unit 64 comprises: a first tone generator 74, a second tone generator 76, a first cross spectrum analyzer 78, and a second cross spectrum analyzer 80. The first tone generator 74 provides the first speaker signal 68 indicative of the first signal 56 to the first speaker 54 and the first cross spectrum analyzer 78. The second tone generator 76 provides the second speaker signal 70 indicative of the second signal 60 to the second speaker 58 and the second cross spectrum analyzer 80. The first cross spectrum analyzer 78 and the second cross spectrum analyzer 80 furthermore receive the input signal 66 indicative of the audio output signal 5.

[0058] The first cross spectrum analyzer 78 determines one or more hearing instrument parameters based on cross spectrum analysis of the first signal 56 and the audio output signal 5. The cross spectrum analysis of the first signal 56 and the audio output signal 5 may be based on the first speaker signal 68 indicative of the first signal 56 and the input signal 66 indicative of the audio output signal 5. The first cross spectrum analyzer 78 provides a first analyzer output 82 comprising the determined one or more hearing instrument parameters, such as a first transfer function or a first cross spectrum function of the first signal 56 and the audio output signal 5.

[0059] The second cross spectrum analyzer 80 determines one or more hearing instrument parameters based on cross spectrum analysis of the second signal 60 and the audio output signal 5. The cross spectrum analysis of the second signal 60 and the audio output signal 5 may be based on the second speaker signal 70 indicative of the second signal 60 and the input signal 66 indicative of the audio output signal 5. The second cross spectrum analyzer 80 provides a second analyzer output 84 comprising the determined one or more hearing instrument parameters, such as a second transfer function or a second cross spectrum function of the second signal 56 and the audio output signal 5.

[0060] The first analyzer output 82 and the second analyzer output 84 may be provided to the interface 72 and/or a second processing unit. The first analyzer output 82 and the second analyzer output 84 may be combined to form a

processing unit output, i.e. the first analyzer output 82 and the second analyzer output 84 may be combined to determine a front-to-back ratio of the hearing instrument 2. Alternatively and/or additionally, the first analyzer output 82 and the second analyzer output 84 may be provided individually.

[0061] Fig. 3 shows a flow diagram of an exemplary method 100 for testing a directional hearing instrument 2. The method comprises: transmitting 102 a first signal 56 through a first speaker 54; transmitting 104 a second signal 60 through a second speaker; receiving 106 an audio output signal 5 from the hearing instrument 2; and determining 108 one or more hearing instrument parameters based on the first signal 56 and the audio output signal 5.

[0062] The first signal 56 has a first frequency component at a first frequency. The second signal 60 has a second frequency component at a second frequency. The first frequency and the second frequency may be substantially the same frequency and/or the difference between the first frequency and the second frequency may be less than 10 Hz, such as less than 5 Hz, such as less than 2 Hz.

[0063] Determining 108 one or more hearing instrument parameters is based on cross spectrum analysis of the first signal 56 and the audio output signal 5. Additionally, determining 108 one or more hearing instrument parameters may be based on cross spectrum analysis of the second signal 60 and the audio output signal 5.

[0064] Transmitting 102 the first signal 56 and transmitting 104 the second signal 60 may be interchanged and/or performed simultaneously. Transmitting 102 the first signal 56 and transmitting 104 the second signal 60 may be performed simultaneously to resemble a natural occurring situation e.g. a situation comprising speech from a front direction and noise from a rear direction.

[0065] The one or more hearing instrument parameters may comprise a first hearing instrument parameter. The first hearing instrument parameter may be a function of frequency. The first hearing instrument parameter may be a front-to-back ratio, e.g. a ratio of the first signal 56 and the second signal 60. The front-to-back ratio may be based on a first transfer function and a second transfer function. The first transfer function may be based on the first signal 56 and the audio output signal 5, e.g. based on cross spectrum analysis of the first signal 56 and the audio output signal 5. The second transfer function may be based on the second signal 60 and the audio output signal 5, e.g. based on cross spectrum analysis of the second signal 60 and the audio output signal 5.

[0066] The determining 108 of the one or more hearing instrument parameters, such as the first hearing instrument parameter, such as the front-to-back-ratio, may comprise determining the first transfer function based on cross spectrum analysis of the first signal 56 and the audio output signal 5, determining the second transfer function based on cross spectrum analysis of the second signal 60 and the audio output signal 5, and determining a ratio of the first transfer function and the second transfer function.

[0067] The method 100, or parts of the method 100, may be implemented in an apparatus such as the apparatus 50 for testing a directional hearing instrument. Alternatively and/or additionally the method 100, or parts of the method 100, may be implemented in a processing unit, such as the apparatus processing unit 64 of an apparatus 50 for testing a directional hearing instrument 2. Alternatively and/or additionally, the method 100, or part of the method 100, may be implemented in software adapted to be executed in a processing unit, e.g. a processing unit of a personal computer, a laptop, a smartphone, or a tablet computer. Particularly, the determining 108 of the one or more hearing instrument parameters may be implemented in a processing unit and/or in software adapted to be executed in a processing unit.

[0068] One or more hearing instrument parameters may comprise a first transfer function, such as a first transfer function between the first signal and the audio output signal, a second transfer function, such as a second transfer function between the second signal and the audio output signal, and/or a front-to-back ratio, such as a front-to-back ratio between the first transfer function and the second transfer function. All of these functions may be a function of frequency (f).

[0069] In an exemplary method and/or apparatus, the first transfer function may be determined by:

- determining a first cross spectrum function ($G_{1,0}(f)$) between the first signal (x_1) and the audio output signal (y_o) by cross spectrum analysis of the first signal and the audio output signal,
- determining a first power spectrum function ($G_{1,1}(f)$) of the first signal, and
- determining the first transfer function ($H_1(f)$) of the first signal and the audio output signal based on the first cross spectrum function and the first power spectrum function, e.g. a ratio of the first cross spectrum function and the first power spectrum function:

$$H_1(f) = \frac{G_{1,0}(f)}{G_{1,1}(f)}$$

[0070] In an exemplary method and/or apparatus, the first signal (x_1) may be a front signal, and/or the first transfer function may be a front-to-output frequency response for the hearing instrument.

[0071] The second transfer function may be determined by:

- determining a second cross spectrum function ($G_{2,o}(f)$) between the second signal (x_2) and the audio output signal (y_o) by cross spectrum analysis of the second signal and the audio output signal,
- determining a second power spectrum function ($G_{2,2}(f)$) of the second signal, and
- determining the second transfer function ($H_2(f)$) of the second signal and the audio output signal based on the second cross spectrum function and the second power spectrum function, e.g. a ratio of the second cross spectrum function and the second power spectrum function:

$$H_2(f) = \frac{G_{2,o}(f)}{G_{2,2}(f)}$$

[0072] In an exemplary method and/or apparatus, the second signal (x_2) may be a rear signal, and/or the second transfer function may be a rear-to-output frequency response for the hearing instrument.

[0073] The front-to-back ratio (FB(f)) may be determined based on the first transfer function and the second transfer function and/or based on the first and second cross spectrums and the first and second power spectrums, e.g.:

$$FB(f) = \frac{H_1(f)}{H_2(f)} = \frac{G_{1,o}(f) \cdot G_{2,2}(f)}{G_{1,1}(f) \cdot G_{2,o}(f)}$$

[0074] Several algorithms may be used to compute one or more of $G_{1,1}(f)$, $G_{1,o}(f)$, $H_1(f)$, $G_{2,2}(f)$, $G_{2,o}(f)$, $H_2(f)$. For example, Welch's method and/or Bartlett's method may be used to compute cross spectrum functions and/or power spectrum functions.

[0075] These methods determine cross spectrum functions and/or power spectrum functions by averaging cross spectrum functions and/or power spectrum functions of short segments of the original signals. For example, calculation of the first cross spectrum function, the original signals are divided into short segments ...k-1, k, k+1, For each segment, a Fourier transform is performed for each signal, and the two Fourier transforms representing segment k of the original signals are combined to obtain a segment cross spectrum for segment k:

$$G_{1,o,k}(f) = X_{1,k}(f) \cdot Y_{o,k}^*(f)$$

[0076] Wherein $X_{1,k}(f)$ is the first Fourier transform of the kth segment of the first signal (x_1). * denotes the complex conjugate. Hence, $Y_{o,k}^*(f)$ is the complex conjugate of the output Fourier transform of the kth segment of the audio output signal (y_o).

[0077] $G_{1,o}$ is calculated by averaging the segment cross spectrums:

$$G_{1,o}(f) = \frac{1}{n} \sum_{i=1}^n G_{1,o,i}(f) = \frac{1}{n} \sum_{i=1}^n X_{1,i}(f) \cdot Y_{o,i}^*(f),$$

wherein n is the total number of segments. Similarly $G_{1,1}(f)$, $G_{2,2}(f)$, $G_{2,o}(f)$ may be found:

$$G_{1,1}(f) = \frac{1}{n} \sum_{i=1}^n X_{1,i}(f) \cdot X_{1,i}^*(f)$$

$$G_{2,2}(f) = \frac{1}{n} \sum_{i=1}^n X_{2,i}(f) \cdot X_{2,i}^*(f)$$

$$G_{2,o}(f) = \frac{1}{n} \sum_{i=1}^n X_{2,i}(f) \cdot Y_{o,i}^*(f),$$

where * denotes the complex conjugate.

[0078] Fig. 4 shows an illustrative example of determining the first cross spectrum function $G_{1,o}$ from the first signal

200 and the second signal 201. The first signal 200 is divided in a plurality of segments 202, 222, 242, e.g. corresponding to the segments $k-1$, k , and $k+1$ above.

[0079] To obtain the $k-1$ segment cross spectrum $G_{1,0,k-1}$, the $k-1$ segment 202 of the first signal 200 is Fourier transformed 204 and multiplied 212 with the $k-1$ segment 206 of the second signal 201 being Fourier transformed 208 and complex conjugated 210.

[0080] To obtain the k segment cross spectrum $G_{1,0,k}$, the k segment 222 of the first signal 200 is Fourier transformed 224 and multiplied 232 with the k segment 226 of the second signal 201 being Fourier transformed 228 and complex conjugated 230.

[0081] To obtain the $k+1$ segment cross spectrum $G_{1,0,k+1}$, the $k+1$ segment 242 of the first signal 200 is Fourier transformed 244 and multiplied 252 with the $k+1$ segment 246 of the second signal 201 being Fourier transformed 248 and complex conjugated 250.

[0082] The resulting segment cross spectrums 214, 234, 254 may be averaged or weighted to find the first cross spectrum function $G_{1,0}$.

[0083] The present method allows obtaining the transfer functions $H_1(f)$ and $H_2(f)$ and frequency responses for the hearing instrument, even in the presence of other signals which may act as a disturbance to the measurement procedure, such as the rear signal, e.g. the second signal, in front-to-output calculations, and as the front signal, e.g. the first signal, in rear-to-output calculations.

[0084] In events of the first signal and the second signal being very different, e.g. in contents of frequency components and/or time variation, a reliable estimate of the cross spectrum functions ($G_{1,2}$ and $G_{2,1}$) may be obtained from a relatively short sample, i.e. a few number of segments. Conversely, in events of the first signal and the second signal being less different, e.g. in contents of frequency components and/or time variation, a reliable estimate of the cross spectrum functions ($G_{1,2}$ and $G_{2,1}$) may require a longer sample, i.e. an increased number of segments.

[0085] The Fourier transformations above may be determined using discrete Fourier transformation (DFT), such as the Fast Fourier Transformation (FFT).

[0086] Fig. 5 shows a simulated example of power spectra 300 of an exemplary first signal 306 and an exemplary second signal 308. The power spectra 300 are shown in a diagram having a first logarithmic axis 302 with units of Hz, and a second axis 304 with units of dB. In the exemplary power spectra 300 the first signal 306 being a speech signal and the second signal 308 is a noise signal. It is seen that the second signal 308 comprises more power in higher frequencies than the first signal 306. Also seen is that the first signal 306 and the second signal 308 comprise overlapping frequencies. E.g. the power of the first signal 306 between 900 Hz and 1000 Hz is approximately similar to the power of the second signal 308 between 900 Hz and 1000 Hz.

[0087] Fig. 6 shows an example of exemplary hearing instrument parameters 400 obtained from testing a hearing instrument operating in an omni-directional mode. The exemplary hearing instrument parameters 400 are shown in a diagram having a first logarithmic axis 402 with units of Hz, and a second axis 404 with units of dB. The first hearing instrument parameter 406 shows an obtained first transfer function, in this example a front-to-output frequency response for the hearing instrument. The second hearing instrument parameter 408 shows an obtained second transfer function, in this example, a rear-to-output frequency response for the hearing instrument. It is seen that, when operating in an omni-directional mode, the front-to-output frequency response 406 and the rear-to-output frequency response 408 are substantially equivalent. Hence, the hearing instrument performs as intended in the omni-directional mode.

[0088] Fig. 7 shows an example of exemplary hearing instrument parameters 500 obtained from testing a hearing instrument operating in a directional mode. The exemplary hearing instrument parameters 500 are shown in a diagram having a first logarithmic axis 502 with units of Hz, and a second axis 504 with units of dB. The first hearing instrument parameter 506 shows an obtained first transfer function, in this example a front-to-output frequency response for the hearing instrument. The second hearing instrument parameter 508 shows an obtained second transfer function, in this example, a rear-to-output frequency response for the hearing instrument. It is seen that, when operating in a directional mode, the front-to-output frequency response 506 and the rear-to-output frequency response 508 differ substantially, and in particular they differ comparing with the results for the omni-directional mode as illustrated in Fig. 6. Hence, the hearing instrument performs as intended in the directional mode.

LIST OF REFERENCES

[0089]

- 2 hearing instrument
- 4 output
- 5 audio output signal
- 6 first input transducer
- 8 second input transducer

10	hearing instrument processing unit
12	hearing instrument housing
50	apparatus
52	first microphone
5	54 first speaker
56	first signal
58	second speaker
60	second signal
62	apparatus housing
10	64 apparatus processing unit
66	input signal
68	first speaker signal
70	second speaker signal
72	interface
15	74 first tone generator
76	second tone generator
78	first cross spectrum analyzer
80	second cross spectrum analyzer
82	first analyzer output
20	84 second analyzer output
100	method for testing a directional hearing instrument
102	transmit first signal
104	transmit second signal
106	receive audio output signal
25	108 determine hearing instrument parameters

Claims

- 30 1. An apparatus for testing a directional hearing instrument, the apparatus comprising:
- a first microphone for coupling with an output of the hearing instrument, wherein the first microphone is configured to receive an audio output signal from the hearing instrument,
 - a first speaker for transmission of a first signal, the first signal is a front signal, and the first signal having a
 - 35 first frequency component at a first frequency,
 - a second speaker for transmission of a second signal, the second signal is a rear signal, and the second signal having a second frequency component at a second frequency,
 - a processing unit configured to determine one or more hearing instrument parameters,
- 40 **characterized in that :**
- the determination is based on cross spectrum analysis of the first signal and the audio output signal, and based on cross spectrum analysis of the second signal and the audio output signal,
 - the one or more hearing instrument parameters comprises a first transfer function based on the first signal
 - 45 and the audio output signal,
 - the one or more hearing instrument parameters comprises a second transfer function based on the second signal and the audio output signal,
 - the one or more hearing instrument parameters comprises a first hearing instrument parameter being a front-to-back ratio, and
 - 50 - the front-to-back ratio is based on the first transfer function and the second transfer function.
2. Apparatus according to claim 1, wherein the difference between the first frequency and the second frequency is less than 10 Hz.
- 55 3. Apparatus according to any of the preceding claims, wherein a relationship between the first frequency component (dB SPL) and the second frequency component (dB SPL) is in the range from 0.2 to 5.
4. Apparatus according to any of the preceding claims, wherein the processing unit is configured to perform a dual

channel DFT of the first signal and the audio output signal and/or of the second signal and the audio output signal.

5. Apparatus according to any of the preceding claims, wherein the first signal and the second signal are at least partly separate in time.

6. Apparatus according to any of the preceding claims, wherein the first signal is an International Speech Test Signal.

7. Method for testing a directional hearing instrument, the method comprising:

- transmitting a first signal through a first speaker, the first signal is a front signal, and the first signal having a first frequency component at a first frequency;
- transmitting a second signal through a second speaker, the second signal is a rear signal, and the second signal having a second frequency component at a second frequency;
- receiving an audio output signal from the hearing instrument;
- determining one or more hearing instrument parameters, **characterized in that** :
 - the determination is based on cross spectrum analysis of the first signal and the audio output signal and based on cross spectrum analysis of the second signal and the audio output signal;
 - the one or more hearing instrument parameters comprises a first transfer function based on the first signal and the audio output signal;
 - the one or more hearing instrument parameters comprises a second transfer function based on the second signal and the audio output signal;
 - the one or more hearing instrument parameters comprises a first hearing instrument parameter being a front-to-back ratio; and
 - the front-to-back ratio is based on the first transfer function and the second transfer function.

8. Method according to claim 7, wherein the difference between the first frequency and the second frequency is less than 10 Hz.

Patentansprüche

1. Vorrichtung zum Testen eines direktionalen Hörgeräts, welche Vorrichtung Folgendes umfasst:

- ein erstes Mikrofon zum Koppeln mit einem Ausgang des Hörgeräts, wobei das erste Mikrofon dafür ausgelegt ist, ein Audioausgangssignal vom Hörgerät zu empfangen,
- einen ersten Lautsprecher zur Übertragung eines ersten Signals, wobei das erste Signal ein vorderes Signal ist, und das erste Signal eine erste Frequenzkomponente bei einer ersten Frequenz aufweist,
- einen zweiten Lautsprecher zur Übertragung eines zweiten Signals, wobei das zweite Signal ein hinteres Signal ist, und das zweite Signal eine zweite Frequenzkomponente bei einer zweiten Frequenz aufweist,
- eine Verarbeitungseinheit, die dafür ausgelegt ist, einen oder mehrere Hörgerätparameter zu bestimmen,

dadurch gekennzeichnet, dass:

- die Bestimmung auf Kreuzspektrumanalyse des ersten Signals und des Audioausgangssignals basiert und auf Kreuzspektrumanalyse des zweiten Signals und des Audioausgangssignals basiert,
- der eine oder mehrere Hörgerätparameter eine erste Übertragungsfunktion auf Basis des ersten Signals und des Audioausgangssignals umfasst bzw. umfassen,
- der eine oder mehrere Hörgerätparameter eine zweite Übertragungsfunktion auf Basis des zweiten Signals und des Audioausgangssignals umfasst bzw. umfassen,
- der eine oder mehrere Hörgerätparameter einen ersten Hörgerätparameter umfasst bzw. umfassen, der ein Vor-Rück-Verhältnis ist, und
- das Vor-Rück-Verhältnis auf der ersten Übertragungsfunktion und der zweiten Übertragungsfunktion basiert.

2. Vorrichtung nach Anspruch 1, wobei der Unterschied zwischen der ersten Frequenz und der zweiten Frequenz weniger als 10 Hz ist.

3. Vorrichtung nach einem der vorgehenden Ansprüche, wobei ein Verhältnis zwischen der ersten Frequenzkomponente (dB SPL) und der zweiten Frequenzkomponente (dB SPL) im Bereich von 0,2 bis 5 liegt.

4. Vorrichtung nach einem der vorgehenden Ansprüche, wobei die Verarbeitungseinheit dafür ausgelegt ist, eine Zweikanal-DFT des ersten Signals und des Audioausgangssignals und/oder des zweiten Signals und des Audioausgangssignals auszuführen.

5. Vorrichtung nach einem der vorgehenden Ansprüche, wobei das erste Signal und das zweite Signal zumindest teilweise zeitlich getrennt sind.

6. Vorrichtung nach einem der vorgehenden Ansprüche, wobei das erste Signal ein internationaler Sprachtest-Signal ist.

7. Verfahren zum Testen eines direktionalen Hörgeräts, welches Verfahren Folgendes umfasst:

- Übertragen eines ersten Signals durch einen ersten Lautsprecher, wobei das erste Signal ein vorderes Signal ist, und das erste Signal eine erste Frequenzkomponente bei einer ersten Frequenz aufweist;
- Übertragen eines zweiten Signals durch einen zweiten Lautsprecher, wobei das zweite Signal ein hinteres Signal ist, und das zweite Signal eine zweite Frequenzkomponente bei einer zweiten Frequenz aufweist;
- Empfangen eines Audioausgangssignals vom Hörgerät;
- Bestimmen von einem oder mehreren Hörgerätparameter(n),

dadurch gekennzeichnet, dass:

- die Bestimmung auf Kreuzspektrumanalyse des ersten Signals und des Audioausgangssignals basiert und auf Kreuzspektrumanalyse des zweiten Signals und des Audioausgangssignals basiert;
- der eine oder mehrere Hörgerätparameter eine erste Übertragungsfunktion auf Basis des ersten Signals und des Audioausgangssignals umfasst bzw. umfassen;
- der eine oder mehrere Hörgerätparameter eine zweite Übertragungsfunktion auf Basis des zweiten Signals und des Audioausgangssignals umfasst bzw. umfassen;
- der eine oder mehrere Hörgerätparameter einen ersten Hörgerätparameter umfasst bzw. umfassen, der ein Vor-Rück-Verhältnis ist; und
- das Vor-Rück-Verhältnis auf der ersten Übertragungsfunktion und der zweiten Übertragungsfunktion basiert.

8. Verfahren nach Anspruch 7, wobei der Unterschied zwischen der ersten Frequenz und der zweiten Frequenz weniger als 10 Hz ist.

Revendications

1. Dispositif pour tester une prothèse auditive directionnelle, l'appareil comprenant :

- un premier microphone pour le couplage avec une sortie de la prothèse auditive, le premier microphone étant configuré pour recevoir un signal de sortie audio de la prothèse auditive,
- un premier haut-parleur pour la transmission d'un premier signal, le premier signal étant un signal avant, et le premier signal ayant une première composante de fréquence à une première fréquence,
- un deuxième haut-parleur pour la transmission d'un deuxième signal, le deuxième signal étant un signal arrière, le deuxième signal ayant une deuxième composante de fréquence à une deuxième fréquence,
- une unité de traitement configurée pour déterminer un ou plusieurs paramètres de prothèse auditive,

caractérisé en ce que

- la détermination est basée sur une analyse de spectre croisé du premier signal et du signal de sortie audio, et basée sur une analyse de spectre croisé du deuxième signal et du signal de sortie audio,
- l'un ou plusieurs paramètres de prothèse auditive comprend une première fonction de transfert basée sur le premier signal et le signal de sortie audio,
- l'un ou plusieurs paramètres de prothèse auditive comprend une deuxième fonction de transfert basée sur le deuxième signal et le signal de sortie audio,
- l'un ou plusieurs paramètres de prothèse auditive comprend un premier paramètre de prothèse auditive étant un rapport avant-arrière, et
- le rapport avant-arrière est basé sur la première fonction de transfert et la deuxième fonction de transfert.

2. Dispositif selon la revendication 1, dans lequel la différence entre la première fréquence et la deuxième fréquence est inférieure à 10 Hz.

3. Dispositif selon l'une quelconque des revendications précédentes, dans lequel une relation entre la première composante de fréquence (dB SPL) et la deuxième composante de fréquence (dB SPL) est comprise entre 0,2 et 5.

4. Dispositif selon l'une quelconque des revendications précédentes, dans lequel l'unité de traitement est configurée pour effectuer une TFD à deux canaux du premier signal et du signal de sortie audio et / ou du deuxième signal et du signal de sortie audio.

5. Dispositif selon l'une quelconque des revendications précédentes, dans lequel le premier signal et le deuxième signal sont au moins partiellement séparés dans le temps.

6. Dispositif selon l'une quelconque des revendications précédentes, dans lequel le premier signal est un signal de test de parole international.

7. Procédé pour tester une prothèse auditive directionnelle, le procédé comprenant :

- la transmission d'un premier signal par un premier haut-parleur, le premier signal étant un signal avant, et le premier signal ayant une première composante de fréquence à une première fréquence ;
- la transmission d'un deuxième signal par un deuxième haut-parleur, le deuxième signal étant un signal arrière, le deuxième signal ayant une deuxième composante de fréquence à une seconde fréquence ;
- la réception d'un signal de sortie audio à partir de la prothèse auditive ;
- la détermination d'un ou de plusieurs paramètres de prothèse auditive,

caractérisé en ce que

- la détermination est basée sur une analyse de spectre croisé du premier signal et du signal de sortie audio, et basée sur une analyse de spectre croisé du deuxième signal et du signal de sortie audio ;
- l'un ou plusieurs paramètres de prothèse auditive comprend une première fonction de transfert basée sur le premier signal et le signal de sortie audio ;
- l'un ou plusieurs paramètres de prothèse auditive comprend une deuxième fonction de transfert basée sur le deuxième signal et le signal de sortie audio ;
- l'un ou plusieurs paramètres de prothèse auditive comprend un premier paramètre de prothèse auditive étant un rapport avant-arrière ; et
- le rapport avant-arrière est basé sur la première fonction de transfert et la deuxième fonction de transfert.

8. Procédé selon la revendication 7, dans lequel la différence entre la première fréquence et la deuxième fréquence est inférieure à 10 Hz.

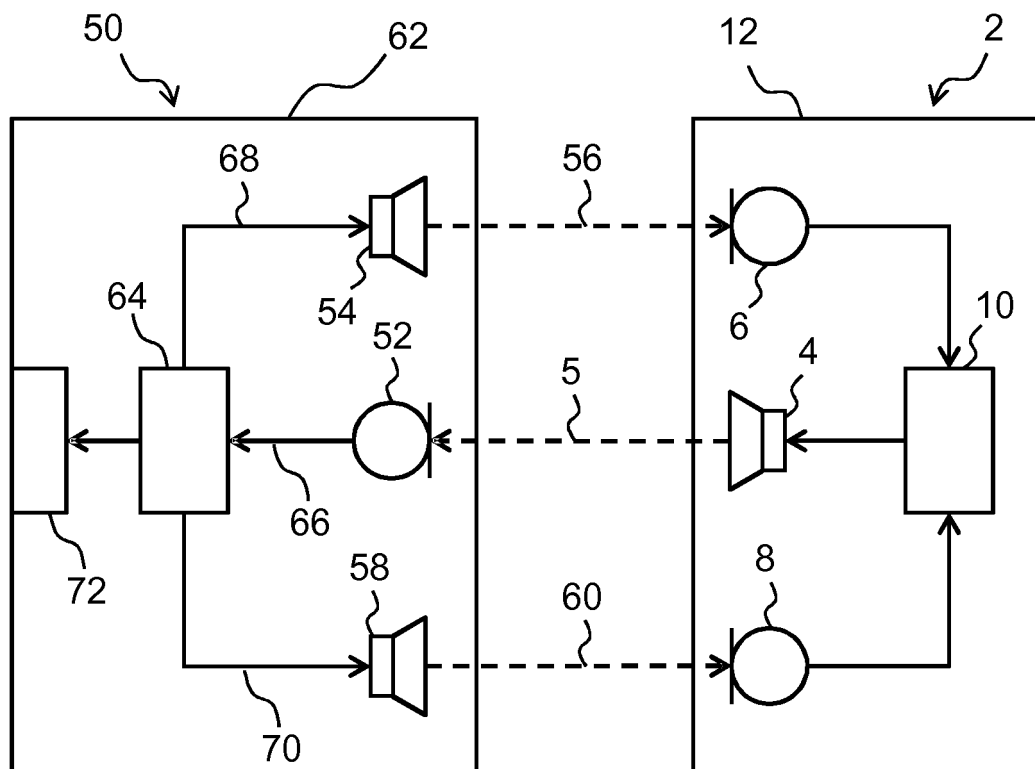


Fig. 1

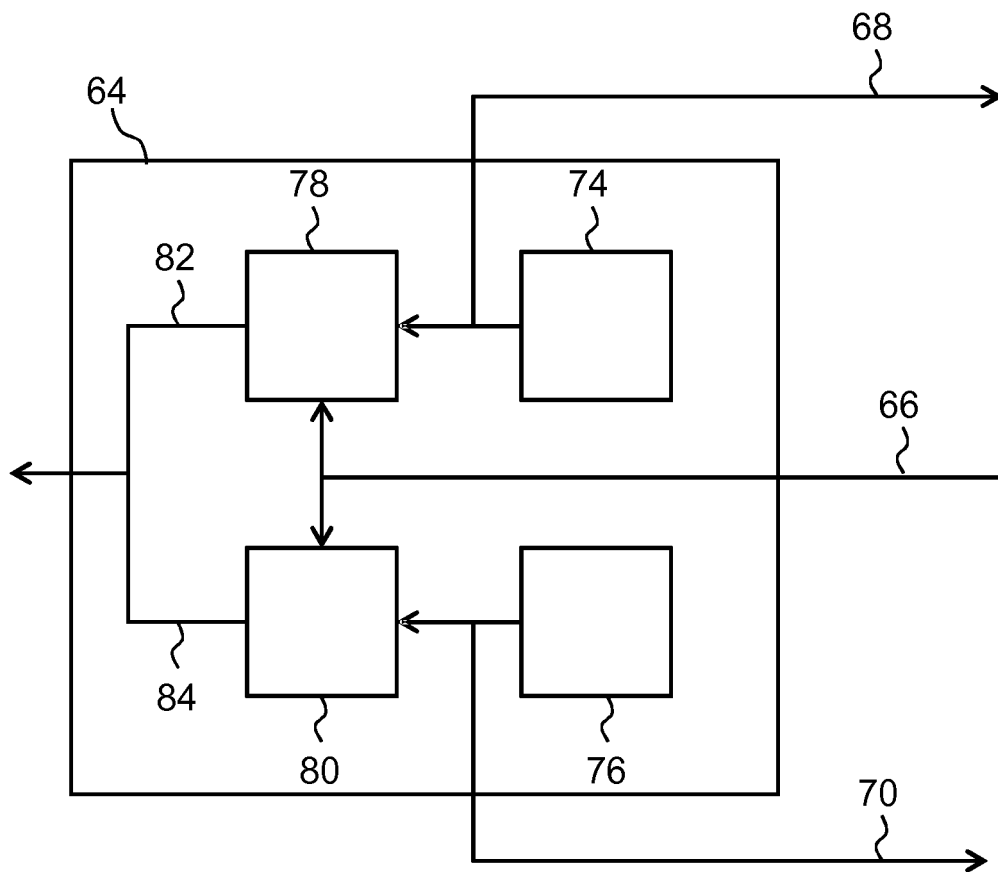


Fig. 2

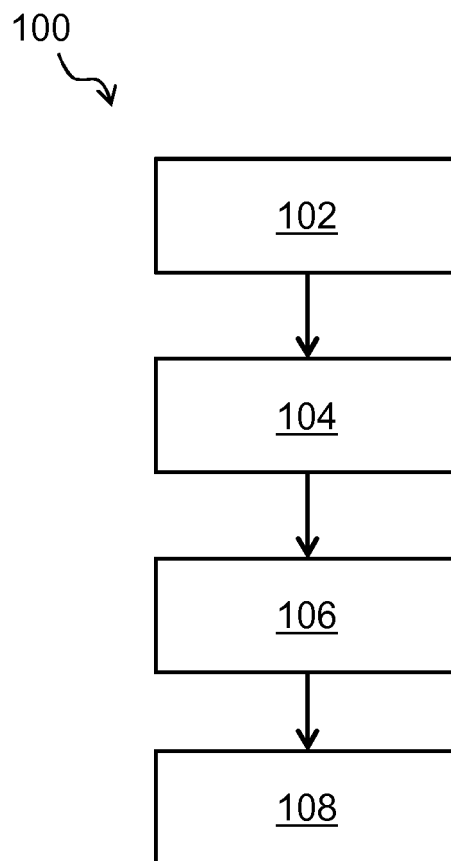


Fig. 3

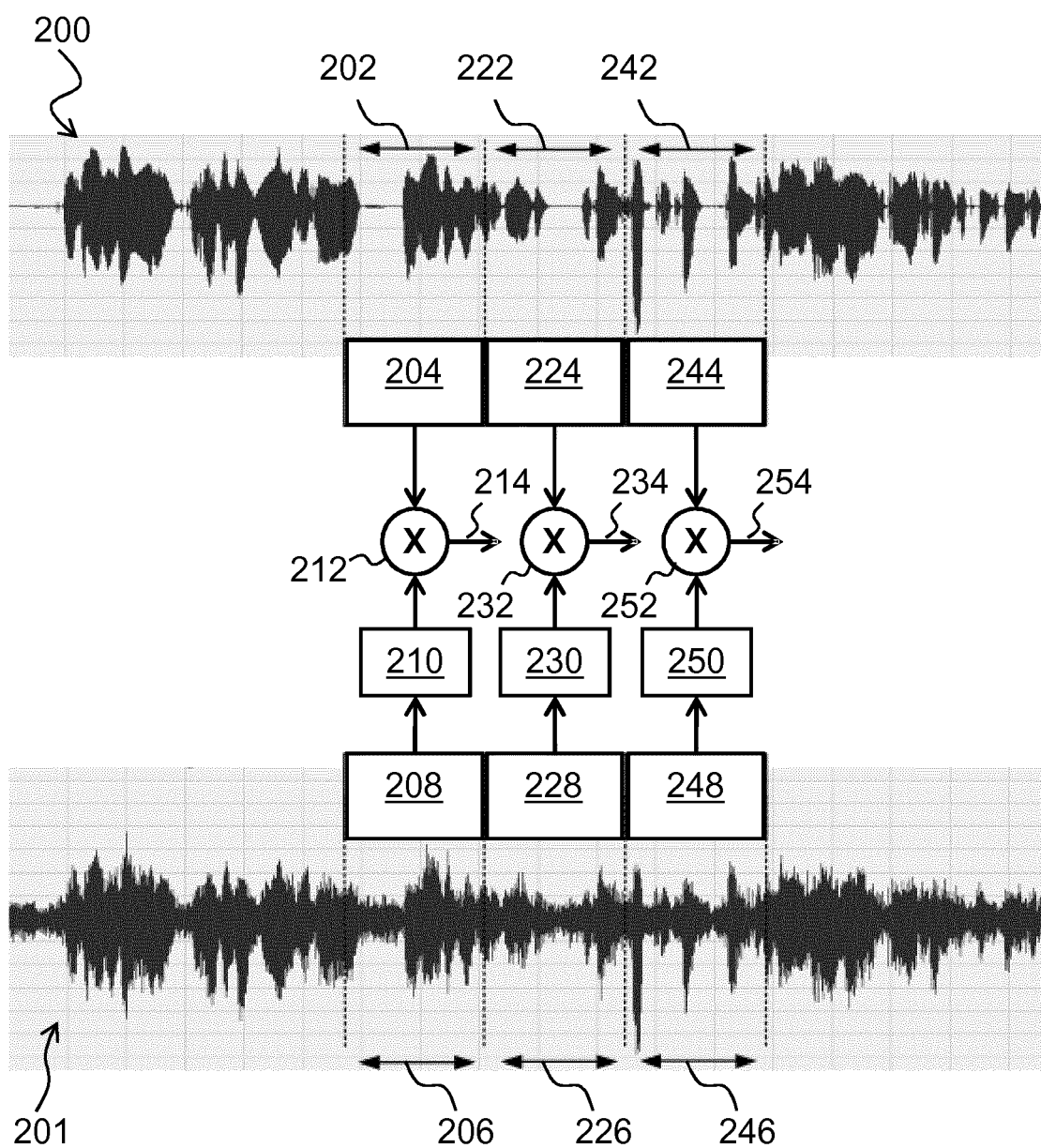


Fig. 4

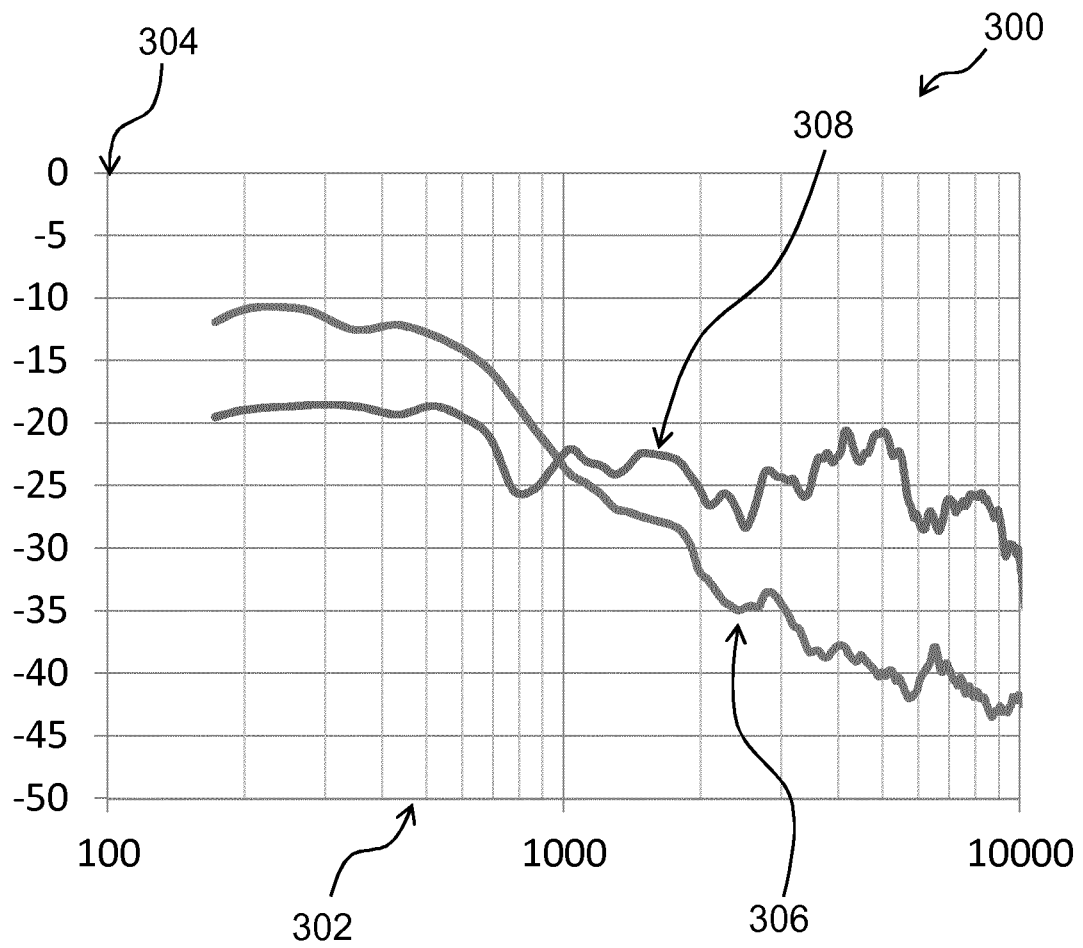


Fig. 5

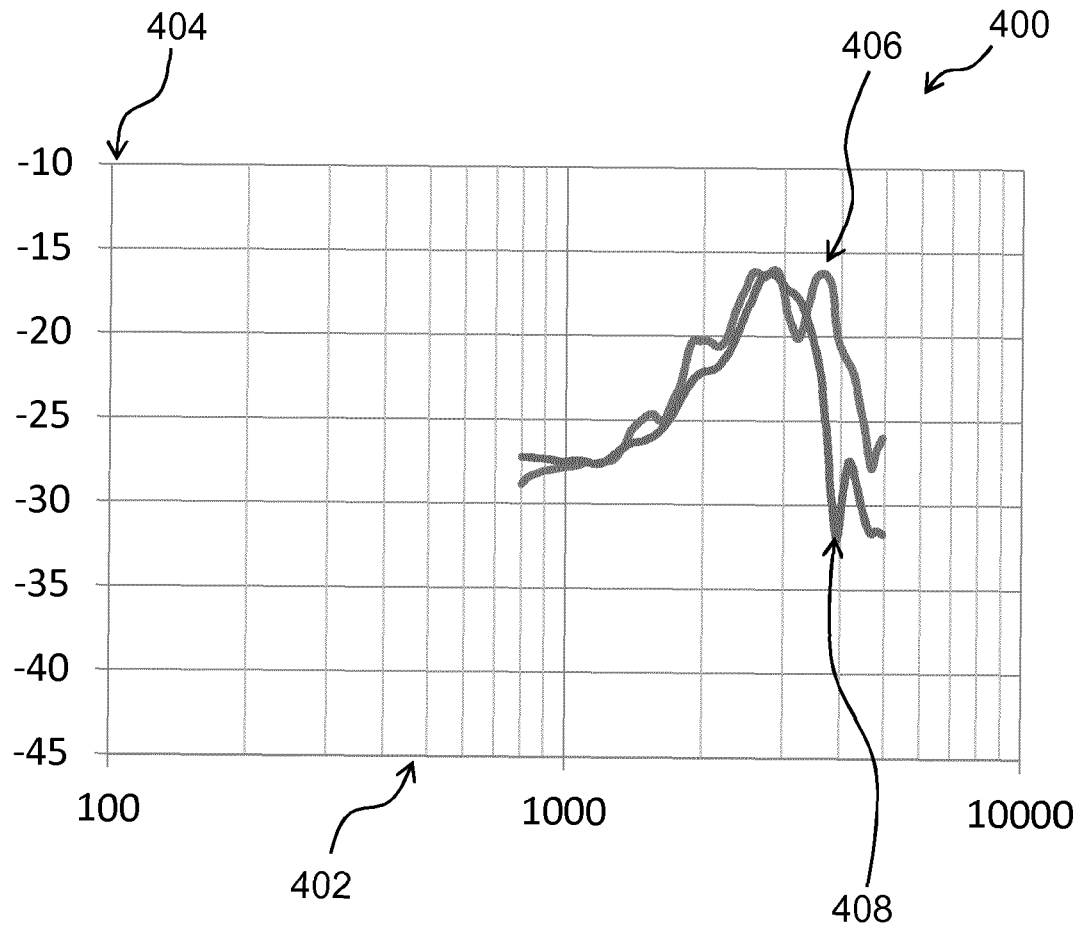


Fig. 6

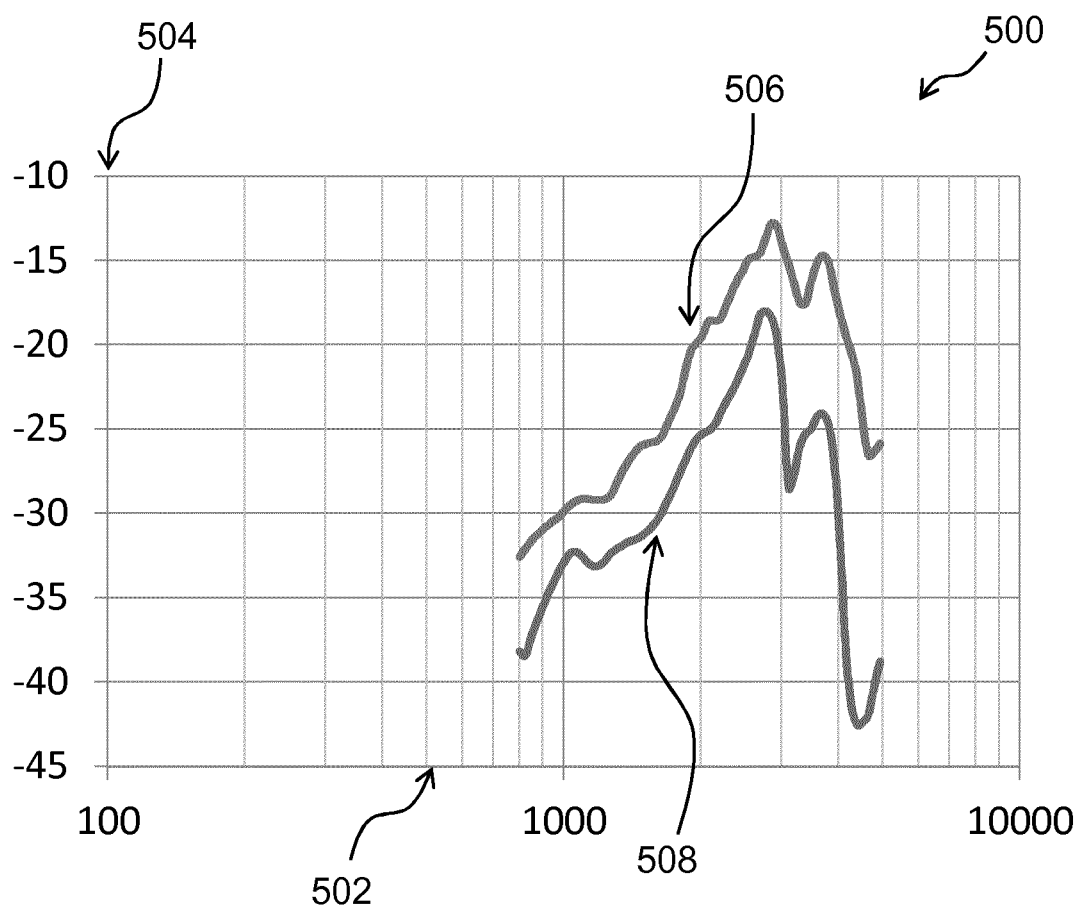


Fig. 7

REFERENCES CITED IN THE DESCRIPTION

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