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(54) METHOD FOR DETECTING A MALFUNCTION OF A HEARING INSTRUMENT AND HEARING INSTRUMENT

(57) The invention relates to a method for detecting a malfunction of a hearing instrument, the hearing instrument comprising at least one microphone, a receiver, a sound processor configured to process input sound signals from the microphone and to provide output sound signals to the receiver, and an active vent adjustable to be in one of at least two states, the method comprising a diagnosis comprising:
- playing back a specific broadband sound with known characteristics by the receiver and/or switching the active vent back and forth to produce a click sound,
- capturing the played back sound and/or the click sound by the at least one microphone to obtain an input sound signal,
- analyzing a frequency response of the captured input sound signal by the sound processor,
- wherein the frequency response is compared to a reference frequency response representing a properly functioning hearing instrument, wherein a malfunction is detected if the comparison yields any differences beyond a defined threshold, the method further comprising:
- informing the user of a malfunction detected.

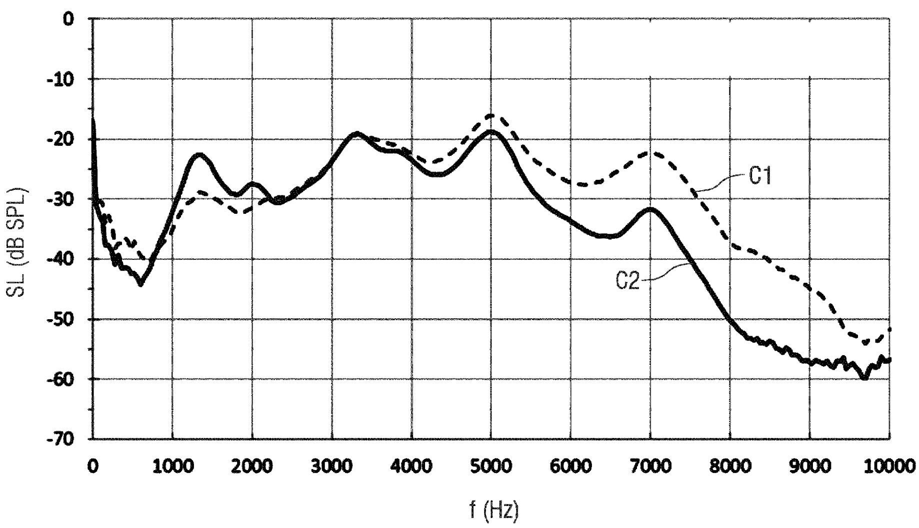

FIG 2

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Description

Technical Field

[0001] The invention relates to a method for detecting a malfunction of a hearing instrument according to claim 1.

Background of the Invention

[0002] An active-vent receiver is a special type of receiver with a mechanism that can be activated to alter the configuration of the vent. In the mechanism an electromagnet may be used to toggle the position of a disk between two stable mechanical positions. At one extreme, the disk obstructs the vent and closes it, while at the other extreme, the vent is left open. This allows for two types of acoustic coupling configurations that can be changed at will, depending on the current listening situation of the user. The gain of the hearing instrument is adapted accordingly for delivering the best sound experience and the most helpful amplification.

[0003] One problem that can be encountered with the active-vent receiver is that dirt or debris such as cerumen accumulated during continuous wearing can prevent the correct functioning of the device after a while. If the receiver is mechanically prevented from toggling to the desired vent state and the gain is changed nonetheless, this wrong gain setting can potentially lead to providing too much or too little gain, depending on the current situation.

Summary of the Invention

[0004] It is an object of the present invention to provide a method for detecting a malfunction of a hearing instrument.

[0005] The object is achieved by a method for detecting a malfunction of a hearing instrument according to claim 1.

[0006] Preferred embodiments of the invention are given in the dependent claims.

[0007] The present invention provides a method for detecting a malfunction of a hearing instrument. The hearing instrument comprises at least one microphone, a receiver, a sound processor configured to process input sound signals from the microphone and to provide output sound signals to the receiver, and an active vent adjustable to be in one of at least two states. The method comprises a diagnosis comprising:

- playing back a specific broadband sound with known characteristics by the receiver and/or switching the active vent back and forth to produce a click sound,
- capturing the played back sound and/or the click sound by the at least one microphone to obtain an input sound signal,
- analyzing a frequency response of the captured input sound signal by the sound processor,
- wherein the frequency response is compared to a reference frequency response representing a properly functioning hearing instrument, wherein a malfunction is detected if the comparison yields any differences beyond a defined threshold,

the method further comprising:

- informing the user of a malfunction detected.

[0008] The defined threshold may relate to differences in the frequency peak magnitude and position. The most relevant threshold values can be estimated at best with the help of a training set, but a change of 5 dB or more in magnitude and/or 100Hz in frequency can be considered as significant.

[0009] In an exemplary embodiment the specific broadband sound is a maximum length sequence signal. A maximum length sequence (MLS) is a pseudorandom binary sequence with a flat frequency response that is particularly well suited for this purpose. Other sequences or signals with a flat frequency response could likewise be used.

[0010] In an exemplary embodiment the diagnosis is performed during or at the end of a charging operation of a battery of the hearing instrument.

[0011] In an exemplary embodiment an ambient sound level is measured.

[0012] In an exemplary embodiment the diagnosis is started only if the ambient sound level is below a defined threshold. This defined threshold may for example be roughly -40dB sound pressure level.

[0013] In an exemplary embodiment a sound level of the played back sound is adjusted automatically depending on the ambient sound level and on the captured signal.

[0014] In an exemplary embodiment a reference diagnosis is performed in a state where the hearing instrument is known to be properly functioning by:

- playing back the specific broadband sound with known characteristics by the receiver and/or switching the active vent back and forth to produce the click sound,
- capturing the played back sound and/or the click sound by the at least one microphone to obtain an input sound signal,
- analyzing a frequency response of the captured input sound signal by the sound processor to obtain the reference frequency response.

[0015] In an exemplary embodiment the diagnosis is run repeatedly and the results thereof are averaged before comparing them to the reference.

[0016] In an exemplary embodiment the diagnosis is run with the active vent switched to one of the states and run again with the active vent switched to the other one of the states.

[0017] In an exemplary embodiment the method is performed by a state machine running on a processor.

[0018] In an exemplary embodiment the processor is located in a hearing instrument or in an electronic module located in a charger or in a smartphone.

[0019] In an exemplary embodiment the user is informed of a malfunction detected by displaying information on a smartphone.

[0020] In an exemplary embodiment lowering of one or more specific regions of the frequency response is interpreted as indicating an obstruction of the at least one microphone.

[0021] In an exemplary embodiment a frequency shift of a resonance peak of the frequency response is interpreted as indicating a clogged or damaged receiver.

[0022] According to an aspect of the present invention a hearing instrument comprises at least one microphone, a receiver, a sound processor configured to process input sound signals from the microphone and to provide output sound signals to the receiver, and an active vent adjustable to be in one of at least two states, wherein the hearing instrument is configured to perform the method described above.

[0023] The present invention proposes a solution for detecting potential malfunction risks by running an automated diagnosis procedure during the charging phase, taking place typically during the night, and informing the user in case a problem is detected.

[0024] The solution aims at counterbalancing the risk of active-vent receiver clogging by regularly testing the proper mechanical toggling, without disturbing the user. The presented solution consists in an automated measurement procedure taking place without involving the user.

[0025] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

Brief Description of the Drawings

[0026] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitative of the present invention, and wherein:

Figure 1 is a schematic view of a maximum length sequence signal,

Figure 2 is a schematic view of a typical frequency response of input sound signals from a front microphone when playing back an MLS signal by a receiver,

Figure 3 is a schematic view of a typical frequency response of input sound signals from a back microphone when playing back an MLS signal by a receiver,

Figure 4 is a schematic view of a typical frequency response of the input sound signals from the front microphone when playing back an MLS signal by the receiver while the receiver is at least partially occluded, and

Figure 5 is a schematic view of a typical frequency response of the input sound signals from the back microphone when playing back an MLS signal by the receiver while the receiver is at least partially occluded.

[0027] Corresponding parts are marked with the same reference symbols in all figures.

Detailed Description of Preferred Embodiments

[0028] A hearing instrument comprises at least one microphone, a receiver which may also be referred to as a speaker, a sound processor configured to process input sound signals from the microphone and to provide output sound signals to the receiver, and an active vent which may be adjusted to be at least in one of two states, i.e. an open state and a closed state, wherein in the open state the microphone and the receiver are acoustically coupled to each other to a higher extent than in the closed state. Optionally, there may be one or more intermediate state between the open state and the closed state.

[0029] In an exemplary embodiment, the battery may be rechargeable and a charger may be provided to receive the hearing instrument for recharging the battery.

[0030] The present invention proposes a solution for detecting potential malfunction risks in a hearing instrument by running an automated diagnosis procedure during the charging phase, taking place typically during the night, and informing the user in case a problem is detected.

[0031] For the most accurate measurements without too much background noise perturbating the results, it would be beneficial to wait for the acoustic environment to be quiet enough before starting the measurements. The method could for example wait for the end of a battery charging operation as a trigger for starting a self-test. That would typically correspond to a few hours after a user puts the hearing instruments in a charger for the night, a timeframe where the acoustic environment is more likely to be quiet.

[0032] Anyway, the background sound environment may not always be appropriate. For example, one user could have the hearing instruments in the bathroom during the night, next to a washing machine which may be in its tumbling cycle at the moment the charge stops. Therefore, it may be desirable to measure an ambient sound level before starting the test.

[0033] For the test to be able to detect a deterioration of the hearing instrument's performance, a first reference measurement may be made to compare against in later measurements. The reference measurement can occur for example at the hearing care professional's office or at the user's home during the first days after he/she has received his/her hearing instruments, before any degradation has had time to occur.

[0034] By repeating the measurement consistently over time under similar background sound environments and tracking the evolution of the results and comparing them against the reference measurement, an onset of degradation can be detected early and the user may be informed that a cleaning action and/or a maintenance check would be beneficial.

[0035] The measurement itself may comprise the following aspects:

- The receiver of the hearing aid, or one of the hearing aids in case there are two, plays a specific broadband sound with known characteristics, e.g. a maximum length sequence signal (MLS).
- The microphones of the hearing aid capture the produced sound.
- If necessary, the sound level can be adjusted automatically depending on the level of the background environment (noise floor) and captured signal.
- A signal processing unit in the hearing instrument analyses the frequency response of the captured sound.
- For better accuracy, the sequence may be repeated several times and the results averaged.
- A further improvement of the method could comprise switching the vent back and forth several times and record and analyze the produced clicking sound. This allows for assessing whether the switching of the vent position takes place as expected or not, based on the clicking sound.
- A frequency response resulting from the operation of the signal processing unit is compared to the reference measurement and any discrepancy is detected.
- The same procedure is repeated after the active vent is toggled into is other state.
- The measurement with both active vent states may be repeated for the second hearing instrument, if applicable.

[0036] **Figure 1** is a schematic view of a maximum length sequence signal (MLS).

[0037] **Figure 2** is a schematic view of a typical frequency response of the input sound signals from a front microphone when playing back an MLS signal by the receiver. The diagram shows sound level SL over frequency f. Curve C1 shows a reference frequency response for a clean front microphone and curve C2 shows a frequency response for a dirty front microphone.

[0038] **Figure 3** is a schematic view of a typical frequency response of the input sound signals from a back microphone when playing back an MLS signal by the receiver. Curve C3 shows a reference frequency response for a clean front microphone and curve C4 shows a frequency response for a dirty front microphone.

[0039] The steps of the measurement as well as the analysis of the signals and the comparison of the results can be performed by a state-machine which may run on a processor located:

- in the hearing instrument,
- in an electronic module located in the charger, or
- in a smartphone of the user, through an app that activates itself automatically during the night.

[0040] The results of the test can be communicated to an app on the user's smartphone and in case any issue is detected, an information or warning can be shown to the user.

[0041] Since the test procedure involves playing a sound through the receiver of the hearing instrument in both active-vent states and capturing the signal through by the hearing instrument's microphone, the test is sensitive to alterations and degradations in each and every element of the electroacoustic chain, namely the receiver, all of the microphones and the active vent including a toggling mechanism thereof.

[0042] In **figures 2 and 3** it can be seen that some regions of the frequency response are lower for one curve than for another. Detecting a lowering of specific regions, in particular at higher frequencies, of the frequency response would be a sign of obstruction of the corresponding microphone.

[0043] **Figure 4** is a schematic view of a typical frequency response of the input sound signals from the front microphone when playing back an MLS signal by the receiver while the receiver is at least partially occluded. Detecting frequency shifts of the resonance peaks of the frequency response would indicate a clogged or damaged receiver. Curve C5 shows a reference frequency response for a clean receiver and curve C6 shows a frequency response for a clogged receiver.

[0044] **Figure 5** is a schematic view of a typical frequency response of the input sound signals from the back microphone when playing back an MLS signal by the receiver while the receiver is at least partially occluded. Curve C7 shows a reference frequency response for a clean receiver and curve C8 shows a frequency response for a dirty receiver.

List of References

[0045]

C1 to C8	curve
f	frequency
SL	sound level

Claims

1. A method for detecting a malfunction of a hearing instrument, the hearing instrument comprising at least one microphone, a receiver, a sound processor configured to process input sound signals from the microphone and to provide output sound signals to the receiver, and an active vent adjustable to be in one of at least two states, the method comprising a diagnosis comprising:

   - playing back a specific broadband sound with known characteristics by the receiver and/or switching the active vent back and forth to produce a click sound,
   - capturing the played back sound and/or the click sound by the at least one microphone to obtain an input sound signal,
   - analyzing a frequency response of the captured input sound signal by the sound processor,
   - wherein the frequency response is compared to a reference frequency response representing a properly functioning hearing instrument, wherein a malfunction is detected if the comparison yields any differences beyond a defined threshold,

   the method further comprising:

   - informing the user of a malfunction detected.

2. The method of claim 1, wherein the specific broadband sound is a maximum length sequence signal.

3. The method of claim 1 or 2, wherein the diagnosis is performed during or at the end of a charging operation of a battery of the hearing instrument.

4. The method according to any one of the preceding claims, wherein an ambient sound level (SL) is measured.

5. The method of claim 4, wherein the diagnosis is started only if the ambient sound level (SL) is below a defined threshold.

6. The method of claim 4 or 5, wherein a sound level (SL) of the played back sound is adjusted automatically depending on the ambient sound level (SL) and on the captured signal.

7. The method according to any one of the preceding claims, wherein a reference diagnosis is performed in a state where the hearing instrument is known to be properly functioning by:

   - playing back the specific broadband sound with known characteristics by the receiver and/or switching the active vent back and forth to produce the click sound,
   - capturing the played back sound and/or the click sound by the at least one microphone to obtain an input sound signal,
   - analyzing a frequency response of the captured input sound signal by the sound processor to obtain the reference frequency response.

8. The method according to any one of the preceding claims, wherein the diagnosis is run repeatedly and the results thereof are averaged before comparing them to the reference.

9. The method according to any one of the preceding claims, wherein the diagnosis is run with the active vent switched to one of the states and run again with the active vent switched to the other one of the states.

10. The method according to any one of the preceding claims, performed by a state machine running on a processor.

11. The method according to claim 10, wherein the processor is located in a hearing instrument or in an electronic module located in a charger or in a smartphone.

12. The method according to any one of the preceding claims, wherein the user is informed of a malfunction detected by displaying information on a smartphone.

13. The method according to any one of the preceding claims, wherein lowering of one or more specific regions of the frequency response is interpreted as indicating an obstruction of the at least one microphone.

14. The method according to any one of the preceding claims, wherein a frequency shift of a resonance peak of the frequency response is interpreted as indicating a clogged or damaged receiver.

15. A hearing instrument, comprising at least one microphone, a receiver, a sound processor configured to process input sound signals from the microphone and to provide output sound signals to the receiver, and an active vent adjustable to be in one of at least two states, wherein the hearing instrument is configured to perform the method according to any one of the preceding claims.

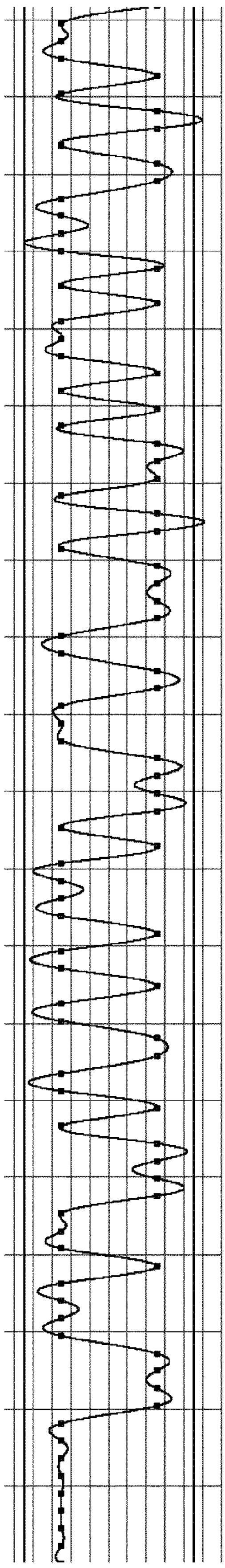

FIG 1

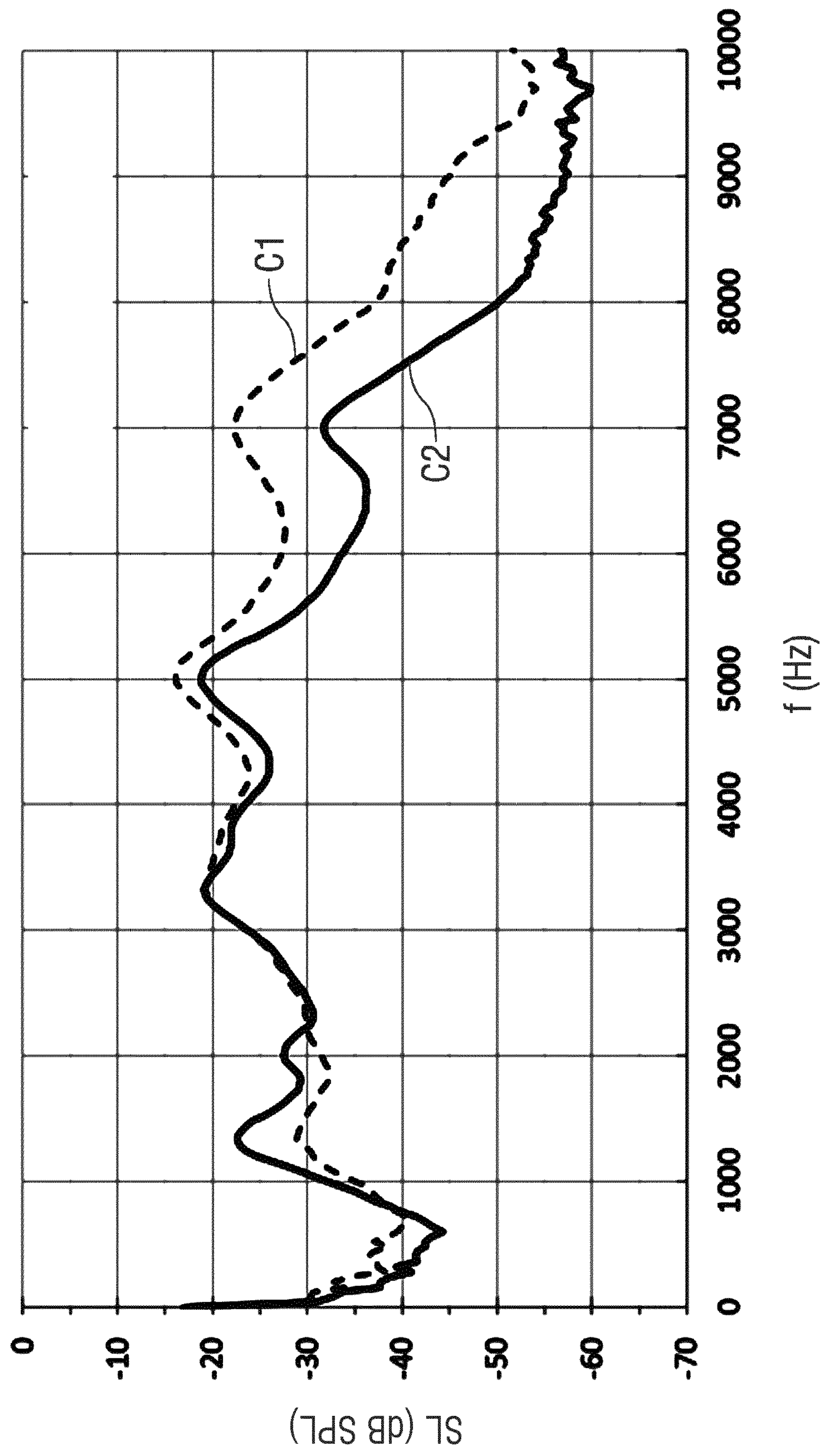
SL (dB SPL)
0
-10
-20
-30
-40
-50
-60
-70
f (Hz)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
C1
C2

FIG 2

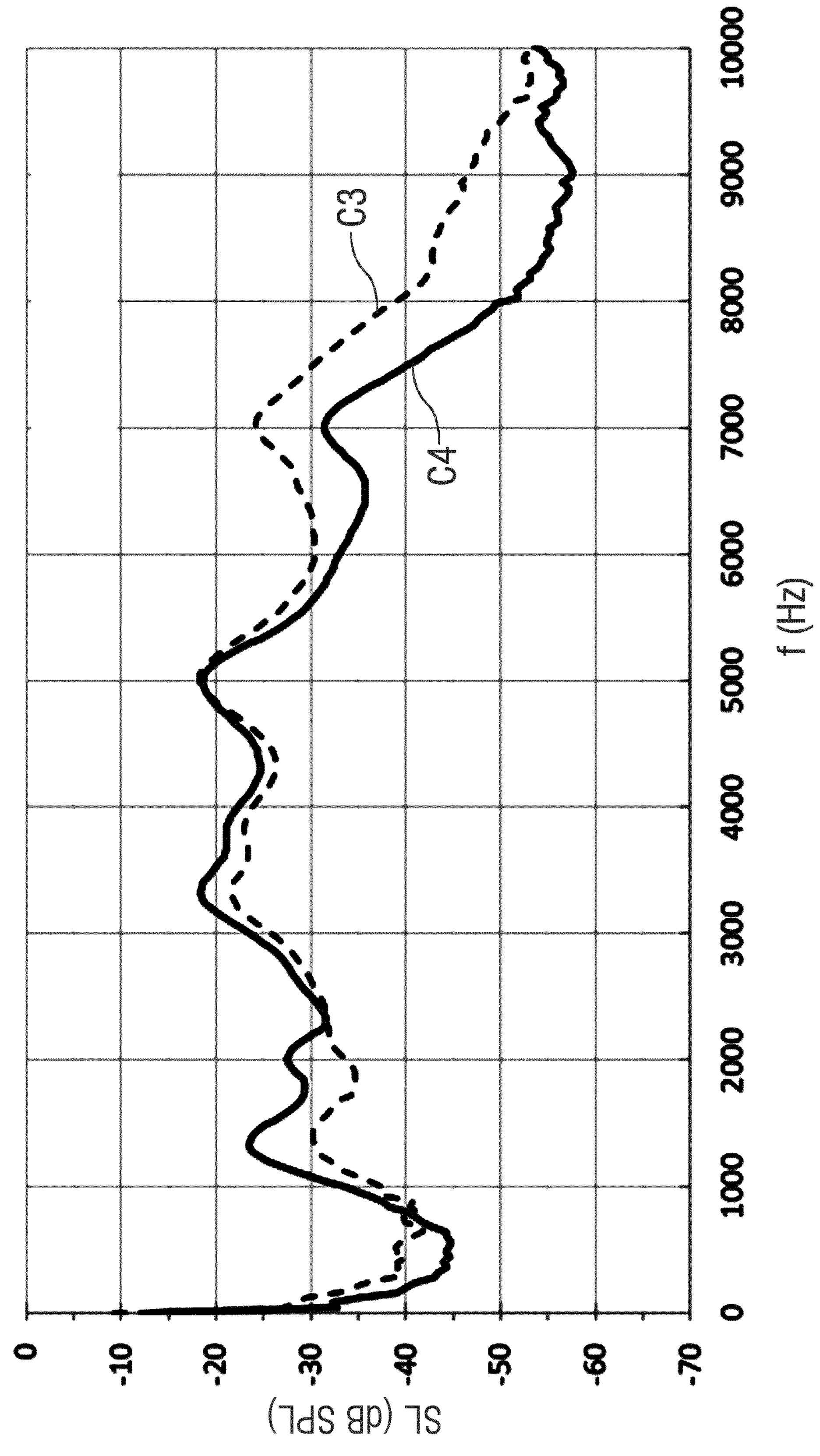
C3
C4
f (Hz)
SL (dB SPL)
0
-10
-20
-30
-40
-50
-60
-70
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

FIG 3

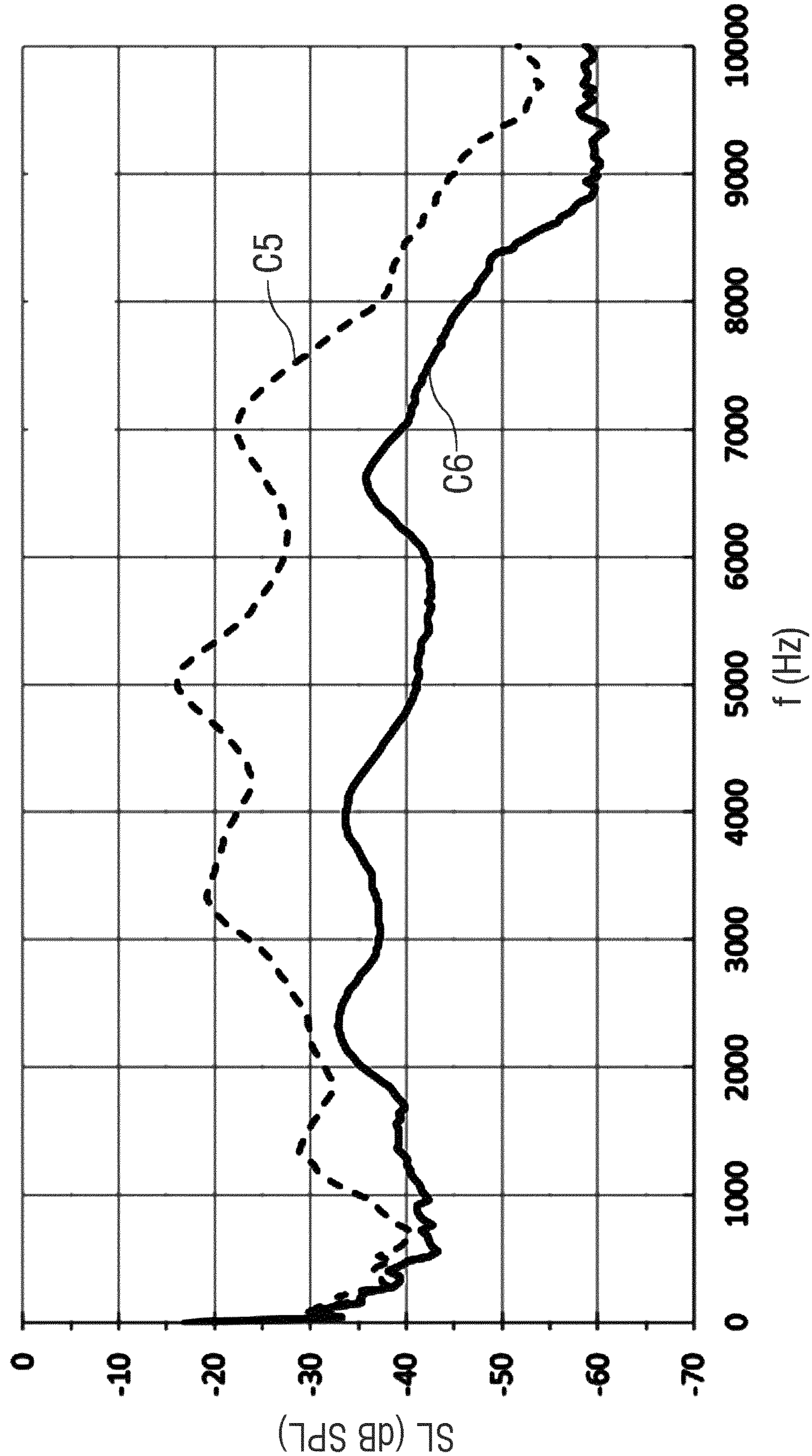
C5
C6
f (Hz)
SL (dB SPL)
0
-10
-20
-30
-40
-50
-60
-70
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

FIG 4

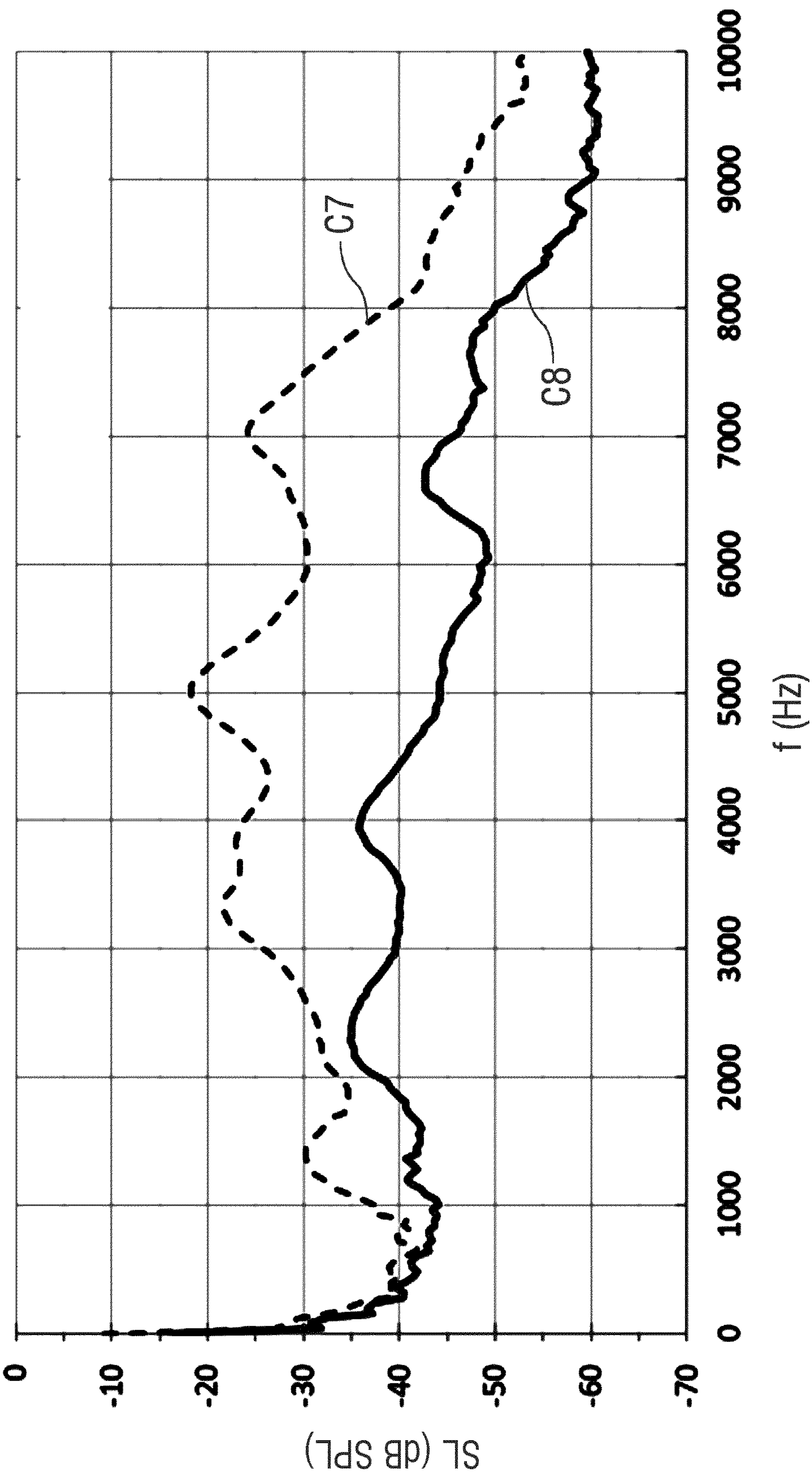
SL (dB SPL)
0
-10
-20
-30
-40
-50
-60
-70
f (Hz)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
C7
C8

FIG 5

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 0928

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 675 524 A1 (GN HEARING AS [DK]) 1 July 2020 (2020-07-01) * paragraph [0011] * * paragraph [0079] - paragraph [0080] * * paragraph [0108] * * paragraph [0112] - paragraph [0126] * * figures 1-2B,5A,6A-8 * -----	1-15	INV. H04R25/00
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			TECHNICAL FIELDS SEARCHED (IPC)
			H04R

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	13 August 2021	Streckfuss, Martin

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