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(54) EARPIECE FOR A HEARING DEVICE

(57) The invention relates to an earpiece (2) for a hearing device (1), the earpiece (2) configured to be connected to a behind the ear part (3) of the hearing device (1), the earpiece (2) comprising a receiver (11) and a telecoil (14) configured as an antenna for picking up signals from a loop system generating an electromagnetic field carrying a sound signal, wherein the earpiece (2) and/or the hearing device (1) has an operating mode in which the sound signal picked up by the telecoil (14) is played back by the receiver (11).

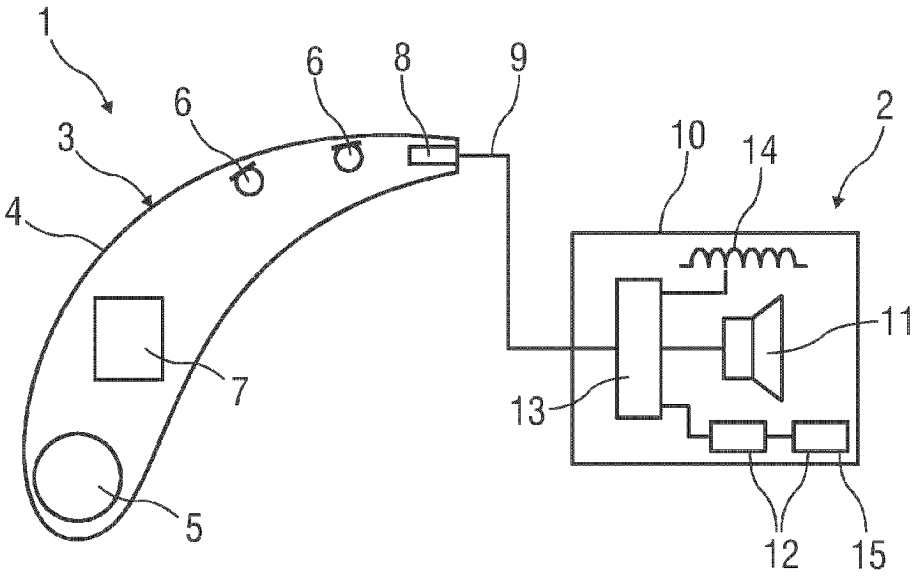

FIG 1

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Description

Technical Field

[0001] The invention relates to an earpiece for a hearing device, a hearing device and a method of operating the earpiece

Background of the Invention

[0002] Hearing devices are small objects, containing digital electronics which generates electromagnetic radiation. Thus, an antenna in proximity to this radiation is prone to pick up such radiation, which is considered as noise and is unwanted. Telecoils in hearing devices are an example of such antennas and thus difficult to place, requiring bulky shielding of the electronics, exact and repeatable location in space relative to such radiation emitters in order to reduce or even eliminate unwanted hum noise from entering the telecoil receiver. Systems supplying such devices with audio content are for example installed in places of worship. Development of devices with such telecoils is difficult and requires significantly more time than development of devices without. Respective devices are thus prone to be delivered later to the market than other devices of the same generation without such telecoils.

Summary of the Invention

[0003] It is an object of the present invention to provide a novel earpiece for a hearing device, a novel hearing device and a novel method of operating the earpiece.

[0004] The object is achieved by an earpiece according to claim 1, by a hearing device according to claim 11 and by a method of operating the earpiece according to claim 13.

[0005] Preferred embodiments of the invention are given in the dependent claims.

[0006] According to the invention, an earpiece for a hearing device is configured to be connected to a behind the ear part of the hearing device, the earpiece comprising a receiver and a telecoil configured as an antenna for picking up signals from a loop system generating an electromagnetic field carrying a sound signal, wherein the earpiece and/or the hearing device has an operating mode in which the sound signal picked up by the telecoil is played back by the receiver. This sound signal may be played back as is or it may be processed prior to being played back. This operating mode may for example be selected by a switch provided on the ear piece. In particular, the ear piece does not contain any circuitry performing radio transmission and/or considerable digital signal processing which would possibly disturb the telecoil. Digital radios generate intermittent electromagnetic disturbance due to the frame-like transmission and reception pattern they must follow. This intermittence or frame rate respectively is within an audible frequency, thus easily picked up by a telecoil, which is intended to pick up electromagnetic signals at such frequencies. Digital signal processing (DSP) will be performed in circuitry located in the behind the ear part, such digital signal processing may be configured to process audio signals from microphones and/or the telecoil, thus applying functions such as beamforming, noise cancelling, nonlinear frequency dependent amplification, feedback cancellation, spectral compression, limiting, classification of the acoustic situation and many more. In doing so, it may account for an audio signal dependent processing cycle count to compute these algorithms, thus allowing for a sufficiently high processing cycle budget. For the most sets of audio samples processed in this way, the processing cycle budget is not fully needed, thus leaving a few processing cycles where the digital signal processor is idle, thus using significantly less current. Further, during processing of such algorithms, there are portions where most of the DSP's processing resources are utilized concurrently, thus drawing more current from the battery then for other portions, where only a small part of the DSPs resources are used. This combined time-varying current consumption of the radio and the DSP leads to a significant, stochastic electromagnetic disturbance radiated from various wires carrying this time-varying current, potentially being picked up again by a telecoil if it was conventionally placed in close vicinity in the behind-the-ear part of the hearing device.

[0007] In an exemplary embodiment, the earpiece further comprises a cable configured to be connected to the behind the ear part of the hearing device.

[0008] In an exemplary embodiment, the earpiece further comprises earpiece circuitry connected to the receiver and the telecoil and configured to control operation of the earpiece.

[0009] In an exemplary embodiment, the earpiece further comprises one or more sensors connected to the earpiece circuitry, wherein the earpiece circuitry is further configured to perform sensor frontend processing.

[0010] In an exemplary embodiment, the one or more sensors comprise at least one of an accelerometer, a gyroscope, a compass, a skin impedance sensor, an ECG sensor, an EEG sensor, an EMG sensor, an EOG sensor and a photoplethysmography sensor.

[0011] In an exemplary embodiment, the earpiece circuitry is further configured to perform at least one of D/A conversion, analogue amplification, A/D conversion, controlling at least one switch actuator and amplifying sensor signals.

[0012] In an exemplary embodiment, the sensor frontend processing comprises periodically acquiring a PPG signal from the photoplethysmography sensor, and pausing acquisition of the PPG signal while the output signal of the telecoil is being played back.

[0013] In an exemplary embodiment, the output signal of the telecoil and/or of another analogue sensor is filtered with a matched filter according to a photoplethysmography measurement base frequency and duty cycle,

wherein one or more LEDs included in the photoplethysmography sensor are switched between an on state and an off state in a regular pattern, wherein the output signal of the telecoil and/or of the other analogue sensor is filtered using a bandstop filter having a stopband comprising the base frequency and optionally harmonics thereof, or wherein the output signal of the telecoil and/or of the other analogue sensor is filtered using an adaptive filter fed with such a duty cycled signal, the adaptative filter configured to minimize a known disturbance signal from the LED duty cycling.

[0014] In an exemplary embodiment, the analogue sensor is only sampled while a LED or another actuator has not been switched recently and any electromagnetic interference effects have settled.

[0015] In an exemplary embodiment, the earpiece further comprises an earpiece housing, wherein the telecoil is arranged within the earpiece housing.

[0016] According to an aspect of the present invention, a hearing device is provided, comprising a behind the ear part and an earpiece as described above, connected to or configured to connect to the behind the ear part by a cable and a connector.

[0017] In an exemplary embodiment, the behind the ear part comprises a battery, one or more microphones and circuitry comprising at least one of a digital signal processor, power management circuitry and radio circuitry.

[0018] According to an aspect of the present invention, a method of operating the earpiece as described above is provided, comprising periodically acquiring a PPG signal from the photoplethysmography sensor, and pausing acquisition of the PPG signal while the output signal of the telecoil is being played back.

[0019] In an exemplary embodiment, the output signal of the telecoil and/or of another analogue sensor is filtered with a matched filter according to a photoplethysmography measurement base frequency and duty cycle, wherein one or more LEDs included in the photoplethysmography sensor are switched between an on state and an off state in a regular pattern, wherein the output signal of the telecoil and/or of the other analogue sensor is filtered using a bandstop filter having a stopband comprising the base frequency and optionally harmonics thereof, or wherein the output signal of the telecoil and/or of the other analogue sensor is filtered using an adaptive filter fed with such a duty cycled signal, the adaptative filter configured to minimize a known disturbance signal from the LED duty cycling.

[0020] In an exemplary embodiment, the analogue sensor is only sampled while a LED or another actuator has not been switched recently and any electromagnetic interference effects have settled.

[0021] The solution according to the present invention provides a hearing device with telecoil reception capability which can be added in a modular way.

[0022] 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

[0023] 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 hearing device, and

Figure 2 is a schematic view of an exemplary embodiment of a method for operating an earpiece circuitry with an output signal of a telecoil, other sensors and a photoplethysmography sensor.

[0024] Corresponding parts are marked with the same reference symbols in all figures.

Detailed Description of Preferred Embodiments

[0025] **Figure 1** is a schematic view of a hearing device 1, comprising an earpiece 2 or in the ear part and a behind the ear part 3. The behind the ear part 3 comprises a behind the ear part housing 4, in which a battery 5, e.g. a rechargeable battery, one or two microphones 6, and circuitry 7 comprising a digital signal processor, power management circuitry and radio circuitry, e.g. Bluetooth radio circuitry, are arranged. The radio circuitry may be configured for wireless data communication with at least one external device, e.g. a remote control, and/or for audio streaming from an external audio source. A connector 8 is arranged at an end of the behind the ear part housing 4, the connector 8 configured to connect to a cable 9.

[0026] The earpiece 2 comprises an earpiece housing 10, a receiver 11 or speaker, one or more sensors 12, earpiece circuitry 13 for controlling the receiver 11 and/or the one or more sensors 12, and a telecoil 14 also connected to the earpiece circuitry 13. The telecoil 14 works as an antenna for picking up signals from a loop system generating an electromagnetic field carrying an analogue sound signal.

[0027] The cable 9 is connected to the earpiece 2, in particular to the receiver 11.

[0028] The battery 5 and the circuitry 7 comprising the digital signal processor, power management circuitry and radio circuitry are arranged in the behind the ear part 3 and thus relatively far away from the earpiece 2 and its earpiece circuitry 13, where for example only sensor frontend processing or D/A conversion takes place. The fron-

tend processing may also contain analogue amplification, A/D conversion, digital outputs to switch actuators, electrodes and respective amplifiers to measure skin impedance, electrical body signals (e.g. ECG, EEG, EMG, EOG), galvanic responses, etc., using the one or more sensors 12. Thus, the earpiece circuitry 13 generates much lower levels of electromagnetic interference for the telecoil 14 and/or the receiver 11 placed in the earpiece 2.

[0029] The telecoil 14 is placed in an active earpiece 2 together with the one or more sensors 12 and associated earpiece circuitry 13 which emits only minor amounts of disturbing radiation; so the telecoil 14 is less prone to disturbance from the radio and digital signal processing performed in the circuitry 7 of the behind the ear part 3, which both cannot get readily switched off or paused.

[0030] Digital radios generate intermittent electromagnetic disturbance due to the frame-like transmission and reception pattern they must follow. This intermittence or frame rate respectively is within an audible frequency, thus easily picked up by a telecoil 14, which is intended to pick up electromagnetic signals at such frequencies, if the telecoil 14 was placed in close vicinity to the circuitry 7. Likewise, the digital signal processing (DSP) in the circuitry 7 processes the audio signals from the microphones 6 and/or the telecoil 14, thus applying functions such as beamforming, noise cancelling, nonlinear frequency dependent amplification, feedback cancellation, spectral compression, limiting, classification of the acoustic situation and many more. In doing so, it accounts for an audio signal dependent processing cycle count to compute these algorithms, thus allows for a sufficiently high processing cycle budget. For the most sets of audio samples processed such, the processing cycle budget is not fully needed, thus leaving a few processing cycles where the digital signal processor is idle, thus using significantly less current. Further, during processing of such algorithms, there are portions where most of the DSP's processing resources are utilized concurrently, thus drawing more current from the battery then for other portions, where only a small part of the DSPs resources are used. This combined time-varying current consumption of the radio and the DSP leads to a significant, stochastic electromagnetic disturbance radiated from various wires carrying this time-varying current, potentially being picked up again by a telecoil 14 if it was conventionally placed in close vicinity in the behind-the-ear part 3 of the hearing device 1.

[0031] The presently proposed embodiment avoids such a drawback by placing the telecoil 14further away from such stochastic noise sources.

[0032] As an additional benefit, the earpiece 2 is replaceable with other types of earpieces 2; i.e. different behind the ear parts 3, e.g. with smaller or larger batteries 5 for different runtime, may be combined with different earpieces 2, either with a telecoil 14 or without a telecoil 14. Thus, a user may purchase telecoil capability also later on after purchase, without having to discard the behind the ear part 3.

[0033] In an exemplary embodiment, the at least one sensor 12 may comprise at least one photoplethysmography sensor (PPG) 15.

[0034] **Figure 2** is a schematic view of an exemplary embodiment of a method for operating the earpiece circuitry 13 with an output signal S_{TC} of the telecoil 14, with signals of other sensors 12 and with a PPG signal S_{PPG} of the photoplethysmography sensor 15.

[0035] In an exemplary embodiment, acquisition of the PPG signal S_{PPG} is paused while the output signal S_{TC} of the telecoil 14 signal is used as an audio source.

[0036] In an exemplary embodiment, the output signal S_{TC} of the telecoil 14 and/or of another analogue sensor (e.g. EEG, ECG) is filtered with a matched filter according to a PPG measurement base frequency and duty cycle; i.e. one or more LEDs included in the photoplethysmography sensor 15 are switched between an on state LED on and an off state in a regular pattern, e.g. 1 ms on and 9 ms off, so the base frequency is 100 Hz. The output signal S_{TC} of the telecoil 14 and/or of the other analogue sensor may now get filtered using a bandstop filter having a stopband comprising the base frequency (and optionally harmonics thereof) so the base frequency and optionally the harmonics are filtered out. In another embodiment, the output signal S_{TC} of the telecoil 14 and/or of the other analogue sensor may be filtered using an adaptive filter 16 fed with such a duty cycled signal, the adaptation aiming to minimize the known disturbance signal from the LED duty cycling.

[0037] In an exemplary embodiment, an adjacent analogue sensor is only sampled while a LED or another actuator has not been switched recently and any electromagnetic interference effects have settled. For example, at least a part of the off state time of the LED, e.g. 8 ms out of 9 ms off state time, could be used to sample other sensors with a waiting period, e.g. 1 ms, after the LED has been switched off.

List of References

[0038]

1	hearing device
2	earpiece
3	behind the ear part
4	behind the ear part housing
5	battery
6	microphone
7	circuitry
8	connector
9	cable
10	earpiece housing
11	receiver
12	sensor
13	earpiece circuitry
14	telecoil
15	photoplethysmography sensor

16	adaptive filter
LED on	on state
S_{PPG}	PPG signal
S_{TC}	output signal of the telecoil

Claims

1. An earpiece (2) for a hearing device (1), the earpiece (2) configured to be connected to a behind the ear part (3) of the hearing device (1), the earpiece (2) comprising a receiver (11) and a telecoil (14) configured as an antenna for picking up signals from a loop system generating an electromagnetic field carrying a sound signal, wherein the earpiece (2) and/or the hearing device (1) has an operating mode in which the sound signal picked up by the telecoil (14) is played back by the receiver (11).

2. The earpiece (2) of claim 1, further comprising a cable (9) configured to be connected to the behind the ear part (3) of the hearing device (1).

3. The earpiece (2) according to claim 1 or 2, further comprising earpiece circuitry (13) connected to the receiver (11) and the telecoil (14) and configured to control operation of the earpiece (2).

4. The earpiece (2) according to any one of the preceding claims, further comprising one or more sensors (12) connected to the earpiece circuitry (13), wherein the earpiece circuitry (13) is further configured to perform sensor frontend processing.

5. The earpiece (2) according to claim 4, wherein the one or more sensors (12) comprise at least one of an accelerometer, a gyroscope, a compass, a skin impedance sensor, an ECG sensor, an EEG sensor, an EMG sensor, an EOG sensor and a photoplethysmography sensor (15).

6. The earpiece (2) according to any one of claims 3 to 5, wherein the earpiece circuitry (13) is further configured to perform at least one of D/A conversion, analogue amplification, A/D conversion, controlling at least one switch actuator and amplifying sensor signals.

7. The earpiece (2) according to claim 5 or 6, wherein the sensor frontend processing comprises periodically acquiring a PPG signal (S_{PPG}) from the photoplethysmography sensor (15), and pausing acquisition of the PPG signal (S_{PPG}) while the output signal (S_{TC}) of the telecoil (14) is being played back.

8. The earpiece (2) according to claim 7, wherein the output signal (S_{TC}) of the telecoil (14) and/or of another analogue sensor is filtered with a matched filter according to a photoplethysmography measurement base frequency and duty cycle, wherein one or more LEDs included in the photoplethysmography sensor (15) are switched between an on state (LED on) and an off state in a regular pattern, wherein the output signal (S_{TC}) of the telecoil (14) and/or of the other analogue sensor is filtered using a bandstop filter having a stopband comprising the base frequency and optionally harmonics thereof, or wherein the output signal (S_{TC}) of the telecoil (14) and/or of the other analogue sensor is filtered using an adaptive filter (16) fed with such a duty cycled signal, the adaptative filter (16) configured to minimize a known disturbance signal from the LED duty cycling.

9. The earpiece (2) according to claim 8, wherein the analogue sensor is only sampled while a LED or another actuator has not been switched recently and any electromagnetic interference effects have settled.

10. The earpiece (2) according to any one of the preceding claims, further comprising an earpiece housing (10), wherein the telecoil (14) is arranged within the earpiece housing (10).

11. A hearing device (1), comprising a behind the ear part (3) and an earpiece (2) according to any one of the preceding claims connected to or configured to connect to the behind the ear part (3) by a cable (9) and a connector (8).

12. The hearing device (1) of claim 11, wherein the behind the ear part (3) comprises a battery (5), one or more microphones (6) and circuitry (7) comprising at least one of a digital signal processor, power management circuitry and radio circuitry.

13. A method of operating an earpiece (2) according to any one of claims 5 to 10, comprising periodically acquiring a PPG signal (S_{PPG}) from the photoplethysmography sensor (15), and pausing acquisition of the PPG signal (S_{PPG}) while the output signal (S_{TC}) of the telecoil (14) is being played back.

14. The method of claim 13, wherein the output signal (S_{TC}) of the telecoil (14) and/or of another analogue sensor is filtered with a matched filter according to a photoplethysmography measurement base frequency and duty cycle, wherein one or more LEDs included in the photoplethysmography sensor (15) are switched between an on state (LED on) and an off state in a regular pattern, wherein the output signal (S_{TC}) of the telecoil (14) and/or of the other analogue sensor is filtered using a bandstop filter having a stopband comprising the base frequency and optionally harmonics thereof, or wherein the output signal (S_{TC}) of the telecoil (14) and/or of the other

analogue sensor is filtered using an adaptive filter (16) fed with such a duty cycled signal, the adaptative filter (16) configured to minimize a known disturbance signal from the LED duty cycling.

15. The method of claim 14, wherein the analogue sensor is only sampled while a LED or another actuator has not been switched recently and any electromagnetic interference effects have settled.

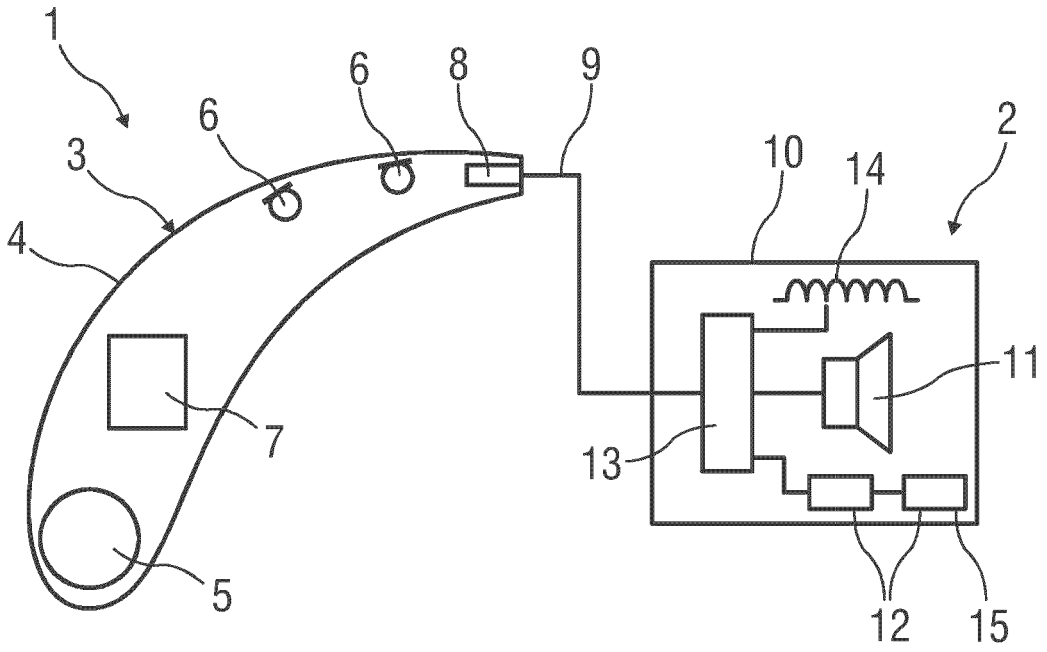
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FIG 1

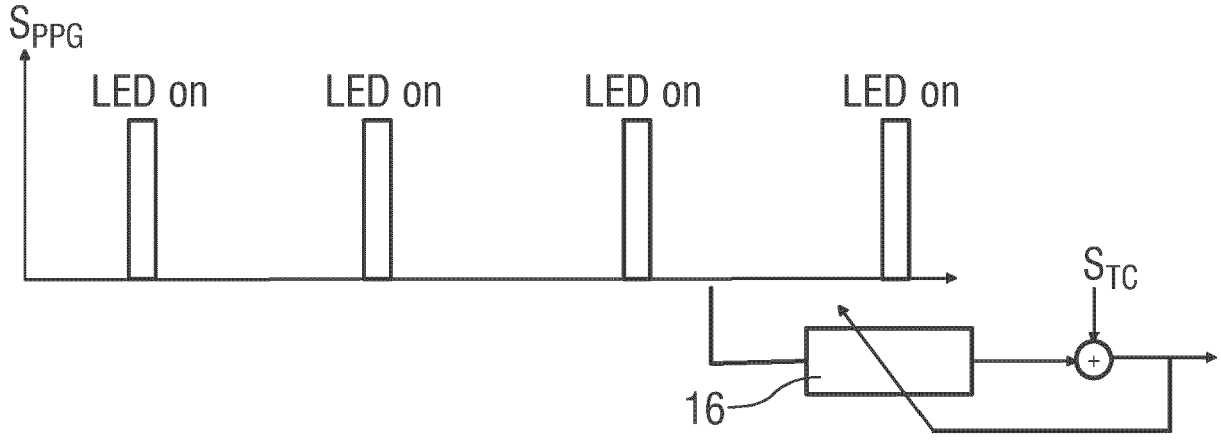
S_{PPG}
LED on
LED on
LED on
LED on
S_{TC}
16

FIG 2

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EUROPEAN SEARCH REPORT

Application Number
EP 21 21 5365

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 June 2022	Borowski, Michael

CATEGORY OF CITED DOCUMENTS

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