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(54) **A COMMUNICATION SYSTEM COMPRISING A PLURALITY OF HEARING AIDS**

(57) A communication system is disclosed. The communication system comprises a plurality of hearing aids. Each of the plurality of hearing aids comprises an input unit configured to generate a signal indicative of an own voice of a user wearing a respective hearing aid of the plurality of hearing aids. Each of the plurality of hearing aids comprises a wireless transceiver unit configured to transmit, to each other hearing aid of the plurality of hearing aids, the signal. The wireless transceiver unit is further configured to receive, from each other hearing aid of the plurality of hearing aids, a respective other signal indicative of an own voice of another user wearing each of the other hearing aids of the plurality of hearing aids. The wireless transceiver unit comprises a wireless interface configured to establish a wireless network with each of the other hearing aids of the plurality of hearing aids. Each of the plurality of hearing aids comprises an output unit configured to output, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids.

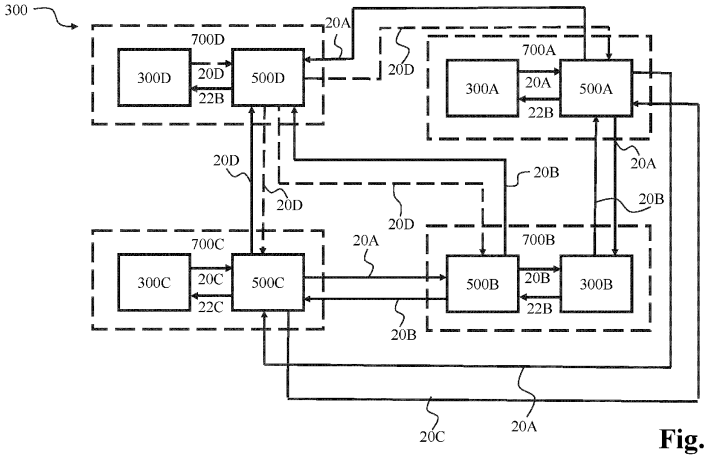

Fig. 1

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Description

TECHNICAL FIELD

[0001] The present application relates to the field of hearing aids. The present disclosure relates to a communication system comprising a plurality of hearing aid, and a related method.

BACKGROUND

[0002] It may be challenging for hearing aid users to communicate in situations that are only mildly challenging for normal hearing people, such as when two or a group of people are at a restaurant or doing an activity not facing each other.

[0003] A remote or table microphone or FM broadcasting systems can only be seen as valid options if a group of people is surrounding a table or if there is one target speaker. However, speech intelligibility and perception can be substantially impacted when the group of people is on the move, when the group of people is not facing the middle of the table, or when the majority of people suffers are hearing aid users.

[0004] There is a need for communication systems that enable use of hearing aids as both reception and transmission devices, such as systems allowing communication of audio signals between a plurality of hearing aids.

SUMMARY

A communication system:

[0005] A communication system is disclosed. The communication system comprises a plurality of hearing aids. Each of the plurality of hearing aids comprises an input unit configured to generate a signal indicative of an own voice of a user wearing a respective hearing aid of the plurality of hearing aids. Each of the plurality of hearing aids comprises a wireless transceiver unit configured to transmit, to each other hearing aid of the plurality of hearing aids, the signal. The wireless transceiver unit is further configured to receive, from each of the other hearing aid of the plurality of hearing aids, a respective other signal indicative of an own voice of another user wearing each of the other hearing aids of the plurality of hearing aids. The wireless transceiver unit comprises a wireless interface configured to establish a wireless network with each of the other hearing aids of the plurality of hearing aids. Each of the plurality of hearing aids comprises an output unit configured to output, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids.

[0006] Thereby an improved communication system may be provided.

[0007] It is an advantage of embodiments of the present disclosure that each of the plurality of hearing aids of the communication system can receive other signal from each of the other hearing aids from the plurality of hearing aids using a same set of resources. For example, each of the plurality of hearing aids can receive a combination of the signals of each of the other hearing aids from the plurality of hearing aids.

[0008] It is an advantage of embodiments of the present disclosure that each of the plurality of hearing aids can generate a signal with improved signal-to-noise ratio (SNR) as the signal is generated from an input signal acquired by a microphone that is placed close to the user's mouth wearing the respective hearing aid of the plurality of hearing aids. Furthermore, embodiments of present disclosure are less prone to getting noise from the surroundings, e.g., noise from touching table where a group of users are located), thereby contributing for transmission and reception of audio signals with improved signal-to-noise ratio (SNR).

[0009] Embodiments of the present disclosure advantageously can provide for wireless transmission and reception of audio signals, thereby improving speech intelligibility and perception as such audio signals are more resistant to noise sources. For example, each of the plurality of hearing aids can transmit the signal wirelessly (e.g., electronically) to each of the other hearing aid of the plurality of hearing aids. Likewise, each of the plurality of hearing aids can receive the other signal wirelessly (e.g., electronically) from each of the other hearing aid of the plurality of hearing aids.

[0010] Embodiments of the present disclosure can also advantageously provide for a more mobile solution through creation of hearing aid (HA) communities. An HA community may allow a group of users wearing hearing aids to communicate with each other through a wireless network as long as they are within coverage of the wireless network. The group of users being part of HA community can sit and/or move across the space where the wireless network has been established (e.g., not necessarily around a table facing a remote microphone).

[0011] Embodiments of the present disclosure can allow connection of hearing-impaired users in scenarios requiring audio signals with improved SNR while enabling freedom of movement of the hearing-impaired users across the space where the wireless network has been established. For example, embodiments of the present disclosure can be particularly useful for a group of users performing a sporting activity, such as a golf game and/or a cycling activity.

[0012] In one or more example communication systems, each of the plurality of hearing aids comprises an input unit configured to provide an electric input signal representing sound. The input unit may comprise an input transducer (e.g., a microphone) configured to convert an input signal (e.g., an input sound and/or a microphone input signal) to an electric input signal. The input unit may comprise a one or more input transducers (e.g., a plurality of microphones) configured to convert an input signal to an electric input signal.

[0013] Stated differently, each of the plurality of hearing aids may be configured to obtain an input signal via the one or more microphones. For example, each of the plurality of hearing aids can be configured to obtain a first input signal using a first microphone, a second input signal using a second microphone and/or a third input signal using a third microphone. The first input signal, the second input signal and/or the third input signal may be combined and be seen as the input signal. In one or more example communication systems, the input unit is configured to generate the signal based on the input signal.

[0014] In one or more example communication systems, an input signal is indicative of a sound generated by user(s), people, or other sound sources in an environment of the communication system (e.g., an environment where each of the plurality of hearing aids is positioned). In one or more example communication systems, the input signal can be indicative of a sound generated by the user wearing the respective hearing aid (e.g., while using the hearing aid). Put differently, an input signal may be indicative of user speech. In one or more example communication systems, an input signal can comprise one or more of: the user's speech, interfering speech, echo, and noise (e.g., ambient noise, continuous noise, intermittent noise, impulsive noise, and/or low-frequency noise).

[0015] In one or more example communication systems, each of the plurality of hearing aids comprises voice activity detector (VAD) for estimating whether (e.g., or with what probability) an input signal comprises a voice signal (e.g., at a given point in time). A voice signal may in the present context be taken to include a speech signal from a human being. It may also include other forms of utterances generated by the human speech system (e.g., singing). The VAD may be configured to classify a current acoustic environment of the user as a VOICE or NO-VOICE environment. This may be advantageous in that time segments of the electric input signal comprising human utterances (e.g., speech) in the user's environment can be identified, and thus separated from time segments only (e.g., or mainly) comprising other sound sources (e.g., artificially generated noise). The VAD may be configured to detect as a VOICE also the user's own voice. Alternatively, the VAD may be configured to exclude a user's own voice from the detection of a VOICE.

[0016] In one or more communication systems, each of the plurality of hearing aids may comprise an own voice activity detector (OVAD) for estimating whether (e.g., or with what probability) a given input sound (e.g., a voice and/or speech) originates from the voice of the user of the system. A microphone system of the hearing aid may be configured to differentiate between a user's own voice and another person's voice and possibly from NON-voice sounds.

[0017] An analogue electric signal representing an acoustic signal may be converted to a digital audio signal in an analogue-to-digital (AD) conversion process, where the analogue electric signal is sampled with a predefined sampling frequency or rate f_s, with f_s being e.g., in the range from 8 kHz to 48 kHz (e.g., adapted to the particular needs of the application) to provide digital samples x_n (e.g., or $x[n]$) at discrete points in time t_n (or n), with each audio sample representing the value of the acoustic signal at t_n by a predefined number N_b of bits, with N_b being e.g., in the range from 1 to 48 bits, e.g., 24 bits. In other words, each audio sample may be quantized using N_b bits (e.g., resulting in 2^{Nb} different possible values of the audio sample). A digital sample x has a length in time of $1/f_s$, e.g., 50μs, for f_s = 20 kHz. A number of audio samples may be arranged in a time frame. A time frame may comprise 64 or 128 audio data samples. Other frame lengths may be used depending on the practical application.

[0018] In one or more example communication systems, each of the plurality of hearing aid comprises an analogue-to-digital converter (ADC) configured to digitize an analogue input (e.g., from an input transducer, such as a microphone) with a predefined sampling rate (e.g., 20 kHz). In one or more example communication systems, each of the plurality of hearing aids comprises a digital-to-analogue converter (DAC) configured to convert a digital signal to an analogue output signal, e.g., for being presented to a user via an output transducer (e.g., a speaker).

[0019] In one or more example communication systems, each of the plurality of hearing aids is configured to convert the electric input signal (e.g., an analogue electric signal) to a digital audio signal using the ADC. In one or more example communication systems, each of the plurality of hearing aids is configured to generate the signal by applying to the digital audio signal one or more of: a VAD method, and an OVAD method. For example, applying such methods to the digital audio signal may comprise determining the signal as being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids. For example, applying such methods to the digital audio signal may comprise determining the signal as not being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids.

[0020] The signal may be seen as a clean input signal (e.g., with improved signal to noise ratio (SNR)) as the microphone configured to acquire the input signal is placed close to the user's mouth wearing a respective hearing aid of the plurality of hearing aids.

[0021] Each of the plurality of hearing aids comprises a wireless transceiver unit configured to transmit, to each other hearing aid of the plurality of hearing aids, the signal. The wireless transceiver unit is further configured to receive, from each other hearing aid of the plurality of hearing aids, a respective other signal indicative of an own voice of another user wearing each of the other hearing aids of the plurality of hearing aids.

[0022] In one or more example communication systems, the wireless transceiver unit is configured to receive and/or transmit an electromagnetic signal in the

radio frequency range (3kHz to 300GHz). In one or more example communication systems, the wireless transceiver unit is configured to receive and/or transmit an electromagnetic signal in a frequency range of light (e.g., infrared light 300 GHz to 430 THz, or visible light, e.g., 430 THz to 770 THz).

[0023] In one or more example communication systems, the wireless transceiver unit may comprise one or more antennas for wireless transmission and reception of an audio signal, such as for wireless transmission of a wireless output signal (e.g., the signal from each other hearing aid of the plurality of hearing aids) and/or wireless reception of a wireless input signal (e.g., the respective other signal of the other hearing aids of the plurality of hearing aids). For example, the wireless transceiver unit can be denoted a radio transceiver (e.g., antenna and transceiver circuitry). Optionally, the input unit comprises a wireless receiver configured to receive a wireless signal, such as the wireless output signal (e.g., the respective other signal of the other hearing aids of the plurality of hearing aids) comprising or representing sound, and provide an electric input signal representing said sound.

[0024] In one or more example communication systems, each of the plurality of hearing aids is configured to, upon determining the signal as being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids, transmit the signal to each other hearing aid of the plurality of hearing aids. Put differently, each of the plurality of hearing aids may be configured to transmit the signal when the VAD and/or OVAD detects a voice signal in the input signal. In one or more example communication systems, each of the plurality of hearing aids is configured to, upon determining the signal as not being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids, forego transmission of the signal to each other hearing aid of the plurality of hearing aids. In other words, each of the plurality of hearing aids may be configured to, upon determining the signal as not being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids, not transmit the signal to each other hearing aid of the plurality of hearing aids. Put differently, each of the plurality of hearing aids may not be configured to transmit the signal when the VAD and/or OVAD do not detect a voice signal in the input signal.

[0025] In one or more example communication systems, the wireless transceiver unit may be configured to operate as a wireless interface, e.g., configured to establish and/or connect to a wireless network. In other words, each of the plurality of hearing aids may be configured to establish and/or to connect to a wireless network via the wireless interface (e.g., a Bluetooth interface). The wireless interface may be configured to establish the wireless network with the other hearing aids of the plurality of hearing aids. The wireless interface may be configured to connect to an existing wireless network, e.g., established by other hearing aid of the plurality of hearing aids.

[0026] In one or more example communication systems, the user wearing the respective hearing aid of the plurality of hearing aids can be seen as a user wearing a pair of hearing aids. In one or more example communication systems, another user wearing the other hearing aid of the plurality of hearing aids can be seen as another user wearing a pair of other hearing aids. For example, establishing the wireless network allows the user wearing the respective hearing aid of the plurality of hearing aid to communicate with another user wearing each of the other hearing aids of the plurality of hearing aids. For example, embodiments of the present disclosure enable communication between a plurality of hearing aids, with the plurality of hearing aids belonging to different users. Embodiments of the present disclosure does not apply to binaural systems (e.g., to a communication between hearing aids belonging to the same user).

[0027] In one or more examples communications systems, the wireless network comprises an identifier (ID). The wireless network may be seen as a hearing aid (HA) community, e.g., a plurality of hearing aids connected to the same wireless network enabling communication of information between each other.

[0028] Each of the plurality of hearing aids comprises an output unit configured to output, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids.

[0029] In one or more example communication systems, each of the plurality of hearing aids comprises an output unit configured to provide a stimulus perceived by the user as an acoustic signal based on a processed electric signal. The output unit may comprise an output transducer. The output transducer may comprise a receiver (e.g., a loudspeaker) for providing the stimulus as an acoustic signal to the user (e.g., in an acoustic (air conduction based) hearing aid). The output unit may (additionally or optionally) comprise a (e.g., wireless) transmitter configured to transmit the signal, e.g., sound picked up-by the respective hearing aid to another device, e.g., a far-end communication partner (e.g., via the wireless network, e.g., in a telephone mode of operation).

[0030] In one or more example communication systems, each of the plurality of hearing aids is configured to communicate with each of the other hearing aid of the plurality of hearing aids via a communication link. In one or more example communication systems, each of the plurality of hearing aids is configured to communicate with each of the other hearing aid of the plurality of hearing aids by transmitting the signal to each of the other hearing aid of the plurality of hearing aids. In one or more example communication systems, each of the plurality of hearing aids is configured to communicate with each of the other hearing aid of the plurality of hearing aids by receiving the respective other signal from each of the other hearing aid of the plurality of hearing aids. In other words, to communicate comprises transmission of a signal and reception of respective other

signals. In one or more example communication systems, the communication link is a digital link forming the wireless network. In one or more example communication systems, the digital link forms a wireless network with communication devices of the communication system, e.g., with the plurality of hearing aids. In one or more example communication systems, the digital link is a wireless link. The wireless link may be established by the wireless transceiver unit (e.g., antenna and transceiver circuitry) of the hearing aid. For example, the wireless link may be established by the wireless interface. In one or more example communication systems, hearing aids being part of the wireless network may share time-frequency resources, e.g., be allocated to the same time-frequency resource. Each of the plurality of hearing aids may be part of the wireless network. In one or more example communication systems, a pair of hearing aids (e.g., belonging to different users) being part of the wireless network can alternatively transmit and receive signals between each other. For example, transmission and reception alternatively occur between a pair of hearing aids communicating with each other. A hearing aid of such pair of hearing aids may transmit a signal to other hearing aids being part of the wireless network and form another pair with each of the other hearing aids.

[0031] In one or more example communication systems, the OVAD is configured, upon establishing and/or connecting to the wireless network, to estimate whether the input signal comprises an own voice signal. In one or more example communication systems, each of the plurality of hearing aids is configured to, upon determining that the input signal comprises an own voice signal, transmit the signal to each other hearing aid of the plurality of hearing aids.

[0032] In one or more example communication systems, each of the plurality of hearing aids is configured to be an initiator hearing aid. In one or more example communication systems, the initiator hearing aid is configured to establish the wireless network with each of the other hearing aid of the plurality of hearing aids. The initiator hearing aid may be seen as a hearing aid responsible for establishing the wireless network. In one or more example communication systems, the initiator hearing aid is configured to broadcast a first connection signal to each of the other hearing aid of the plurality of hearing aids. In other words, the initiator hearing aid may be configured to transmit the first connection signal to each of the other hearing aid of the plurality of hearing aids. The first connection signal may be construed as an invitation signal inviting each of the other hearing aid of the plurality of hearing aids to connect to the wireless network. For example, the first connection signal comprises the ID identifying the wireless network. The identifier of the wireless network may be a sequence of tokens, such as a sequence of numbers and/or letters and/or characters. The first connection signal may be a lower power signal, e.g., a Bluetooth Low Energy (BLE) signal.

[0033] For example, each of the other hearing aid of the plurality of hearing aids may be located within the range of the wireless network, such as within the network coverage area (e.g., frequency range, transmission power range and/or location range). For example, the wireless network node covers an area including each of the other hearing aid of the plurality of hearing aids. For example, the wireless network can be seen as a unique named HA community in the proximity of each of the other hearing aid of the plurality of hearing aids. For example, a hearing aid of the plurality of hearing aids may be configured to connect to the wireless network based on a proximity to the initiator hearing aid and/or to any other hearing aid that has joined.

[0034] In one or more example communication systems, each of the other hearing aid of the plurality of hearing aids is configured to transmit, to the initiator hearing aid, an acceptance signal indicating acceptance to connect to the network node in response to receiving the first connection signal. Each of the other hearing aid of the plurality of hearing aids may be configured to, upon transmitting the acceptance signal, connect to the wireless network. In one or more example communication systems, each of the other hearing aid of the plurality of hearing aids is configured to transmit, to the initiator hearing aid, a rejection signal indicating rejection to connect to the wireless network in response to receiving the first connection signal. Each of the other hearing aid of the plurality of hearing aids may not connect to the wireless network when transmitting the rejection signal to the initiator hearing aid.

[0035] For example, each of the plurality of hearing aids are configured to connect to a wireless network upon receiving the first connection signal from the initiator hearing aid. Each of the plurality of hearing aids may be configured to connect to a wireless network based on the power of the first connection signal (e.g., transmit power and/or receive power). For example, each of the plurality of hearing aids can be configured to connect to a wireless network based on a BLE strength. Each of the plurality of hearing aids may be configured to connect to the wireless network when the power of the first connection signal is equal to or greater than a power threshold. Each of the plurality of hearing aids may not be configured to connect to the wireless network when the power of the first connection signal is less than the power threshold. Each of the plurality of hearing aids may be configured to transmit, to the initiator hearing aid, the acceptance signal and/or rejection signal in response to such determination.

[0036] Optionally, each of the other hearing aid of the plurality of hearing aids is configured to, upon receiving the first connection signal, automatically connect to the wireless network, e.g., without transmission of the acceptance signal and/or rejection signal to the initiator hearing aid. Each of the plurality of hearing aids may be configured to connect automatically in response to determining that the power of the first connection signal is

equal to or greater than a power threshold. For example, each of the plurality of hearing aids are configured to connect when reception of the first connection signal is activated and when each of the plurality of hearing aids are within the wireless network coverage area (e.g., when the power of the first connection signal is equal to or greater than a power threshold). In other words, only activation of reception of the first connection signal and proximity to the wireless network may be required to have each of the plurality of hearing aids connecting to the wireless network.

[0037] In one or more example communication systems, each of the plurality of hearing aid is configured to disconnect from the wireless network (e.g., to leave the HA community). For example, any hearing aid of the plurality of hearing aids can disconnect from the wireless network. A hearing aid of the plurality of hearing aids may disconnect from the wireless network by moving out of the coverage area of the wireless network. For example, moving out of the coverage area of the wireless network may include a grace period (e.g., a time interval) allowing such hearing aid to re-connect (e.g., re-join and/or re-enter) to the wireless network.

[0038] A hearing aid of the plurality of hearing aids may disconnect from the wireless network by obtaining first user input via a graphical interface (e.g., on an auxiliary device in communication with the hearing aid) and/or via an interface of the hearing aid (e.g., by pressing a button on the hearing aid and/or tapping the hearing aid). In other words, a hearing aid of the plurality of hearing may disconnect from the wireless network when the user wearing such hearing aid chooses to exit the wireless network. For example, the first user input can indicate disconnection from the wireless network. The first user input may trigger disconnection from the wireless network.

[0039] A hearing aid of the plurality of hearing aids may be any hearing aid of the plurality of hearing aid, e.g., including the initiator hearing aid. For example, when the hearing aid disconnecting from the wireless network is the initiator hearing aid, the communication system is configured to assign such role to one of the remaining hearing aids of the plurality of hearing aids. For example, the initiator hearing aid can assign such role to one of the remaining hearing aids of the plurality of hearing aids before disconnecting from the wireless network.

[0040] The initiator hearing aid may be configured to remove a hearing aid of the plurality of hearing aids from the wireless network (e.g., from the HA community). For example, the hearing aid to be removed is not the initiator hearing aid. The initiator hearing aid may be configured to remove such hearing aid from the wireless network by obtaining second user input indicating such hearing aid of the plurality of hearing aids (e.g., and/or at least one of the remaining hearing aids) to be removed from the wireless network (e.g., from the wireless network coverage). The initiator hearing aid may be configured to remove such hearing aid from the wireless network via a graphical interface (e.g., on an auxiliary device in communication with the hearing aid) and/or via an interface of the hearing aid (e.g., by pressing a button on the hearing aid and/or tapping the hearing aid.).

[0041] In one or more example communication systems, a hearing aid of the plurality of hearing aids is configured to disconnect from the wireless network when the initiator hearing aid closes and/or switches off the wireless network. For example, the initiator hearing aid is configured to remove each of the plurality of hearing aids from the wireless network node by obtaining third user input indicative of the plurality of hearing aids for removal. A hearing aid of the plurality of hearing aids may be configured to disconnect from the wireless network via a graphical interface (e.g., on an auxiliary device in communication with the hearing aid) and/or via an interface of the hearing aid (e.g., by pressing a button on the hearing aid and/or tapping the hearing aid).

[0042] In one or more example communication systems, each of the plurality of hearing aids is configured to broadcast a second connection signal to hearing aids not initially forming the wireless network. In one or more example communication systems, the initiator hearing aid and/or other hearing aids forming the wireless network are configured to broadcast the second connection signal to hearing aids not initially forming the wireless network. In one or more example communication systems, the other hearing aids forming the wireless device may be seen as hearing aids that are within the wireless network coverage. In one or more example communication systems, the other hearing aids are configured to transmit the second connection signal to hearing aids not initially forming the wireless network. In one or more example communication systems, hearing aids not initially forming the wireless network can be seen as hearing aids that have not received the first connection signal. In one or more example communication systems, hearing aids not initially forming the wireless network can be seen as hearing aids that have transmitted, to the initiator hearing aid, a rejection signal (e.g., indicating rejection to connect to the wireless network) response to receiving the first connection signal. For example, headset devices with microphones can be part of the wireless network.

[0043] In one or more example communication systems, the initiator hearing aid is configured to initiate establishment of the wireless network upon user interaction. In one or more example communication systems, the initiator hearing aid is configured to obtain user input request indicative of a request from the user wearing the initiator hearing aid to establish the wireless network. In one or more examples, the initiator hearing aid is configured to establish the wireless network upon receiving the user input request (e.g., upon user interaction).

[0044] In one or more example communication systems, the initiator hearing aid is configured to initiate establishment of the wireless network via a graphical interface on an auxiliary device in communication with the initiator hearing aid. In one or more example com-

munication systems, the initiator hearing aid is configured to establish the wireless network by obtaining the user input request via the graphical interface (e.g., on an auxiliary device in communication with the initiator hearing aid) and/or via an interface of the hearing aid (e.g., by pressing a button on the hearing aid and/or tapping the hearing aid). In one or more example communication systems, the auxiliary device in communication with the initiator hearing aid is configured to run an application (e.g., denoted APP) for initiating establishment of the wireless network. In one or more example communication systems, a hearing aid of the plurality of hearing aids may be the initiator hearing aid. The user wearing the initiator hearing aid may trigger establishment of the wireless network by pressing a graphical representation of a button on the graphical interface of the auxiliary device in communication with the initiator hearing aid. The initiator hearing aid may invite the remaining hearing aids of the plurality of hearing aids to connect to the wireless network by transmitting the first connection signal and/or the second connection signal to the remaining hearing aids of the plurality of hearing aids.

[0045] Embodiments of the present disclosure may advantageously allow establishment of an HA community, e.g., of a wireless network between hearing-impaired users, without intervention of an additional party, e.g., an external user to the HA community responsible for managing the wireless network. An external user to the HA community may be seen a user not suffering from hearing loss, such as a user not wearing a hearing aid. An external user to the HA community may be seen as a user not actively participating in the HA community. Put differently, an external user to the HA community may be seen as a user solely responsible for managing the wireless network, e.g., establishing the wireless network and/or inviting users to the wireless network and/or removing users from the wireless network and/or switching off the wireless network. Embodiments of present disclosure also can advantageously allow connection of hearing-impaired users in a golf game and/or a cycling activity, e.g., in situations where it may not be possible to have an external user establishing the HA community.

[0046] Embodiments of the present disclosure may advantageously allow establishment of an HA community, e.g., of a wireless network between hearing-impaired users, with intervention of an additional party, e.g. an external user to the HA community responsible for managing the wireless network. For example, a staff member in a nursing home can manage and/or control participation of hearing-impaired users in an HA community by detecting and inviting hearing aids in the vicinity, such as located within the range of the wireless network. For example, the wireless network may be identified by a sequence of tokens (e.g., as "Common Room" and/or "Physio Department").

[0047] Embodiments of present disclosure also may advantageously allow connection of hearing-impaired users in scenarios that require communication between users (e.g., team sports), such as either with or without intervention of external users for establishing the HA community.

[0048] In one or more example communication systems, a hearing aid of the plurality of hearing aids may be in the acoustic near-field and/or the acoustic far-field of another hearing aid of the plurality of hearing aids. In one or more example communication systems, most sound signal sources (except the user's own voice) are located far away from the user compared to dimensions of a hearing aid, e.g. a distance d_{mic} between two microphones of a directional system. A typical microphone distance in a hearing aid is of the order 10 mm. A *minimum* distance of a sound source of interest to a user of the hearing aid (e.g., sound from the user's mouth or sound from an audio delivery device) is of the order of 0.1 m (> 10 d_{mic}). For such minimum distances, the hearing aid (microphones) would be in the acoustic near-field of the sound source and a difference in level of the sound signals impinging on respective microphones may be significant. A *typical* distance for a communication partner is more than 1 m (>100 d_{mic}). The hearing aid (microphones) would be in the acoustic far-field of the sound source and a difference in level of the sound signals impinging on respective microphones is insignificant. The difference in *time of arrival* of sound impinging in the direction of the microphone axis (e.g. the front or back of a normal hearing aid) is $\Delta T = d_{mic}/v_{sound} = 0.01/343$ [s] $= 29$ μs, where v_{sound} is the speed of sound in air at 20°C (343 m/s).

[0049] In one or more example communication systems, the wireless network comprises a plurality of sub-wireless networks. In one or more example communication systems, each of the plurality of hearing aids being part of a sub-wireless network of the plurality of sub-wireless networks is configured to communicate with each hearing aid being part of the same sub-wireless network. In one or more example communication systems, each of the plurality of hearing aids is configured to communicate with each hearing aid being part of the same wireless network by transmitting the signal to each of the other hearing aid being part of the same sub-wireless network. In one or more example communication systems, each of the plurality of hearing aids is configured to communicate with each hearing aid being part of the same wireless network by receiving the other signal from each of the other hearing aid being part of the same sub-wireless network.

[0050] In one or more example communication systems, the initiator hearing aid is configured to allow (e.g., give permission to) each of the plurality of hearing aids being part of a sub-wireless network to establish a sub-wireless network. Optionally, each of the plurality of the hearing aids connecting to the wireless network (e.g., to a main wireless network) can be configured to establish a sub-wireless network upon joining the wireless network, such as without permission of the initiator hearing aid.

[0051] In one or more example communication sys-

tems, hearing aids being part of the same sub-wireless network are configured to communicate with each other despite being part of the same wireless network, such as the same main wireless network, such as the wireless network established by the initiator hearing aid. Each sub-wireless network of the plurality of sub-wireless networks may comprise an identifier allowing communication of signals between hearing aids of the same sub-wireless network. In other words, each of the plurality of hearing aids may be configured to detect a speech preference, such as each of the plurality of hearing aids may only receive respective other signal from other hearing aids of the plurality of hearing aids that are useful to the user wearing the respective hearing aid. For example, each of the plurality of hearing aids may receive the respective other signal from each of the other hearing aid of the plurality of hearing aids (e.g., and/or at least two other hearing aids) being part of the same sub-wireless network. For example, each of the plurality of hearing aids can receive the respective other signal from each of the other hearing aid of the plurality of hearing aids (e.g., and/or at least two other hearing aids), each of the other hearing aid of the plurality of hearing aids (e.g., and/or at least two other hearing aids) being within the network coverage area of the sub-wireless network, such as within the same range and/or distance threshold.

[0052] Establishment of sub-wireless networks within a main wireless network may enable filtering of audio signals being of no interest to a user. For example, audio signals communicated between hearing aids belonging to the same sub-wireless network can be construed as audio signals of interest for users wearing such hearing aids. For example, users wearing such hearing aids can avoid reception of audio signals from users belonging to different sub-wireless networks.

[0053] Optionally, each of the plurality of hearing aids can comprise a directional microphone system adapted to spatially filter sounds from the environment, and thereby enhancing a target acoustic source among a multitude of acoustic sources in the local environment of the user wearing the respective hearing aid. The directional system may be adapted to detect (such as adaptively detect) from which direction a particular part of the microphone signal originates. This can be achieved in various different ways as e.g., described in the prior art. In hearing aids, a microphone array beamformer is often used for spatially attenuating background noise sources. The beamformer may comprise a linear constraint minimum variance (LCMV) beamformer. Many beamformer variants can be found in literature. The minimum variance distortionless response (MVDR) beamformer is widely used in microphone array signal processing. Ideally the MVDR beamformer keeps the signals from the target direction (also referred to as the look direction) unchanged, while attenuating sound signals from other directions maximally. The generalized sidelobe canceller (GSC) structure is an equivalent representation of the MVDR beamformer offering computational and numerical advantages over a direct implementation in its original form.

[0054] In one or more example communication systems, the communication system comprises a plurality of auxiliary devices. In one or more example communication systems, each of the plurality of hearing aids is in communication with a respective auxiliary device of the plurality of auxiliary devices. Put differently, the communication system comprises a plurality of hearing aids, each of the plurality of hearing aids in communication with a respective auxiliary device. The communication system may comprise a plurality of hearing systems, each hearing system comprising a hearing aid and an auxiliary device. In one or more example communication systems, the wireless transceiver unit of each of the plurality of hearing aids is configured to transmit, to each other hearing aid of the plurality of hearing aids, the signal via the respective auxiliary device.

[0055] In one or more example communication systems, the communication system comprises a plurality of hearing aids, each of the plurality of hearing aids in communication with a respective auxiliary device (e.g., a mobile phone). Stated differently, the communication system may comprise a plurality of hearing systems. Each of the plurality of hearing systems may comprise a hearing aid and an auxiliary device.

[0056] In one or more example communication systems, the communication system is configured to establish a communication link (e.g., a wireless link) between each of the plurality of hearing systems (e.g., between each of the plurality of hearing aids and the respective auxiliary device of the plurality of auxiliary devices) for providing that information (e.g., control signals and/or status signals and/or audio signals and/or wireless signals) can be exchanged or forwarded from one hearing system to the other hearing system. For example, establishment of the communication link between each of the plurality of hearing systems enables each of the plurality of hearing systems to transmit the signal to each of the other hearing system of the plurality of hearing systems. For example, each of the plurality of hearing systems is configured to transmit the signal to each of the other hearing system of the plurality of hearing systems by transmitting such signal to each of the other hearing aid of the plurality of hearing aids via the respective auxiliary device.

[0057] The communication system may be configured to establish an internal communication link (e.g., an internal wireless link) between communication devices of the same hearing system. In other words, the communication system may be configured to establish an internal communication link between a hearing aid and an auxiliary device (e.g., comprised in a hearing system of the plurality of hearing systems) for providing that information (e.g., control signals and/or status signals and/or audio signals and/or wireless signals) can be exchanged or forwarded from one to the other. For example, the hearing aid (e.g., the wireless transceiver of the hearing

aid) is configured to transmit the signal to the auxiliary device (e.g., of the same hearing system). For example, the auxiliary device (e.g., a wireless interface of the auxiliary device) is configured to transmit the signal to each of the other hearing system of the plurality of hearing systems. In other words, the auxiliary device may be configured to broadcast the signal to each of the other hearing aids of the plurality of hearing aids, such as to hearing devices within the coverage area of the wireless network.

[0058] The wireless link and/or the internal wireless link may be a link based on near-field communication, e.g., an inductive link based on an inductive coupling between antenna coils of transmitter and receiver parts. The wireless link may be based on far-field, electromagnetic radiation. For example, frequencies used to establish a communication link between the hearing aid and other communication device is below 70 GHz, e.g., located in a range from 50 MHz to 70 GHz, e.g., above 300 MHz, e.g., in an ISM range above 300 MHz, e.g., in the 900 MHz range or in the 2.4 GHz range or in the 5.8 GHz range or in the 60 GHz range (ISM=Industrial, Scientific and Medical, such standardized ranges being e.g., defined by the International Telecommunication Union (ITU)). The wireless link may be based on a standardized or proprietary technology. The wireless link may be based on Bluetooth technology (e.g., Bluetooth Low-Energy technology, e.g., LE audio), or Ultra-Wide Band (UWB) technology.

[0059] The respective auxiliary device may comprise one or more of: remote control, a smartphone (e.g., a mobile phone), a portable electronic device, a wearable electronic device (e.g., a smartwatch), an any other suitable auxiliary device. The auxiliary may be a standalone device. The auxiliary device may comprise a wireless interface, a memory, and a processor.

[0060] The respective auxiliary device may comprise a remote control for controlling functionality and operation of the respective hearing aid. The function of a remote control may be implemented in a smartphone, the smartphone possibly running an APP allowing to control the functionality of the audio processing device via the smartphone (the hearing aid comprising an appropriate wireless interface to the smartphone, e.g., based on Bluetooth or some other standardized or proprietary scheme). The respective auxiliary device may comprise another hearing aid. The hearing system may comprise two hearing aids adapted to implement a binaural hearing system, e.g. a binaural hearing aid system.

[0061] The wireless transceiver unit of each of the plurality of hearing aids may allow a wireless link to one or more of: an entertainment device (e.g., a TV-set), a communication device (e.g., a telephone), a wireless microphone, a separate (external) processing device, and another hearing aid. The wireless transceiver unit (e.g., antenna and transceiver circuitry) of each of the plurality of hearing aids may be configured for wireless communications with one or more electronic devices (e.g., a speakerphone, a smartphone, a tablet, a computer and/or a smartwatch). Each of the plurality of hearing aids may comprise an antenna for converting one or more wireless input audio signals to antenna output signal(s).

[0062] The communication system (e.g., each of the plurality of hearing aids and/or respective auxiliary device) may be configured for wireless communications via a wireless communication system, such as short-range wireless communications systems, such as Wi-Fi, Bluetooth, Zigbee, IEEE 802.11, IEEE 802.15, infrared and/or the like.

[0063] The communication system (e.g., each of the plurality of hearing aids and/or respective auxiliary device) may be configured for wireless communications via a wireless communication system, such as a 3rd Generation Partnership Project (3GPP) system, such as a 3GPP system supporting one or more of: New Radio (NR), Narrow-band Internet of Things (NB-IoT), Long Term Evolution - enhanced Machine Type Communication (LTE-MTC), and millimeter-wave communications (e.g., millimeter-wave communications in licensed bands, such as device-to-device (D2D) millimeter-wave communications in licensed bands).

[0064] The wireless transceiver unit (e.g., of each of the plurality of hearing aids) and/or the wireless interface (e.g., of respective auxiliary device) may comprise one or more of: a Bluetooth interface, Bluetooth low energy interface, and a magnetic induction interface. For example, the wireless interface unit of each of the plurality of hearing aids and/or the wireless interface of each of the plurality of auxiliary devices comprise a Bluetooth antenna and/or a magnetic interference antenna. Optionally, the wireless interface unit and/or the wireless interface may comprise a connector for wired communications, via a connector, such as by using an electrical cable. The connector may connect a hearing aid of the plurality of hearing aids to other hearing aid of the plurality of hearing aids. The connector may connect a hearing aid to an auxiliary device (e.g., to an electronic device), e.g., for a wired connection. The connector may connect a hearing system of the plurality of hearing systems to other hearing system of the plurality of hearing systems.

[0065] In one or more example communication systems, the wireless transceiver unit of each of the plurality of hearing aids is further configured to receive, from each of other hearing aid of the plurality of hearing aids, the respective other signal via the respective auxiliary device. For example, the respective auxiliary device (e.g., the wireless interface of the auxiliary device) is configured to receive the respective other signal from each of the other hearing aid of the plurality of hearing aids. For example, the respective auxiliary device (e.g., the wireless interface of the auxiliary device) is configured to transmit the respective other signal of the other hearing aid of the plurality of hearing aids to the hearing aid in communication with the respective auxiliary device (e.g., of the same hearing system).

[0066] In one or more example communication systems, each of the plurality of hearing aids is configured to communicate with each of the other hearing aid of the plurality hearing aids via the respective auxiliary device. For example, communicating with each of the other hearing aid of the plurality hearing aids via the respective auxiliary device comprises transmitting, to each of the other hearing aid of the plurality of hearing aids, the signal via the respective auxiliary device. For example, communicating with each of the other hearing aid of the plurality hearing aids via the respective auxiliary device comprises receiving, from each of other hearing aid of the plurality of hearing aids, the respective other signal via the respective auxiliary device.

[0067] In one or more example communication systems, an auxiliary device of a hearing aid being part of a sub-wireless network is configured to transmit the signal to other hearing aids being part of the same sub-wireless network. In one or more example communication systems, an auxiliary device of a hearing aid being part of a sub-wireless network is configured to receive other signals from other hearing aids being part of the same sub-wireless network.

[0068] In one or more example communication systems, the respective auxiliary device is configured to combine the respective other signal of each of the other hearing aid of the plurality of hearing aids for provision of a respective combined signal. In other words, an auxiliary device in communication with a hearing aid of the plurality of hearing aids may be configured to combine other signals (e.g., received from each of the other hearing aids of the plurality of hearing aids) from provision of a combined signal. The combined signal may include a plurality of second signals. For example, an auxiliary device is configured to combine at least two other signals obtained from at least two other hearing aids of the plurality of hearing aids for provision of a combined signal. The combined signal may include at least two second signals. In one or more example communication systems, the respective auxiliary device is configured to transmit, to the hearing aid in communication with the respective auxiliary device, the respective combined signal. In one or more example communication systems, the wireless transceiver unit of each of the plurality of hearing aids is configured to receive, from the respective auxiliary device, the respective combined signal.

[0069] In one or more example communication systems, the respective auxiliary device can comprise an audio gateway device configured to receive a plurality of audio signals (e.g., from an entertainment device, e.g. a TV or a music player, a telephone apparatus, e.g. a mobile telephone or a computer, e.g. a PC, a wireless microphone, etc.) and configured to select and/or combine some of the received audio signals for transmission to the hearing aid.

[0070] In one or more example communication systems, the respective auxiliary device is configured to remove noise from the respective combined signal, such as by applying a noise reduction technique to the respective combined signal. Put differently, noise sources (e.g., background talkers) may be present in more than one other signal of the other signals. In one or more example communication systems, the respective auxiliary device is configured to apply a noise reduction technique to the combined signal before transmitting the respective combined signal to the hearing aid in communication with the respective auxiliary device. For example, applying the noise reduction technique to the respective combined signal can comprise averaging the respective other signals received from the other hearing aids of the plurality of hearing aids.

[0071] In one or more example communication systems, the respective auxiliary device is configured to receive the signal indicative of the own voice of the user wearing the hearing aid in communication with the respective auxiliary device. The respective auxiliary device may combine the respective other signal obtained from each of the other hearing aid of the plurality of hearing aids with the signal indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids. Each of the plurality of hearing aids may be configured to apply an echo cancellation method to the respective combined signal, e.g., via the respective auxiliary device. For example, applying an echo cancellation method to the respective combined signal comprises removing and/or dampening the signal from the combined signal. Put differently, applying the echo cancellation method to the respective combined signal may comprise removing the signal indicative of the own voice of the user wearing the respective hearing aid, such as the hearing aid in communication with the respective auxiliary device.

[0072] In one or more example communication systems, each of the plurality of hearing aids can comprise an acoustic (and/or mechanical) feedback control (e.g., suppression) or echo cancelling system. For example, adaptive feedback cancellation has the ability to track feedback path changes over time. It is typically based on a linear time invariant filter to estimate the feedback path, but its filter weights are updated over time. The filter update may be calculated using stochastic gradient algorithms, including some form of the Least Mean Square (LMS) or the Normalized LMS (NLMS) algorithms. For example, they both have the property to minimize the error signal in the mean square sense with the NLMS additionally normalizing the filter update with respect to the squared Euclidean norm of some reference signal.

[0073] In one or more example communication systems, the respective combined signal comprises a cleaned version of the respective other signal indicative of an own voice of another user wearing each of the other hearing aids of the plurality of hearing aids, such as a signal with reduced noise and/or echo. In one or more example communication systems, the respective combined signal comprises a cleaned version of at least two other signals obtained from at least two other hearing

aids from the plurality of hearing aids, such as from hearing systems having detected own voice of a user wearing the respective other hearing aid.

[0074] In one or more example communication systems, the respective auxiliary device is further configured to combine and/or mix the combined signal (e.g., a HA community signal) with an environment input signal obtained from an omni type beamformer. The environment input signal may be indicative of a sound from the environment where the user wearing the respective hearing aid of the plurality of hearing aids is located.

[0075] For example, when a hearing aid of the plurality of hearing aids connects to the wireless network (e.g., to the HA community) the hearing aid may enter a mode and/or a program where reception of signals (e.g., reception of other signals and/or of a combined signal) is allowed. Such mode and/or program may allow reception of a mixed signal that results from an optimal mix of an environmental input signal with the combined signal.

[0076] In one or more example communication systems, the output unit of each of the plurality of hearing aids is configured to output, based the respective combined signal, the audible signal to the user wearing the respective hearing aid of the plurality of hearing aids.

[0077] Embodiments of the present disclosure may enable provision of an output signal comprising a level of environmental noise that do not impair sound perception of the user wearing the respective hearing aid of the plurality of hearing aids.

[0078] Embodiments of the present disclosure may advantageously provide a community mode and/or program in a hearing system in which speech from the HA community, environmental awareness and echo minimization can be enhanced by balancing and filtering streamed input (e.g., the other signals and/or the combined signal) and microphone input (e.g., environmental noise and/or the signal).

[0079] In one or more example communication systems, to combine the respective other signal of each of the other hearing aid of the plurality of hearing aids comprises applying to the respective other signal one or more of: a threshold-based method and a spatial-based method.

[0080] In one or more example communication systems, a threshold-based method can comprise an automatic gain control, AGC, method. For example, applying the threshold-based method to the respective other signal comprises linearly combining the respective other signal of each of the other hearing aid of the plurality of hearing aids. In one or more example communication systems, linearly combining the respective other signal of each of the other hearing aid of the plurality of hearing aids comprises to apply a gain to the respective other signal of each of the other hearing aid of the plurality of hearing aids. In one or more example communication systems, the gain is applied based on the level of sound associated with the respective other signal. For example, the gains to be applied can attenuate the respective other signal (when another user speaks loudly) or amplify the respective other signal (when another user speaks quietly) from each of the other hearing aids of the plurality of hearing aids. In one or more example communication systems, applying the threshold-based method to the respective other signal comprises linearly combining at least two other signals obtained from at least two other hearing aids of the plurality of hearing aids. For example, linearly combining the at least two other signals comprise to apply a gain to each of the at least two signals.

[0081] In one or more example communication systems, applying a spatial-based method to the respective other signal of each of the other hearing aid of the plurality of hearing aids enables combining the respective other signal of each of the other hearing aid of the plurality of hearing aids based on spatial knowledge, such as based on knowledge of the environment where the plurality of hearing aids is positioned.

[0082] Optionally, each of the plurality of hearing aids is configured to combine the respective other signal of each of the other hearing aid of the plurality of hearing aids for provision of a respective combined signal. Each of the plurality of hearing aids may be configured to apply a threshold-based method and/or a spatial-based method to the respective combined signal.

[0083] In one or more example communication systems, the communication system can comprise an auxiliary device and the plurality of hearing aids. Stated differently, the communication system may comprise a single auxiliary device in communication with each of the plurality of hearing aids, such as an auxiliary device common to each of the plurality of hearing aids. The auxiliary device may be seen as a broadcast device and/or a mixer.

[0084] In one or more example communication systems, the wireless transceiver unit of each of the plurality of hearing aids is configured to transmit, to each of the other hearing aid of the plurality of hearing aids, the signal via the auxiliary device. For example, the auxiliary device is configured to receive the signal from each of the plurality of hearing aids.

[0085] In one or more example communication systems, the wireless transceiver unit of each of the plurality of hearing aids is further configured to receive, from each of the other hearing aid of the plurality of hearing aids, the respective other signal via the auxiliary device. Stated differently, the auxiliary device is configured to receive the respective other signal from each of the other hearing aid of the plurality of hearing aids.

[0086] In one or more example communication systems, the auxiliary device is configured to combine the signal of each of the plurality hearing aids and the respective other signal of each of the other hearing aid of the plurality of hearing aids for provision of a combined signal. In one or more example communication systems, the auxiliary device is configured to transmit the combined signal to each of the plurality of hearing aids. Put differently, the wireless transceiver unit of each of the

plurality of hearing aids is configured to receive a respective combined signal from the auxiliary device.

[0087] In one or more example communication systems, each of the plurality of hearing aids is configured to apply an echo cancellation method to the respective combined signal (e.g., as transmission and/or broadcast of the combined signal may include a slight delay). For example, applying an echo cancellation method to the respective combined signal comprises cancelling (e.g., removing and/or dampening and/or reducing) the signal indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids. Put differently, applying the echo cancellation method to the respective combined signal may comprise removing the signal generated by each of the plurality of hearing aids from the respective combined signal. For example, the signal can be seen as an echo of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids.

[0088] In one or more example communication systems, each of the plurality of hearing aids comprises an output unit configured to output, based on the respective combined signal, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids.

[0089] In one or more example communication systems, each of the plurality of hearing aids can be constituted by or form part of a portable (e.g., configured to be wearable) device, e.g. a device comprising a local energy source, e.g. a battery, e.g. a rechargeable battery. The hearing aid may e.g. be a low weight, easily wearable, device, e.g. having a total weight less than 100 g, such as less than 20 g, such as less than 5 g.

[0090] Each of the plurality of hearing aids may further comprise other relevant functionality for the application in question, such as a compression functionality.

[0091] Each of the plurality of hearing aids may comprise a hearing instrument, e.g., a hearing instrument configured to be located at the ear or fully or partially in the ear canal of a user.

A method:

[0092] A method, performed by at least two hearing aids of a plurality of hearing aids, for operating a communication system comprising the plurality of hearing aids is disclosed. The method comprises generating a signal indicative of an own voice of a user wearing a respective hearing aid of the at least two hearing aids. The method comprises establishing a wireless network with at least two other hearing aids of the plurality of hearing aids. The method comprises transmitting, to the at least two other hearing aids of the plurality of hearing aids, the signal. The method comprises receiving, from a respective other hearing aid of the at least two other hearing aids, other signal indicative of an own voice of another user wearing the respective other hearing aid of the at least two other hearing aids. The method comprises outputting, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the at least two hearing aids.

[0093] It is intended that some or all of the structural features of the communication system described above, in the 'detailed description of embodiments' or in the claims can be combined with embodiments of the method of operating the communication system, when appropriately substituted by a corresponding process and vice versa. Embodiments of the method of operating the communication system have the same advantages as the corresponding communication system.

Use:

[0094] In an aspect, use of a hearing aid as described above, in the 'detailed description of embodiments' and in the claims, is moreover provided. Use may be provided in a system comprising one or more hearing aids (e.g., hearing instruments).

A computer readable medium or data carrier:

[0095] In an aspect, a tangible computer-readable medium (a data carrier) storing a computer program comprising program code means (instructions) for causing a data processing system (a computer) to perform (carry out) at least some (such as a majority or all) of the (steps of the) method described above, in the 'detailed description of embodiments' and in the claims, when said computer program is executed on the data processing system is furthermore provided by the present application.

[0096] By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Other storage media include storage in DNA (e.g., in synthesized DNA strands). Combinations of the above should also be included within the scope of computer-readable media. In addition to being stored on a tangible medium, the computer program can also be transmitted via a transmission medium such as a wired or wireless link or a network, e.g. the Internet, and loaded into a data processing system for being executed at a location different from that of the tangible medium.

A computer program:

[0097] A computer program (product) comprising instructions which, when the program is executed by a computer, cause the computer to carry out (steps of)

the method described above, in the 'detailed description of embodiments' and in the claims is furthermore provided by the present application.

A data processing system:

[0098] In an aspect, a data processing system comprising a processor and program code means for causing the processor to perform at least some (such as a majority or all) of the steps of the method described above, in the 'detailed description of embodiments' and in the claims is furthermore provided by the present application.

An APP:

[0099] In a further aspect, a non-transitory application, termed an APP, is furthermore provided by the present disclosure. The APP comprises executable instructions configured to be executed on an auxiliary device to implement a user interface for a communication system (such as, a plurality of hearing aids and/or a plurality of auxiliary device and/or a plurality of hearing systems) described above in the 'detailed description of embodiments', and in the claims. The APP may be configured to run on an auxiliary device, such as on a cellular phone, e.g., a smartphone, or on another portable device allowing communication with said hearing aid or said hearing system.

Definitions:

[0100] In the present context, a hearing aid, e.g. a hearing instrument, refers to a device, which is adapted to improve, augment and/or protect the hearing capability of a user by receiving acoustic signals from the user's surroundings, generating corresponding audio signals, possibly modifying the audio signals and providing the possibly modified audio signals as audible signals to at least one of the user's ears. Such audible signals may e.g. be provided in the form of acoustic signals radiated into the user's outer ears and/or acoustic signals transferred as mechanical vibrations to the user's inner ears through the bone structure of the user's head and/or through parts of the middle ear.

[0101] The hearing aid may be configured to be worn in any known way, e.g. as a unit arranged behind the ear with a tube leading radiated acoustic signals into the ear canal or with an output transducer, e.g., a loudspeaker, arranged close to or in the ear canal, as a unit entirely or partly arranged in the pinna and/or in the ear canal, as a unit, e.g., a vibrator, attached to a fixture implanted into the skull bone, etc. The hearing aid may comprise a single unit or several units communicating (e.g., acoustically, electrically or optically) with each other. The loudspeaker may be arranged in a housing together with other components of the hearing aid, or may be an external unit in itself (possibly in combination with a flexible guiding element, e.g., a dome-like element).

[0102] A hearing aid may be adapted to a particular user's needs, e.g., a hearing impairment. A configurable signal processing circuit of the hearing aid may be adapted to apply a frequency and level dependent compressive amplification of an input signal. A customized frequency and level dependent gain (amplification or compression) may be determined in a fitting process by a fitting system based on a user's hearing data, e.g. an audiogram, using a fitting rationale (e.g. adapted to speech). The frequency and level dependent gain may e.g. be embodied in processing parameters, e.g., uploaded to the hearing aid via an interface to a programming device (fitting system), and used by a processing algorithm executed by the configurable signal processing circuit of the hearing aid.

[0103] A 'hearing system' refers to a system comprising one or two hearing aids, and a 'binaural hearing system' refers to a system comprising two hearing aids and being adapted to cooperatively provide audible signals to both of the user's ears. Hearing systems or binaural hearing systems may further comprise one or more 'auxiliary devices', which communicate with the hearing aid(s) and affect and/or benefit from the function of the hearing aid(s). Such auxiliary devices may include at least one of a remote control, a remote microphone, an audio gateway device, an entertainment device, e.g., a music player, a wireless communication device, e.g., a mobile phone (such as a smartphone) or a tablet or another device, e.g. comprising a graphical interface. Hearing aids, hearing systems or binaural hearing systems may e.g. be used for compensating for a hearing-impaired person's loss of hearing capability, augmenting or protecting a normal-hearing person's hearing capability and/or conveying electronic audio signals to a person. Hearing aids or hearing systems may e.g. form part of or interact with public-address systems, active ear protection systems, handsfree telephone systems, car audio systems, entertainment (e.g., TV, music playing or karaoke) systems, teleconferencing systems, classroom amplification systems, etc.

[0104] The invention is set out in the appended set of claims.

BRIEF DESCRIPTION OF DRAWINGS

[0105] The aspects of the disclosure may be best understood from the following detailed description taken in conjunction with the accompanying figures. The figures are schematic and simplified for clarity, and they just show details to improve the understanding of the claims, while other details are left out. Throughout, the same reference numerals are used for identical or corresponding parts. The individual features of each aspect may each be combined with any or all features of the other aspects. These and other aspects, features and/or technical effect will be apparent from and elucidated with reference to the illustrations described hereinafter in which:

FIG. 1 illustrate a first example communication system according to this disclosure;

FIG. 2 illustrate a second example communication system according to this disclosure; and

FIG. 3 is a flow-chart of an example method of operating a communication system according to this disclosure.

[0106] The figures are schematic and simplified for clarity, and they just show details which are essential to the understanding of the disclosure, while other details are left out. Throughout, the same reference signs are used for identical or corresponding parts.

[0107] Further scope of applicability of the present disclosure 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 disclosure, are given by way of illustration only. Other embodiments may become apparent to those skilled in the art from the following detailed description.

DETAILED DESCRIPTION OF EMBODIMENTS

[0108] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. Several aspects of the apparatus and methods are described by various blocks, functional units, modules, components, circuits, steps, processes, algorithms, etc. (e.g., collectively referred to as "elements"). Depending upon particular application, design constraints or other reasons, these elements may be implemented using electronic hardware, computer program, or any combination thereof.

[0109] The electronic hardware may include micro-electronic-mechanical systems (MEMS), integrated circuits (e.g., application specific), microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), gated logic, discrete hardware circuits, printed circuit boards (PCB) (e.g., flexible PCBs), and other suitable hardware configured to perform the various functionality described throughout this disclosure, e.g. sensors, e.g. for sensing and/or registering physical properties of the environment, the device, the user, etc. Computer program shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0110] The term ‘or a processed version thereof may e.g. cover such extracted features from an original audio signal. The term ‘or a processed version thereof may e.g. also cover an original audio signal that has been subject to a processing algorithm that applies gain or attenuation and/or delay to the original audio signal and this results in a modified audio signal (preferably enhanced in some sense, e.g. noise reduced relative to a target signal, or simply delayed).

[0111] FIG. 1 illustrate a first example communication system 300 according to this disclosure. The communication system 300 comprises a plurality of hearing aids 300A, 300B, 300C, 300D. In the embodiment of FIG. 1, each of the plurality of hearing aids 300A, 300B, 300C, 300D is in communication with a respective auxiliary device of the plurality of auxiliary devices 500A, 500B, 500C, 500D. For example, hearing aids 300A, 300B, 300C, 300D is in communication with auxiliary devices 500A, 500B, 500C, 500D, respectively. The communication system 300 may comprise a plurality of hearing systems 700A, 700B, 700C, 700D.

[0112] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises an input unit configured to generate a signal indicative of an own voice of a user wearing a respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D.

[0113] In one or more examples, the input unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to provide an electric input signal representing sound. The input unit may comprise an input transducer (e.g., a microphone) configured to convert an input signal (e.g., an input sound and/or a microphone input signal) to an electric input signal. For example, hearing aids 300A, 300B, 300C are configured to obtain a respective input signal via a respective input transducer. In the embodiment of FIG. 1, the hearing aids 300A, 300B, 300C are configured to convert the respective input signal to a respective electric input signal.

[0114] In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to convert the electric input signal (e.g., an analogue electric signal) to a digital audio signal using an ADC. In one or more example examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to generate the signal 20A, 20B, 20C, 20D by applying to the digital audio signal one or more of: a VAD method, and an OVAD method. For example, applying such methods to the digital audio signal may comprise determining the signal 20A, 20B, 20C, 20D as being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. For example, applying such methods to the digital audio signal may comprise determining the signal 20A, 20B, 20C, 20D as not being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. In the embodiment of FIG. 1, the hearing aids 300A, 300B, 300C are configured to convert the respective electric input signal

to a respective digital audio signal using an ADC. For example, the hearing aids 300A, 300B are configured to determine the signal 20A, 20B, 20C as being indicative of an own voice of a user wearing the hearing aid 300A, 300B, 300C respectively by applying a VAD method and/or a OVAD method to the respective digital audio signal.

[0115] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises a wireless transceiver unit, the wireless transceiver unit comprising a wireless interface configured to establish a wireless network with each of the other hearing aids of the plurality of hearing aids 300A, 300B, 300C, 300D. In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to communicate with each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D via a communication link. In one or more examples, the communication link is a digital link forming the wireless network, such as a wireless link.

[0116] In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D can be configured to be an initiator hearing aid. In one or more examples, the initiator hearing aid is configured to establish the wireless network with each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D.

[0117] In one or more examples, the initiator hearing aid is configured to broadcast a first connection signal to each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. Broadcasting the first connection signal may enable connection of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D to the wireless network. The initiator hearing aid may be configured to broadcast the first connection signal to each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D via the auxiliary device in connection with the initiator hearing aid. For example, the initiator hearing aid can be any hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. For example, the hearing aid 300A can be the initiator hearing aid, such as can be responsible for establishing the wireless network and inviting the other hearing aids 300B, 300C, 300D to connect to the wireless network established by the hearing aid 300A.

[0118] In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to broadcast a second connection signal to hearing aids not initially forming the wireless network. Broadcasting the second connection signal may enable connection of the other hearing aids not initially forming the wireless network (not shown in FIG. 1). The initiator hearing aid may be configured to broadcast the second connection signal to hearing aids not initially forming the wireless network via the auxiliary device in connection with the initiator hearing aid.

[0119] In one or more examples, the initiator hearing aid is configured to initiate establishment of the wireless network upon user interaction. In one or more examples, the initiator hearing aid is configured to initiate establishment of the wireless network via a graphical interface on an auxiliary device in communication with the initiator hearing aid. For example, the hearing aid 300A, when acting as the initiator hearing aid, can initiate establishment of the wireless network via a graphical interface in the auxiliary device 500A. In other words, the user wearing the hearing aid 300A may establish the wireless network by touching and/or pushing a button on the auxiliary device 500A and/or on the hearing aid 300A. The user wearing the hearing aid 300A may establish the wireless network by touching a graphical representation of a button on a display of the auxiliary device 500A (e.g., on a smartphone and/or smartwatch).

[0120] In one or more examples, the wireless network comprises a plurality of sub-wireless networks. In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D being part of a sub-wireless network of the plurality of sub-wireless networks is configured to communicate with each hearing aid being part of the same sub-wireless network. For example, the hearing aids 300A, 300B, 300C, 300B may be part of a sub-wireless network, such as within the coverage of the sub-wireless network. The hearing aids 300A, 300B, 300C, 300D may be configured communicate with each other.

[0121] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises a wireless transceiver unit configured to transmit the signal 20A, 20B, 20C, 20D to each other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises a wireless transceiver unit configured to transmit the signal 20A, 20B, 20C, 20D to each other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D via a respective communication link and/or channel. In one or more examples, the wireless transceiver unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to transmit, to each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, the signal 20A, 20B, 20C, 20D via the respective auxiliary device 500A, 500B, 500C, 500D.

[0122] In the embodiment of FIG. 1, the hearing aid 300A is configured to transmit the signal 20A to each of the other hearing aids 300B, 300C, 300D, e.g., via the auxiliary device 500A. For example, the auxiliary device 500A is configured to receive the signal 20A from the hearing aid 300A. For example, the auxiliary device 500A is configured to transmit the signal 20A to the other hearing aids 300B, 300C, 300D. For example, the hearing aid 300B is configured to transmit the signal 20B to each of the other hearing aids 300A, 300C, 300D, e.g., via the auxiliary device 500B. For example, the auxiliary device 500B is configured to receive the signal 20B from the hearing aid 300B. For example, the auxiliary device 500B is configured to transmit the signal 20B to the other hearing aids 300A, 300C, 300D. For example, the hearing aid 300C is configured to transmit the signal 20C to each of the other hearing aids 300A, 300B, 300D, e.g., via

the auxiliary device 500C. For example, the auxiliary device 500C is configured to receive the signal 20C from the hearing aid 300C. For example, the auxiliary device 500C is configured to transmit the signal 20C to the other hearing aids 300A, 300B, 300D.

[0123] The wireless transceiver unit is further configured to receive, from each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, a respective other signal 20A, 20B, 20C, 20D indicative of an own voice of another user wearing each of the other hearing aids of the plurality of hearing aids 300A, 300B, 300C, 300D. In one or more examples, the wireless transceiver unit is further configured to receive, from each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, the respective other signal 20A, 20B, 20C, 20D via a respective communication link and/or channel. In one or more examples, the wireless transceiver unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D is further configured to receive, from each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, the respective other signal 20A, 20B, 20C, 20D via the respective auxiliary device 500A, 500B, 500C, 500D. In the embodiment of FIG. 1, the hearing aid 300A is configured to receive the other signals 20B, 20C from each of the other hearing aids 300B, 300C, e.g., via the auxiliary device 500A. For example, the auxiliary device 500A is configured to receive the other signals 20B, 20C from the other hearing aids 300B, 300C respectively. In the embodiment of FIG. 1, the hearing aid 300B is configured to receive the other signals 20A, 20C from each of the other hearing aids 300A, 300C, e.g., via the auxiliary device 500B. For example, the auxiliary device 500B is configured to receive the other signals 20A, 20C from the other hearing aids 300A, 300C respectively. In the embodiment of FIG. 1, the hearing aid 300C is configured to receive the other signals 20A, 20B from each of the other hearing aids 300A, 300B, e.g., via the auxiliary device 500C. For example, the auxiliary device 500C is configured to receive the other signals 20A, 20B from the other hearing aids 300A, 300B respectively. In the embodiment of FIG. 1, the hearing aid 300D is configured to receive the other signals 20A, 20B, 20C from each of the other hearing aids 300A, 300B, 300C, e.g., via the auxiliary device 500D. For example, the auxiliary device 500D is configured to receive the other signals 20A, 20B, 20C from the other hearing aids 300A, 300B, 300C respectively.

[0124] In one or more examples, the respective auxiliary device 500A, 500B, 500C, 500D is configured to combine the respective other signal 20A, 20B, 20C, 20D of each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D for provision of a respective combined signal 22A, 22B, 22C, 22D. In one or more examples, the respective auxiliary device 500A, 500B, 500C, 500D is configured to transmit the respective combined signal 22A, 22B, 22C, 22D to the hearing aid in communication with the respective auxiliary device 500A, 500B, 500C, 500D. In the embodiment of FIG. 1, the auxiliary device 500A is configured to combine the other signals 20B, 20C of each of the other hearing aids 300B, 300C for provision of the combined signal 22A. For example, the auxiliary device 500A is configured to transmit the combined signal 22A to the hearing aid 300A. In the embodiment of FIG. 1, the auxiliary device 500B is configured to combine the other signals 20A, 20C of each of the other hearing aids 300A, 300C for provision of the combined signal 22B. For example, the auxiliary device 500B is configured to transmit the combined signal 22B to the hearing aid 300B. In the embodiment of FIG. 1, the auxiliary device 500C is configured to combine the other signals 20A, 20B of each of the other hearing aids 300A, 300B for provision of the combined signal 22C. For example, the auxiliary device 500C is configured to transmit the combined signal 22C to the hearing aid 300C. In the embodiment of FIG. 1, the auxiliary device 500D is configured to combine the other signals 20A, 20B, 20C of each of the other hearing aids 300A, 300B, 300C for provision of the combined signal 22D. For example, the auxiliary device 500D is configured to transmit the combined signal 22D to the hearing aid 300D.

[0125] In one or more examples, to combine the respective other signal 20A, 20B, 20C, 20D of each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D comprises applying to the respective other signal 20A, 20B, 20C, 20D one or more of: a threshold-based method and a spatial-based method. For example, the respective auxiliary device 500A, 500B, 500C, 500D is configured to apply a threshold-based method and/or a spatial-based method to the respective combined signal 22A, 22B, 22C, 22D.

[0126] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises an output unit configured to output, based on each of the respective other signal 20A, 20B, 20C, 20D, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. For example, each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises an output unit configured to output, based on each of the respective combined signal 22A, 22B, 22C, 22D, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. In the embodiment of FIG. 1, the output unit of the hearing aid 300A is configured to output, based on the other signals 20B, 20C, a first audible signal to the user wearing the hearing aid 300A. For example, the output unit of the hearing aid 300A is configured to output, based on the combined signal 20A, the first audible signal. In the embodiment of FIG. 1, the output unit of the hearing aid 300B is configured to output, based on the other signals 20A, 20C, a second audible signal to the user wearing the hearing aid 300B. For example, the output unit of the hearing aid 300B is configured to output, based on the combined signal 20B, the second audible signal. In the embodiment of FIG. 1, the output unit of the hearing aid 300C is configured to output, based on the other signals 20A, 20B, a third audible signal to the user

wearing the hearing aid 300C. For example, the output unit of the hearing aid 300C is configured to output, based on the combined signal 20C, the third audible signal. In the embodiment of FIG. 1, the output unit of the hearing aid 300D is configured to output, based on the other signals 20A, 20B, 20C a fourth audible signal to the user wearing the hearing aid 300D. For example, the output unit of the hearing aid 300D is configured to output, based on the combined signal 20D, the fourth audible signal.

[0127] FIG. 2 illustrate a second example communication system 370 according to this disclosure. The communication system 370 comprises an auxiliary device 500 and plurality of hearing aids 300A, 300B, 300C, 300D. The communication system 370 comprises a single auxiliary device in communication with each of the plurality of hearing aids 300A, 300B, 300C, 300D. The auxiliary device may be seen as a broadcast device and/or a mixer.

[0128] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises an input unit configured to generate a signal indicative of an own voice of a user wearing a respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D.

[0129] In one or more examples, the input unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to provide an electric input signal representing sound. The input unit may comprise an input transducer (e.g., a microphone) configured to convert an input signal (e.g., an input sound and/or a microphone input signal) to an electric input signal. For example, hearing aids 300A, 300B, 300C are configured to obtain a respective input signal via a respective input transducer. In the embodiment of FIG. 2, the hearing aids 300A, 300B, 300C are configured to convert the respective input signal to a respective electric input signal.

[0130] In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to convert the electric input signal (e.g., an analogue electric signal) to a digital audio signal using an ADC. In one or more example examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to generate the signal 20A, 20B, 20C, 20D by applying to the digital audio signal one or more of: a VAD method, and an OVAD method. For example, applying such methods to the digital audio signal may comprise determining the signal 20A, 20B, 20C, 20D as being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. For example, applying such methods to the digital audio signal may comprise determining the signal 20A, 20B, 20C, 20D as not being indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. In the embodiment of FIG. 2, the hearing aids 300A, 300B, 300C are configured to convert the respective electric input signal to a respective digital audio signal using an ADC. For example, the hearing aids 300A, 300B are configured to determine the signal 20A, 20B, 20C as being indicative of an own voice of a user wearing the hearing aid 300A, 300B, 300C respectively by applying a VAD method and/or a OVAD method to the respective digital audio signal.

[0131] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises a wireless transceiver unit, the wireless transceiver unit comprising a wireless interface configured to establish a wireless network with each of the other hearing aids of the plurality of hearing aids 300A, 300B, 300C, 300D. In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to communicate with each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D via a communication link. In one or more examples, the communication link is a digital link forming the wireless network, such as a wireless link.

[0132] In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D can be configured to be an initiator hearing aid. In one or more examples, the initiator hearing aid is configured to establish the wireless network with each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. In one or more examples, the initiator hearing aid is configured to broadcast a first connection signal to each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. Broadcasting the first connection signal may enable connection of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D to the wireless network. The initiator hearing aid may be configured to broadcast the first connection signal to each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D via the auxiliary device 500. For example, the initiator hearing aid can be any hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. For example, the hearing aid 300A can be the initiator hearing aid, such as can be responsible for establishing the wireless network and inviting the other hearing aids 300B, 300C, 300D to connect to the wireless network established by the hearing aid 300A.

[0133] In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to broadcast a second connection signal to hearing aids not initially forming the wireless network. The initiator hearing aid may be configured to broadcast the second connection signal to each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D via the auxiliary device 500. Broadcasting the second connection signal may enable connection of the other hearing aids not initially forming the wireless network (not shown in FIG. 2).

[0134] In one or more examples, the initiator hearing aid is configured to initiate establishment of the wireless network upon user interaction. In one or more examples, the initiator hearing aid can be configured to initiate establishment of the wireless network via a graphical interface on a personal auxiliary device in communication with the initiator hearing aid, such as on an auxiliary device only connected to the initiator hearing aid. For

example, the hearing aid 300A, when acting as the initiator hearing aid, can initiate establishment of the wireless network via a graphical interface in the personal auxiliary device (not shown in FIG. 2). In other words, the user wearing the hearing aid 300A may establish the wireless network by touching and/or pushing a button on the personal auxiliary device and/or on the hearing aid 300A. The user wearing the hearing aid 300A may establish the wireless network by touching a graphical representation of a button on a display of the personal auxiliary device (e.g., on a smartphone and/or smartwatch).

[0135] In one or more examples, the initiator hearing aid can be configured to initiate establishment of the wireless network via a graphical interface on the auxiliary device in communication with the initiator hearing aid, such as on the auxiliary device common to the plurality of hearing aids 300A, 300B, 300C, 300D.

[0136] In one or more examples, an external user may be responsible for managing the wireless network, e.g., establishing the wireless network and/or inviting users to the wireless network and/or removing users from the wireless network and/or switching off the wireless network. Such external user may be seen as a user not suffering from hearing loss, such as a user not wearing a hearing aid. The external user to the wireless network may be seen as a user not actively participating in the wireless network, such as in a HA community.

[0137] In one or more examples, the wireless network comprises a plurality of sub-wireless networks. In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D being part of a sub-wireless network of the plurality of sub-wireless networks is configured to communicate with each hearing aid being part of the same sub-wireless network. For example, the hearing aids 300A, 300B, 300C, 300B may be part of a sub-wireless network, such as within the coverage of the sub-wireless network. The hearing aids 300A, 300B, 300C, 300D may be configured communicate with each other. In the embodiment of FIG. 2, the plurality of hearing aids 300A, 300B, 300C, 300D are part of the same sub-wireless network.

[0138] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises a wireless transceiver unit configured to transmit the signal 20A, 20B, 20C, 20D to each other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises a wireless transceiver unit configured to transmit the signal 40A, 40B, 40C, 40D to each other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D via a respective communication link and/or channel. In one or more examples, the wireless transceiver unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to transmit, to each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, the signal 40A, 40B, 40C, 40D via the auxiliary device 500. In the embodiment of FIG. 2, the hearing aid 300A is configured to transmit the signal 40A to each of the other hearing aids 300B, 300C, 300D, e.g., via the auxiliary device 500. For example, the auxiliary device 500 is configured to receive the signal 40A from the hearing aid 300A. For example, the hearing aid 300B is configured to transmit the signal 40B to each of the other hearing aids 300A, 300C, 300D, e.g., via the auxiliary device 500. For example, the auxiliary device 500 is configured to receive the signal 40B from the hearing aid 300B. For example, the hearing aid 300C is configured to transmit the signal 40C to each of the other hearing aids 300A, 300B, 300D, e.g., via the auxiliary device 500. For example, the auxiliary device 500 is configured to receive the signal 40C from the hearing aid 300C.

[0139] The wireless transceiver unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D is further configured to receive, from each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, a respective other signal 40A, 40B, 40C, 40D indicative of an own voice of another user wearing each of the other hearing aids of the plurality of hearing aids 300A, 300B, 300C, 300D. In one or more examples, the wireless transceiver unit is further configured to receive, from each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, the respective other signal 40A, 40B, 40C, 40D via a respective communication link and/or channel. In one or more examples, the wireless transceiver unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D is further configured to receive, from each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D, the respective other signal 40A, 40B, 40C, 40D via the auxiliary device 500. In the embodiment of FIG. 2, the hearing aid 300A is configured to receive the other signals 40B, 40C from each of the other hearing aids 300B, 300C, e.g., via the auxiliary device 500. For example, the auxiliary device 500 is configured to receive the other signals 40B, 40C from the other hearing aids 300B, 300C respectively. In the embodiment of FIG. 2, the hearing aid 300B is configured to receive the other signals 40A, 40C from each of the other hearing aids 300A, 300C, e.g., via the auxiliary device 500. For example, the auxiliary device 500 is configured to receive the other signals 40A, 40C from the other hearing aids 300A, 300C respectively. In the embodiment of FIG. 2, the hearing aid 300C is configured to receive the other signals 40A, 40B from each of the other hearing aids 300A, 300B, e.g., via the auxiliary device 500. For example, the auxiliary device 500 is configured to receive the other signals 40A, 40B from the other hearing aids 300A, 300B respectively. In the embodiment of FIG. 2, the hearing aid 300D is configured to receive the other signals 40A, 40B, 40C from each of the other hearing aids 300A, 300B, 300C, e.g., via the auxiliary device 500. For example, the auxiliary device 500 is configured to receive the other signals 40A, 40B, 40C from the other hearing aids 300A, 300B, 300C respectively.

[0140] In one or more examples, the auxiliary device

500 is configured to combine the signal 40A, 40B, 40C, 40D of each of the plurality hearing aids 300A, 300B, 300C, 300D with the respective other signal 40A, 40B, 40C, 40D of each of the other hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D for provision of a combined signal 42. For example, the auxiliary device is configured to mix the signals 40A, 40B, 40C, 40D of each of the plurality hearing aids 300A, 300B, 300C, 300D for provision of the combined signal 42. In one or more examples, the auxiliary device 500 is configured to transmit the combined signal 42 to each of the plurality of hearing aids 300A, 300B, 300C, 300D. In the embodiment of FIG. 2, the auxiliary device 500 is configured to combine the signals 40A, 40B, 40C of the respective hearing aid 300A, 300B, 300C for provision of the combined signal 42. For example, the auxiliary device 500 is configured to transmit the combined signal 42 to each of the plurality of hearing aids 300A, 300B, 300C, 300D. Put differently, the wireless transceiver unit of each of the plurality of hearing aids 300A, 300B, 300C, 300D may be configured to receive the combined signal 42 from the auxiliary device 500.

[0141] In one or more examples, the auxiliary device 500 is configured to combine the signals 40A, 40B, 40C, 40D of each of the plurality hearing aids 300A, 300B, 300C, 300D by applying to the signals 40A, 40B, 40C, 40D one or more of: a threshold-based method and a spatial-based method.

[0142] In one or more examples, each of the plurality of hearing aids 300A, 300B, 300C, 300D is configured to apply an echo cancellation method to the respective combined signal 42 for provision of an echo cancellation signal. For example, applying an echo cancellation method to the respective combined signal 42 comprises cancelling (e.g., removing and/or dampening and/or reducing) the signal 40A, 40B, 40C, 40D indicative of the own voice of the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D from the respective combined signal 42. Put differently, applying the echo cancellation method to the respective combined signal may comprise removing the signal generated by each of the plurality of hearing aids 300A, 300B, 300C, 300D from the respective combined signal 42.

[0143] In the embodiment of FIG. 2, the hearing aid 300A is configured to apply an echo cancellation method to the combined signal 42. For example, the hearing aid 300A is configured to remove the signal 40A from the combined signal 42 for provision of a first echo cancellation signal. In the embodiment of FIG. 2, the hearing aid 300B is configured to apply an echo cancellation method to the combined signal 42. For example, the hearing aid 300B is configured to remove the signal 40B from the combined signal 42 for provision of a second echo cancellation signal. In the embodiment of FIG. 2, the hearing aid 300C is configured to apply an echo cancellation method to the combined signal 42. For example, the hearing aid 300C is configured to remove the signal 40C from the combined signal 42 for provision of a third echo cancellation signal. In the embodiment of FIG. 2, the hearing aid 300D may not be configured to remove their own signal from the combined signal 42, e.g., as the hearing aid 300D has not sent any signal to the other hearing aids 300A, 300B, 300C. For example, the user wearing the hearing aid 300D has not spoken to the other users wearing the hearing aids 300A, 300B, 300C, 300D.

[0144] Each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises an output unit configured to output, based on each of the respective other signal 40A, 40B, 40C, 40D, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D. For example, each of the plurality of hearing aids 300A, 300B, 300C, 300D comprises an output unit configured to output, based on each of the respective echo cancellation signal, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids 300A, 300B, 300C, 300D.

[0145] In the embodiment of FIG. 2, the output unit of the hearing aid 300A is configured to output, based on the other signals 40B, 40C, a first audible signal to the user wearing the hearing aid 300A. For example, the output unit of the hearing aid 300A is configured to output, based on the first echo cancellation signal, the first audible signal. In the embodiment of FIG. 2, the output unit of the hearing aid 300B is configured to output, based on the other signals 40A, 40C, a second audible signal to the user wearing the hearing aid 300B. For example, the output unit of the hearing aid 300B is configured to output, based on the second echo cancellation signal, the second audible signal. In the embodiment of FIG. 2, the output unit of the hearing aid 300C is configured to output, based on the other signals 40A, 40B, a third audible signal to the user wearing the hearing aid 300C. For example, the output unit of the hearing aid 300C is configured to output, based on the third echo cancellation signal, the third audible signal. In the embodiment of FIG. 2, the output unit of the hearing aid 300D is configured to output, based on the other signals 40A, 40B, 40C a fourth audible signal to the user wearing the hearing aid 300D. For example, the output unit of the hearing aid 300D is configured to output, based on the combined signal 42, the fourth audible signal.

[0146] FIG. 3 is a flow-chart of an example method 100, performed by at least two hearing aids of a plurality of hearing aids, for operating a communication system comprising the plurality of hearing aids according to this disclosure.

[0147] The method 100 comprises generating S 102 a signal indicative of an own voice of a user wearing a respective hearing aid of the at least two hearing aids. The method 100 comprises establishing S104 a wireless network with at least two other hearing aids of the plurality of hearing aids. The method 100 comprises transmitting S 106, to the at least two other hearing aids of the plurality of hearing aids, the signal. The method 100 comprises receiving S108, from a respective other hearing aid of the at least two other hearing aids, other signal indicative of

an own voice of another user wearing the respective other hearing aid of the at least two other hearing aids. The method 100 comprises outputting S 110, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the at least two hearing aids.

[0148] It is intended that the structural features of the devices described above, either in the detailed description and/or in the claims, may be combined with steps of the method, when appropriately substituted by a corresponding process.

[0149] As used, the singular forms "a," "an," and "the" are intended to include the plural forms as well (i.e. to have the meaning "at least one"), unless expressly stated otherwise. It will be further understood that the terms "includes," "comprises," "including," and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It will also be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element, but an intervening element may also be present, unless expressly stated otherwise. Furthermore, "connected" or "coupled" as used herein may include wirelessly connected or coupled. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. The steps of any disclosed method are not limited to the exact order stated herein, unless expressly stated otherwise.

[0150] It should be appreciated that reference throughout this specification to "one embodiment" or "an embodiment" or "an aspect" or features included as "may" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the disclosure. Furthermore, the particular features, structures or characteristics may be combined as suitable in one or more embodiments of the disclosure. The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art.

[0151] The claims are not intended to be limited to the aspects shown herein but are to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more.

Claims

1. A communication system comprising:
   a plurality of hearing aids, wherein each of the plurality of hearing aids comprises:

   - an input unit configured to generate a signal indicative of an own voice of a user wearing a respective hearing aid of the plurality of hearing aids;
   - a wireless transceiver unit configured to transmit, to each other hearing aid of the plurality of hearing aids, the signal, the wireless transceiver unit being further configured to receive, from each of the other hearing aid of the plurality of hearing aids, a respective other signal indicative of an own voice of another user wearing each of the other hearing aids of the plurality of hearing aids, and wherein the wireless transceiver unit comprises a wireless interface configured to establish a wireless network with each of the other hearing aids of the plurality of hearing aids; and
   - an output unit configured to output, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the plurality of hearing aids.

2. The communication system according to claim 1, wherein each of the plurality of hearing aids is configured to communicate with each of the other hearing aid of the plurality of hearing aids via a communication link, wherein the communication link is a digital link forming the wireless network.

3. The communication system according to any of the previous claims, wherein each of the plurality of hearing aids is configured to be an initiator hearing aid, wherein the initiator hearing aid is configured to establish the wireless network with each of the other hearing aid of the plurality of hearing aids, and broadcast a first connection signal to each of the other hearing aid of the plurality of hearing aids.

4. The communication system according to claim 3, wherein each of the plurality of hearing aids is configured to broadcast a second connection signal to hearing aids not initially forming the wireless network.

5. The communication system according to any of claims 3-4, wherein the initiator hearing aid is configured to initiate establishment of the wireless network upon user interaction.

6. The communication system according to claim 5, wherein the initiator hearing aid is configured to initiate establishment of the wireless network via a graphical interface on an auxiliary device in communication with the initiator hearing aid.

7. The communication system according to any of the

previous claims, wherein the wireless network comprises a plurality of sub-wireless networks, wherein each of the plurality of hearing aids being part of a sub-wireless network of the plurality of sub-wireless networks is configured to communicate with each hearing aid being part of the same sub-wireless network.

8. The communication system according to any of the previous claims, wherein the communication system comprises a plurality of auxiliary devices, wherein each of the plurality of hearing aids is in communication with a respective auxiliary device of the plurality of auxiliary devices, and wherein the wireless transceiver unit of each of the plurality of hearing aids is configured to transmit, to each of the other hearing aid of the plurality of hearing aids, the signal via the respective auxiliary device.

9. The communication system according to claim 8, wherein the wireless transceiver unit of each of the plurality of hearing aids is further configured to receive, from each of the other hearing aid of the plurality of hearing aids, the respective other signal via the respective auxiliary device.

10. The communication system according to any of claims 8-9, wherein the respective auxiliary device is configured to combine the respective other signal of each of the other hearing aid of the plurality of hearing aids for provision of a respective combined signal, and to transmit, to the hearing aid in communication with the respective auxiliary device, the respective combined signal.

11. The communication system according to claim 10, wherein to combine the respective other signal of each of the other hearing aid of the plurality of hearing aids comprises applying to the respective other signal one or more of: a threshold-based method and a spatial-based method.

12. A method, performed by at least two hearing aids of a plurality of hearing aids, for operating a communication system comprising the plurality of hearing aids, the method comprising:

- generating a signal indicative of an own voice of a user wearing a respective hearing aid of the at least two hearing aids;
- establishing a wireless network with at least two other hearing aids of the plurality of hearing aids;
- transmitting, to the at least two other hearing aids of the plurality of hearing aids, the signal;
- receiving, from a respective other hearing aid of the at least two other hearing aids, other signal indicative of an own voice of another user wearing the respective other hearing aid of the at least two other hearing aids; and
- outputting, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the at least two hearing aids.

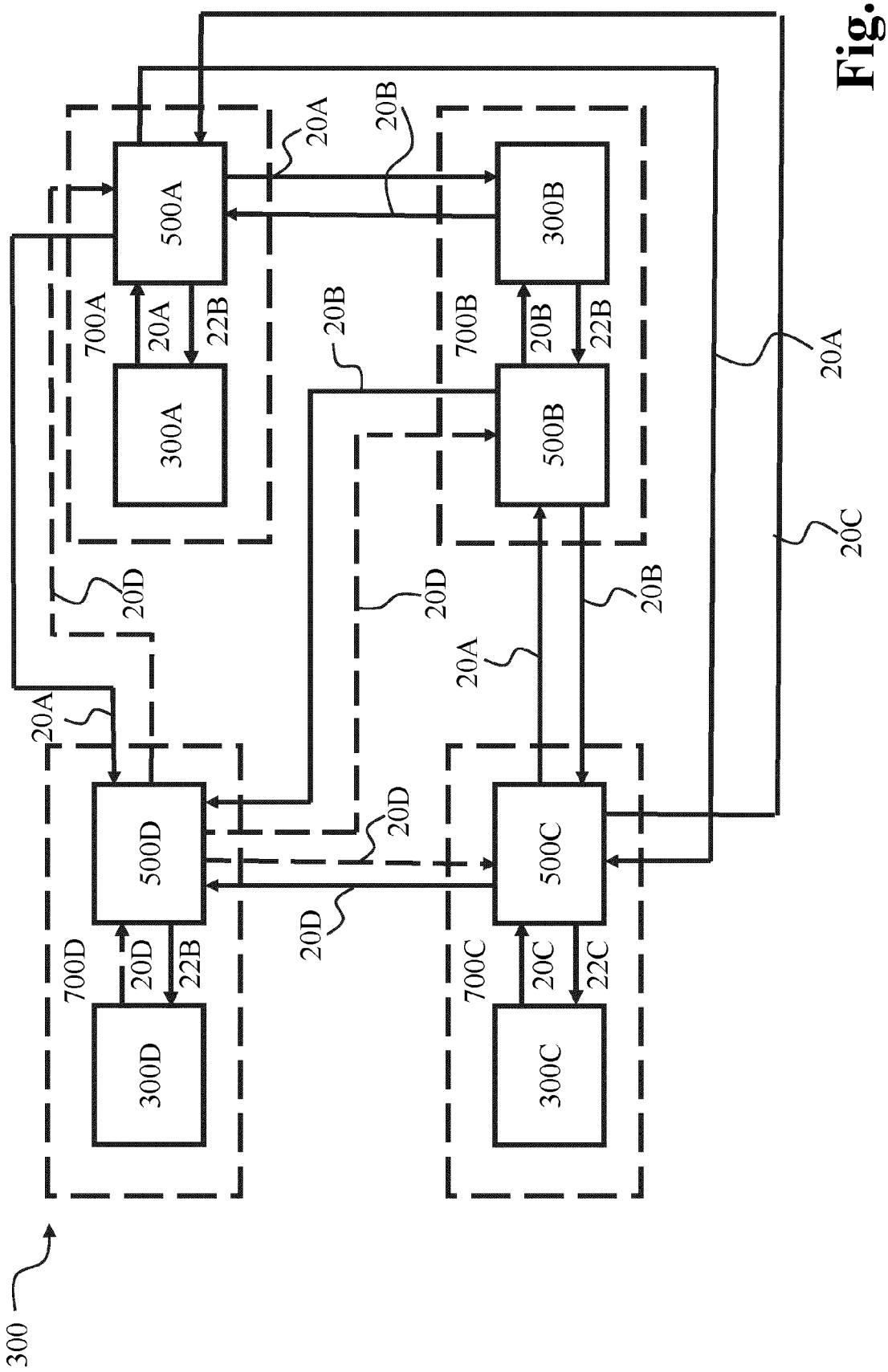
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Fig. 1

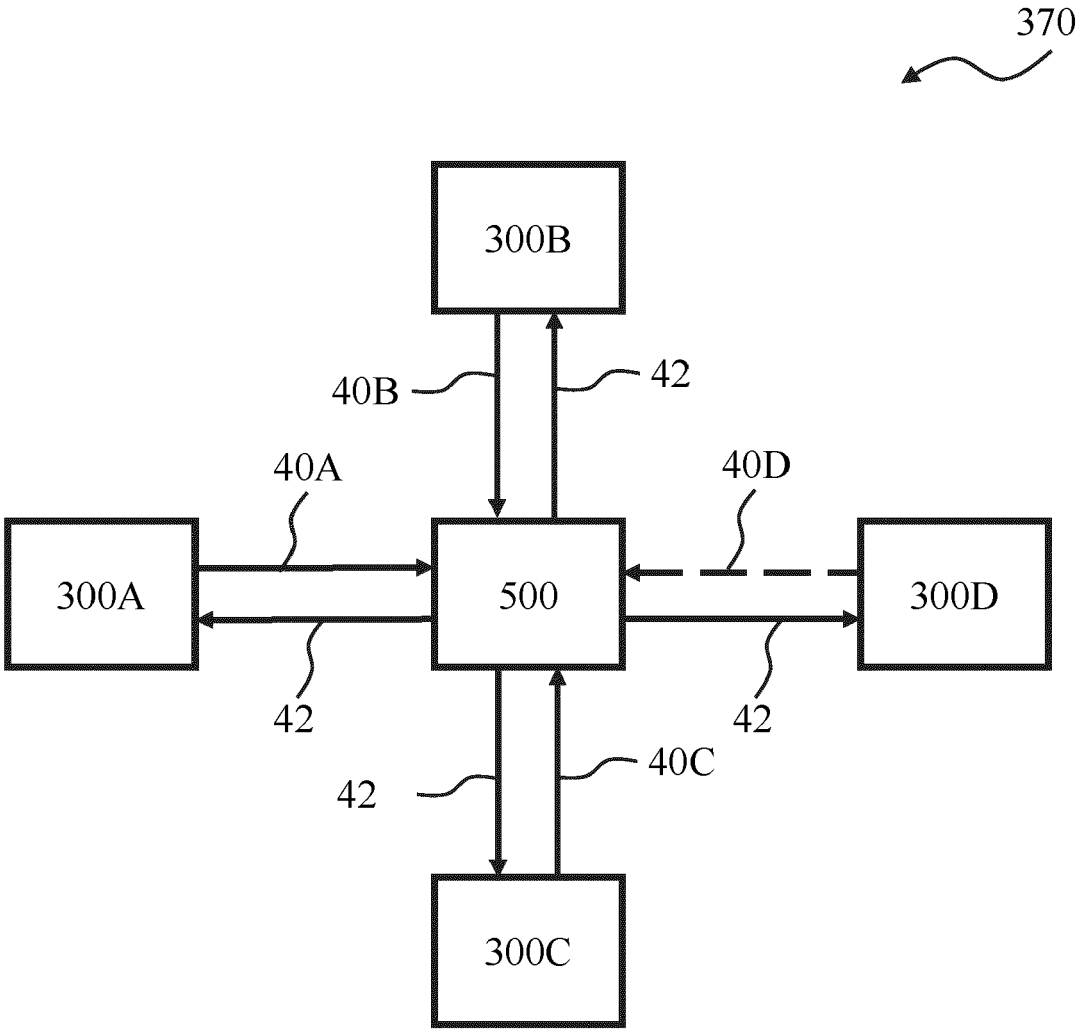

Fig. 2

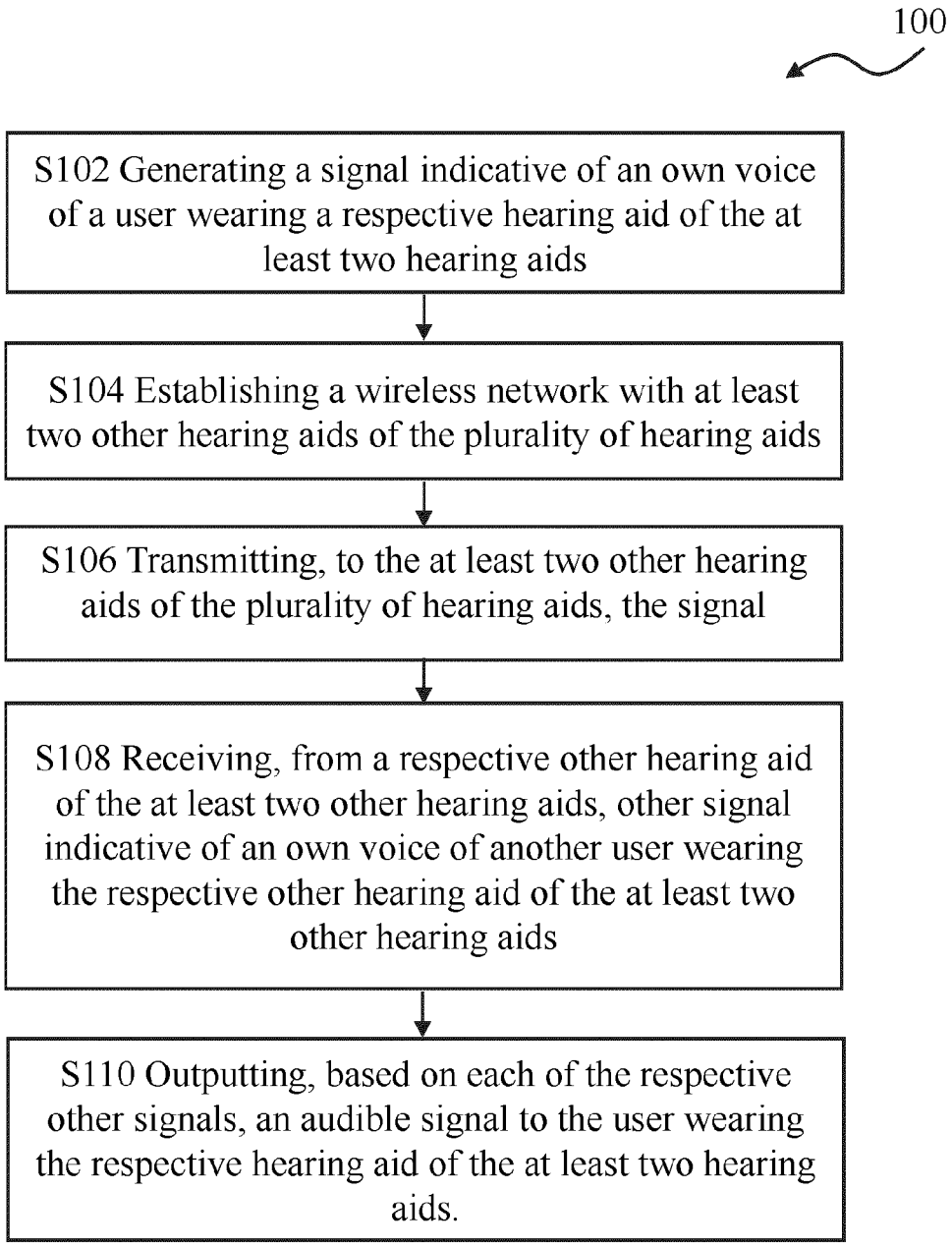
100
S102 Generating a signal indicative of an own voice of a user wearing a respective hearing aid of the at least two hearing aids
S104 Establishing a wireless network with at least two other hearing aids of the plurality of hearing aids
S106 Transmitting, to the at least two other hearing aids of the plurality of hearing aids, the signal
S108 Receiving, from a respective other hearing aid of the at least two other hearing aids, other signal indicative of an own voice of another user wearing the respective other hearing aid of the at least two other hearing aids
S110 Outputting, based on each of the respective other signals, an audible signal to the user wearing the respective hearing aid of the at least two hearing aids.

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 24 16 5109

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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	2 September 2024	Sucher, Ralph

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