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ELECTRONIC DEVICE FOR TRANSMITTING EXTERNAL SOUND AND METHOD FOR OPERATING ELECTRONIC DEVICE

Abstract

An electronic device includes: at least one speaker; an external microphone; an internal microphone; a first filter; a second filter; and at least one processor operatively connected to the at least one speaker, the external microphone, and the internal microphone, wherein the at least one processor is configured to: estimate a passive feature based on a first signal acquired through the external microphone and a second signal acquired through the internal microphone, identify a target frequency response for the passive feature based on a reference passive feature, and filter a third signal acquired through the external microphone through the first filter and the second filter sequentially and output the filtered third signal through the at least one speaker, wherein the second filter is based on the target frequency response.

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Background/Summary

CROSS-REFERENCES TO RELATED APPLICATIONS [0001] This application is a continuation of International Application No. PCT/KR2023/017318, filed on Nov. 1, 2023, at the Korean Intellectual Property Office, which claims priority from Korean Patent Application No. 10-2022-0143756, filed on Nov. 1, 2022, and Korean Patent Application No. 10-2022-0162586, filed on Nov. 29, 2022, at the Korean Intellectual Property Office, the disclosures of which are incorporated by reference in their entireties by reference herein.

BACKGROUND
1. Field
[0002] The disclosure relates to an electronic device and a method of operating the electronic device, and more particularly, to an electronic device and a method of operating the electronic device for hearing an external sound around a user.
2. Related Art
[0003] An electronic device that enables a user to hear a particular sound may be implemented in the form of an earphone worn on/in the user's ear or a headset worn around the user's head.
[0004] Earphones inserted near an external auditory canal of an ear or headsets that completely cover an ear are located between the outside of the ear and an eardrum, which makes it difficult for the user to hear sounds coming from the outside while wearing them.
[0005] Accordingly, the earphone and/or the headset may need a microphone implemented in the outside thereof, and output external sounds of the outside that are acquired from the microphone into a speaker included in the earphone and/or headset. Thus, a user wearing the earphone and/or headset may hear external sounds through the earphone and/or headset.
[0006] In order for a user wearing the earphone and/or the headset to hear naturally external sounds, the earphone and/or headset performs a process of inputting external sounds acquired by an external microphone into an appropriate filter and processing them.
SUMMARY
[0007] According to an aspect of the disclosure, an electronic device includes: at least one speaker; an external microphone; an internal microphone; a first filter; a second filter; and at least one processor operatively connected to the at least one speaker, the external microphone, and the internal microphone, wherein the at least one processor is configured to: estimate a passive feature based on a first signal acquired through the external microphone and a second signal acquired through the internal microphone, identify a target frequency response for the passive feature based on a reference passive feature, and filter a third signal acquired through the external microphone through the first filter and the second filter sequentially and output the filtered third signal through the at least one speaker, wherein the second filter is based on the target frequency response.

[0008] The at least one processor may be further configured to, based on no signal being output through the at least one speaker and a user wearing the electronic device not speaking, estimate the passive feature based on the first signal and the second signal.
[0009] The at least one processor may be further configured to estimate the passive feature based on a normalized least mean squares (NLMS) algorithm.
[0010] The first filter is based on a simulation in a non-wearing state of the electronic device, and the second filter may be based on the target frequency response identified by estimating the passive feature in a state of wearing the electronic device.
[0011] The second filter may be based on a combination of one or more finite impulse response or infinite impulse response filters having the target frequency response.
[0012] The at least one processor may be further configured to update a constitution of the second filter based on various signals output from an external electronic device.
[0013] The electronic device may further include a memory configured to store the reference passive feature, the reference passive feature may be estimated based on a reference passive feature simulation, and the reference passive feature may be stored in the memory.
[0014] The memory may be further configured to store a learning model for correcting a high frequency component of the target frequency response by estimating a high frequency component of the passive feature based on a magnitude of a low frequency component of the passive feature estimated through a passive feature simulation, and the at least one processor may be further configured to correct the target frequency response based on the learning model.
[0015] The memory may be further configured to store a learning model learned to derive a frequency response changing through an external auditory canal until a signal input through the external microphone reaches an eardrum location through a simulation, and the at least one processor may be further configured to correct the target frequency response based on the learning model.
[0016] The electronic device may further include: a first acoustic echo canceller (AEC) operatively connected to the external microphone; and a second AEC operatively connected to the internal microphone, and the at least one processor may be further configured to control the first AEC and the second AEC to remove noise input based on a signal output through the at least one speaker or a speech of a user wearing the electronic device.
[0017] According to an aspect of the disclosure, a method of operating an electronic device, includes: estimating a passive feature based on a first signal acquired through an external microphone of the electronic device and a second signal acquired through an internal microphone of the electronic device; identifying a target frequency response for the passive feature based on a reference passive feature; filtering a third signal acquired through the external microphone through a first filter and a second filter sequentially, wherein the second filter is based on the identified target frequency response; and outputting the filtered third signal through at least one speaker of the electronic device.
[0018] The estimating the passive feature may include, based on no signal being output through the at least one speaker and based on a user wearing the electronic device not speaking, estimating the passive feature based on the first signal and the second signal.
[0019] The first filter may be based on a simulation in a non-wearing state of the electronic device, and the second filter may be based on the target frequency response identified by estimating the passive feature in a state of wearing the electronic device.
[0020] The second filter may be based on a combination of one or more finite impulse response or infinite impulse response filters having the target frequency response.
[0021] The method may further include updating a constitution of the second filter based on various signals output from an external electronic device.
[0022] Technical problems and effects that can be obtained from the disclosure are not limited to the above-described technical problems and effects, and other technical problems and effects that

are not described will be clearly understood by a person having ordinary skill in the technical field to which the disclosure belongs from the description below.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0023] The above and other aspects, features, and advantages of certain embodiments of the present disclosure will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

[0024] FIG. **1** is a block diagram illustrating an electronic device within a network environment according to various embodiments;

[0025] FIG. **2** is a block diagram illustrating an audio module according to various embodiments;

[0026] FIG. **3** is an example of a block diagram illustrating an electronic device according to various embodiments;

[0027] FIG. **4** is a flowchart illustrating a process for transmitting an external sound in an electronic device according to various embodiments;

[0028] FIG. **5** is a diagram illustrating an example of signal flow and a constitution of an electronic device for external signal transmission according to various embodiments;

[0029] FIGS. **6**A and **6**B are graphs illustrating signals input through microphones of an electronic device and signal characteristics estimated based thereon and estimated filters according to various embodiments;

[0030] FIGS. **7**A and **7**B are graphs illustrating estimated signal characteristics based on signals input through microphones according to various variables occurring when wearing an electronic device according to various embodiments;

[0031] FIGS. **8**A and **8**B are graphs illustrating estimated signal characteristics based on signals input through microphones when wearing an electronic device and deviations based on a reference signal characteristic according to various embodiments;

[0032] FIGS. **9**A, **9**B, and **9**C are graphs illustrating estimated signal characteristics based on signals input through microphones when wearing an electronic device and deviations based on a reference signal characteristic according to various embodiments;

[0033] FIGS. **10**A, **10**B, **10**C, and **10**D are graphs illustrating estimated signal characteristics based on signals input through microphones when wearing an electronic device and compensated deviations based on a reference signal characteristic according to various embodiments;

[0034] FIG. **11** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments;

[0035] FIG. **12** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments;

[0036] FIG. **13** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments;

[0037] FIG. **14** is a diagram illustrating an example of learning a method of filtering and providing external sounds based on signals input through microphones of an electronic device by simulating external sounds according to various embodiments; and

[0038] FIG. **15** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments.

DETAILED DISCLOSURE

[0039] FIG. **1** is a block diagram illustrating an electronic device **101** in a network environment **100** according to various embodiments. Referring to FIG. **1**, the electronic device **101** in the network environment **100** may communicate with an electronic device **102** via a first network **198** (e.g., a short-range wireless communication network), or at least one of an electronic device **104** or a server **108** via a second network **199** (e.g., a long-range wireless communication network). According to an embodiment, the electronic device **101** may communicate with the electronic device **104** via the server **108**. According to an embodiment, the electronic device **101** may include a processor **120**, memory **130**, an input **1**module **150**, a sound output **1**module **155**, a display **1**module **160**, an audio module **170**, a sensor module **176**, an interface **177**, a connecting terminal **178**, a haptic module **179**, a camera module **180**, a power management module **188**, a battery **189**, a communication module **190**, a subscriber identification module (SIM) **196**, or an antenna module **197**. In some embodiments, at least one of the components (e.g., the **11**connecting terminal **178**) may be omitted from the electronic device **101**, or one or more other components may be added in the electronic device **101**. In some embodiments, some of the components (e.g., the sensor module **176**, the camera module **180**, or the antenna module **197**) may be implemented as a single component (e.g., the display module **160**). **11**

[0040] The processor **120** may execute, for example, software (e.g., a program **140**) to control at least one other component (e.g., a hardware or software component) of the electronic device **101** coupled with the processor **120**, and may perform various data processing or computation. According to one embodiment, as at least part of the data processing or computation, the processor **120** may store a command or data received from another component (e.g., the sensor module **176** or the communication module **190**) in volatile memory **132**, process the command or the data stored in the volatile memory **132**, and store resulting data in non-volatile memory **134**. According to an embodiment, the processor **120** may include a main processor **121** (e.g., a central processing unit (CPU) or an application processor (AP)), or an auxiliary processor **123** (e.g., a graphics processing unit (GPU), a neural processing unit (NPU), an image signal processor (ISP), a sensor hub processor, or a communication processor (CP)) that is operable independently from, or in conjunction with, the main processor **121**. For example, when the electronic device **101** includes the main processor **121** and the auxiliary processor **123**, the auxiliary processor **123** may be adapted to consume less power than the main processor **121**, or to be specific to a specified function. The auxiliary processor **123** may be implemented as separate from, or as part of the main processor **121**.

[0041] The auxiliary processor **123** may control at least some of functions or states related to at least one component (e.g., the display **1**module **160**, the sensor module **176**, or the communication module **190**) among the components of the electronic device **101**, instead of the main processor **121** while the main processor **121** is in an inactive (e.g., sleep) state, or together with the main processor **121** while the main processor **121** is in an active state (e.g., executing an application). According to an embodiment, the auxiliary processor **123** (e.g., an image signal processor or a communication processor) may be implemented as part of another component (e.g., the camera module **180** or the communication module **190**) functionally related to the auxiliary processor **123**. According to an embodiment, the auxiliary processor **123** (e.g., the neural processing unit) may include a hardware structure specified for artificial intelligence model processing. An artificial intelligence model may be generated by machine learning. Such learning may be performed, e.g., by the electronic device **101** where the artificial intelligence is performed or via a separate server (e.g., the server **108**). Learning algorithms may include, but are not limited to, e.g., supervised learning, unsupervised learning, semi-supervised learning, or reinforcement learning. The artificial intelligence model may include a plurality of artificial neural network layers. The artificial neural network may be a deep neural network (DNN), a convolutional neural network (CNN), a recurrent neural network (RNN), a restricted boltzmann machine (RBM), a deep belief network (DBN), a bidirectional recurrent deep neural network (BRDNN), deep Q-network or a combination of two or more thereof but is not limited thereto. The artificial intelligence model may, additionally or alternatively, include a software structure other than the hardware structure.

[0042] The memory **130** may store various data used by at least one component (e.g., the processor **120** or the sensor module **176**) of the electronic device **101**. The various data may include, for example, software (e.g., the program **140**) and input data or output data for a command related thererto. The memory **130** may include the volatile memory **132** or the non-volatile memory **134**.

[0043] The program **140** may be stored in the memory **130** as software, and may include, for example, an operating system (OS) **142**, middleware **144**, or an application **146**.

[0044] The input module **150** may receive a command or data to be used by another component (e.g., the processor **120**) of the electronic device **101**, from the outside (e.g., a user) of the electronic device **101**. The input **1**module **150** may include, for example, a microphone, a mouse, a keyboard, a key (e.g., a button), or a digital pen (e.g., a stylus pen).

[0045] The sound output module **155** may output sound signals to the outside of the electronic device **101**. The sound output **1**module **155** may include, for example, a speaker or a receiver. The speaker may be used for general purposes, such as playing multimedia or playing record. The receiver may be used for receiving incoming calls. According to an embodiment, the receiver may be implemented as separate from, or as part of the speaker.

[0046] The display module **160** may visually provide information to the outside (e.g., a user) of the electronic device **101**. The display **1**module **160** may include, for example, a display, a hologram device, or a projector and control circuitry to control a corresponding one of the display, hologram device, and projector. According to an embodiment, the display **1**module **160** may include a touch sensor adapted to detect a touch, or a pressure sensor adapted to measure the intensity of force incurred by the touch.

[0047] The audio module **170** may convert a sound into an electrical signal and vice versa. According to an embodiment, the audio module **170** may obtain the sound via the input **1**module **150**, or output the sound via the sound output **1**module **155** or a headphone of an external electronic device (e.g., an electronic device **102**) directly (e.g., wiredly) or wirelessly coupled with the electronic device **101**.

[0048] The sensor module **176** may detect an operational state (e.g., power or temperature) of the electronic device **101** or an environmental state (e.g., a state of a user) external to the electronic device **101**, and then generate an electrical signal or data value corresponding to the detected state. According to an embodiment, the sensor module **176** may include, for example, a gesture sensor, a gyro sensor, an atmospheric pressure sensor, a magnetic sensor, an acceleration sensor, a grip sensor, a proximity sensor, a color sensor, an infrared (IR) sensor, a biometric sensor, a temperature sensor, a humidity sensor, or an illuminance sensor.

[0049] The interface **177** may support one or more specified protocols to be used for the electronic device **101** to be coupled with the external electronic device (e.g., the electronic device **102**) directly (e.g., wiredly) or wirelessly. According to an embodiment, the interface **177** may include, for example, a high definition multimedia interface (HDMI), a universal serial bus (USB) interface, a secure digital (SD) card interface, or an audio interface.

[0050] A connecting terminal **178** may include a connector via which the electronic device **101** may be physically connected with the external electronic device (e.g., the electronic device **102**). According to an embodiment, the connecting terminal **178** may include, for example, a HDMI connector, a USB connector, a SD card connector, or an audio connector (e.g., a headphone connector).

[0051] The haptic module **179** may convert an electrical signal into a mechanical stimulus (e.g., a vibration or a movement) or electrical stimulus which may be recognized by a user via his tactile sensation or kinesthetic sensation. According to an embodiment, the haptic module **179** may include, for example, a motor, a piezoelectric element, or an electric stimulator.

[0052] The camera module **180** may capture a still image or moving images. According to an embodiment, the camera module **180** may include one or more lenses, image sensors, image signal processors, or flashes.

[0053] The power management module **188** may manage power supplied to the electronic device **101**. According to one embodiment, the power management module **188** may be implemented as at least part of, for example, a power management integrated circuit (PMIC).

[0054] The battery **189** may supply power to at least one component of the electronic device **101**. According to an embodiment, the battery **189** may include, for example, a primary cell which is not rechargeable, a secondary cell which is rechargeable, or a fuel cell.

[0055] The communication module **190** may support establishing a direct (e.g., wired) communication channel or a wireless communication channel between the electronic device **101** and the external electronic device (e.g., the electronic device **102**, the electronic device **104**, or the server **108**) and performing communication via the established communication channel. The communication module **190** may include one or more communication processors that are operable independently from the processor **120** (e.g., the application processor (AP)) and supports a direct (e.g., wired) communication or a wireless communication. According to an embodiment, the communication module **190** may include a wireless communication module **192** (e.g., a cellular communication module, a short-range wireless communication module, or a global navigation satellite system (GNSS) communication module) or a wired communication module **194** (e.g., a local area network (LAN) communication module or a power line communication (PLC) module). A corresponding one of these communication modules may communicate with the external electronic device via the first network **198** (e.g., a short-range communication network, such as Bluetooth™, wireless-fidelity (Wi-Fi) direct, or infrared data association (IrDA)) or the second network **199** (e.g., a long-range communication network, such as a legacy cellular network, a 5G network, a next-generation communication network, the Internet, or a computer network (e.g., LAN or wide area network (WAN)). These various types of communication modules may be implemented as a single component (e.g., a single chip), or may be implemented as multi components (e.g., multi chips) separate from each other. The wireless communication module **192** may identify and authenticate the electronic device **101** in a communication network, such as the first network **198** or the second network **199**, using subscriber information (e.g., international mobile subscriber identity (IMSI)) stored in the subscriber identification module **196**.

[0056] The wireless communication module **192** may support a 5G network, after a 4G network, and next-generation communication technology, e.g., new radio (NR) access technology. The NR access technology may support enhanced mobile broadband (eMBB), massive machine type communications (mMTC), or ultra-reliable and low-latency communications (URLLC). The wireless communication module **192** may support a high-frequency band (e.g., the mmWave band) to achieve, e.g., a high data transmission rate. The wireless communication module **192** may support various technologies for securing performance on a high-frequency band, such as, e.g., beamforming, massive multiple-input and multiple-output (massive MIMO), full dimensional MIMO (FD-MIMO), array antenna, analog beam-forming, or large scale antenna. The wireless communication module **192** may support various requirements specified in the electronic device **101**, an external electronic device (e.g., the electronic device **104**), or a network system (e.g., the second network **199**). According to an embodiment, the wireless communication module **192** may support a peak data rate (e.g., 20 Gbps or more) for implementing eMBB, loss coverage (e.g., 164 dB or less) for implementing mMTC, or U-plane latency (e.g., 0.5 ms or less for each of downlink (DL) and uplink (UL), or a round trip of 1 ms or less) for implementing URLLC.

[0057] The antenna module **197** may transmit or receive a signal or power to or from the outside (e.g., the external electronic device) of the electronic device **101**. According to an embodiment, the antenna module **197** may include an antenna including a radiating element composed of a conductive material or a conductive pattern formed in or on a substrate (e.g., a printed circuit board (PCB)). According to an embodiment, the antenna module **197** may include a plurality of antennas (e.g., array antennas). In such a case, at least one antenna appropriate for a communication scheme used in the communication network, such as the first network **198** or the second network **199**, may be selected, for example, by the communication module **190** (e.g., the wireless communication module **192**) from the plurality of antennas. The signal or the power may then be transmitted or received between the communication module **190** and the external electronic device via the selected at least one antenna. According to an embodiment, another component (e.g., a radio frequency integrated circuit (RFIC)) other than the radiating element may be additionally formed as part of the antenna module **197**.

[0058] According to various embodiments, the antenna module **197** may form a mmWave antenna module. According to an embodiment, the mmWave antenna module may include a printed circuit board, a RFIC disposed on a first surface (e.g., the bottom surface) of the printed circuit board, or adjacent to the first surface and capable of supporting a designated high-frequency band (e.g., the mm Wave band), and a plurality of antennas (e.g., array antennas) disposed on a second surface (e.g., the top or a side surface) of the printed circuit board, or adjacent to the second surface and capable of transmitting or receiving signals of the designated high-frequency band.

[0059] At least some of the above-described components may be coupled mutually and communicate signals (e.g., commands or data) there between via an inter-peripheral communication scheme (e.g., a bus, general purpose input and output (GPIO), serial peripheral interface (SPI), or mobile industry processor interface (MIPI)).

[0060] According to an embodiment, commands or data may be transmitted or received between the electronic device **101** and the external electronic device **104** via the server **108** coupled with the second network **199**. Each of the electronic devices **102** or **104** may be a device of a same type as, or a different type, from the electronic device **101**. According to an embodiment, all or some of operations to be executed at the electronic device **101** may be executed at one or more of the external electronic devices **102**, **104**, or **108**. For example, if the electronic device **101** should perform a function or a service automatically, or in response to a request from a user or another device, the electronic device **101**, instead of, or in addition to, executing the function or the service, may request the one or more external electronic devices to perform at least part of the function or the service. The one or more external electronic devices receiving the request may perform the at least part of the function or the service requested, or an additional function or an additional service related to the request, and transfer an outcome of the performing to the electronic device **101**. The electronic device **101** may provide the outcome, with or without further processing of the outcome, as at least part of a reply to the request. To that end, a cloud computing, distributed computing, mobile edge computing (MEC), or client-server computing technology may be used, for example. The electronic device **101** may provide ultra low-latency services using, e.g., distributed computing or mobile edge computing. In another embodiment, the external electronic device **104** may include an internet-of-things (IoT) device. The server **108** may be an intelligent server using machine learning and/or a neural network. According to an embodiment, the external electronic device **104** or the server **108** may be included in the second network **199**. The electronic device **101** may be applied to intelligent services (e.g., smart home, smart city, smart car, or healthcare) based on 5G communication technology or IoT-related technology.

[0061] FIG. **2** is a block diagram **200** illustrating the audio module **170** according to various embodiments. Referring to FIG. **2**, the audio module **170** may include, for example, an audio input interface **210**, an audio input mixer **220**, an analog-to-digital converter (ADC) **230**, an audio signal processor **240**, a digital-to-analog converter (DAC) **250**, an audio output mixer **260**, or an audio output interface **270**.

[0062] The audio input interface **210** may receive an audio signal corresponding to a sound obtained from the outside of the electronic device **101** via a microphone (e.g., a dynamic microphone, a condenser microphone, or a piezo microphone) that is configured as part of the input module **150** or separately from the electronic device **101**. For example, if an audio signal is obtained from the external electronic device **102** (e.g., a headset or a microphone), the audio input interface **210** may be connected with the external electronic device **102** directly via the connecting terminal **178**, or wirelessly (e.g., Bluetooth™ communication) via the wireless communication module **192** to receive the audio signal. According to an embodiment, the audio input interface **210** may receive a control signal (e.g., a volume adjustment signal received via an input button) related to the audio signal obtained from the external electronic device **102**. The audio input interface **210** may include a plurality of audio input channels and may receive a different audio signal via a corresponding one of the plurality of audio input channels, respectively. According to an embodiment, additionally or alternatively, the audio input interface **210** may receive an audio signal from another component (e.g., the processor **120** or the memory **130**) of the electronic device **101**.

[0063] The audio input mixer **220** may synthesize a plurality of inputted audio signals into at least one audio signal. For example, according to an embodiment, the audio input mixer **220** may synthesize a plurality of analog audio signals inputted via the audio input interface **210** into at least one analog audio signal.

[0064] The ADC **230** may convert an analog audio signal into a digital audio signal. For example, according to an embodiment, the ADC **230** may convert an analog audio signal received via the audio input interface **210** or, additionally or alternatively, an analog audio signal synthesized via the audio input mixer **220** into a digital audio signal.

[0065] The audio signal processor **240** may perform various processing on a digital audio signal received via the ADC **230** or a digital audio signal received from another component of the electronic device **101**. For example, according to an embodiment, the audio signal processor **240** may perform changing a sampling rate, applying one or more filters, interpolation processing, amplifying or attenuating a whole or partial frequency bandwidth, noise processing (e.g., attenuating noise or echoes), changing channels (e.g., switching between mono and stereo), mixing, or extracting a specified signal for one or more digital audio signals. According to an embodiment, one or more functions of the audio signal processor **240** may be implemented in the form of an equalizer.

[0066] The DAC **250** may convert a digital audio signal into an analog audio signal. For example, according to an embodiment, the DAC **250** may convert a digital audio signal processed by the audio signal processor **240** or a digital audio signal obtained from another component (e.g., the processor (**120**) or the memory (l**30**)) of the electronic device **101** into an analog audio signal.

[0067] The audio output mixer **260** may synthesize a plurality of audio signals, which are to be outputted, into at least one audio signal. For example, according to an embodiment, the audio output mixer **260** may synthesize an analog audio signal converted by the DAC **250** and another analog audio signal (e.g., an analog audio signal received via the audio input interface **210**) into at least one analog audio signal.

[0068] The audio output interface **270** may output an analog audio signal converted by the DAC **250** or, additionally or alternatively, an analog audio signal synthesized by the audio output mixer **260** to the outside of the electronic device **101** via the sound output device **155**. The sound output device **155** may include, for example, a speaker, such as a dynamic driver or a balanced armature driver, or a receiver. According to an embodiment, the sound output device **155** may include a plurality of speakers. In such a case, the audio output interface **270** may output audio signals having a plurality of different channels (e.g., stereo channels or 5.1 channels) via at least some of the plurality of speakers. According to an embodiment, the audio output interface **270** may be connected with the external electronic device **102** (e.g., an external speaker or a headset) directly via the connecting terminal **178** or wirelessly via the wireless communication module **192** to output an audio signal.

[0069] According to an embodiment, the audio module **170** may generate, without separately including the audio input mixer **220** or the audio output mixer **260**, at least one digital audio signal by synthesizing a plurality of digital audio signals using at least one function of the audio signal processor **240**.

[0070] According to an embodiment, the audio module **170** may include an audio amplifier (not shown) (e.g., a speaker amplifying circuit) that is capable of amplifying an analog audio signal inputted via the audio input interface **210** or an audio signal that is to be outputted via the audio output interface **270**. According to an embodiment, the audio amplifier may be configured as a module separate from the audio module **170**.

[0071] FIG. **3** is a block diagram illustrating an electronic device according to various embodiments disclosed in this document.

[0072] With reference to FIG. **3**, an electronic device **300** (e.g., the electronic device **101** of FIG. **1**) may include a processor **320** (e.g., the processor **120** of FIG. **1**), a memory **330** (e.g., the memory **130** of FIG. **1**), an external microphone **340**, a speaker **350** (e.g., the sound output module **155** of FIG. **1**), and/or an internal microphone **360**. The components included in FIG. **3** are for some of the components included in the electronic device **300**, and the electronic device **300** may include various components, as illustrated in FIG. **1**.

[0073] According to an embodiment, the external microphone **340** may be located in an area exposed to the outside from an ear inlet when wearing the electronic device **300** to acquire an external input signal. According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may correspond to at least a portion of a sound generating outside the electronic device **300**. According to an embodiment, the external input signal may refer to any one of an external sound wave, an external electrical signal, an external pulse coded modulation (PCM) signal, and/or an external frequency signal acquired by the external microphone **340**.

[0074] According to an embodiment, the external microphone **340** may convert the acquired external sound wave into an external electrical signal. For example, the external microphone **340** may convert an external signal, which is an acoustic signal, into an external electrical signal, which is an electronic signal. For example, the external microphone **340** may include a membrane and generate an external electrical signal corresponding to the vibration of the membrane due to the external signal.

[0075] According to an embodiment, the external microphone **340** may digitize the converted external electrical signal and convert it into an external PCM signal. For example, the external microphone **340** may convert the external electrical signal, which is an analog signal, into an external PCM signal, which is a digital signal. For example, the external microphone **340** may generate an external PCM signal by digitizing the external electrical signal by sampling it into a uniform interval, quantizing it into a representative value of the interval, and encoding it into a digital binary code.

[0076] According to an embodiment, the processor **320** may convert a converted external PCM signal, which is a time domain signal, into an external frequency signal, which is a frequency domain signal. For example, the processor **320** may perform a fast Fourier transform (FFT) in the converted PCM signal to generate an external frequency signal.

[0077] The internal microphone **360** according to various embodiments may be located in an area between an ear inlet and an eardrum within the external auditory canal when wearing the electronic device **300** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360** and may correspond to at least a portion of a sound acquired between the electronic device **300** and an external object (e.g., eardrum). For example, the sound acquired by the internal microphone **360** may be a sound output from the speaker **350** and/or a sound output from the speaker **350** and reflected to an external object (e.g., eardrum). According to an embodiment, the internal input signal may refer to any one of an internal sound wave, an internal electrical signal, an internal PCM signal, and/or an internal frequency signal acquired by the internal microphone **360**. According to an embodiment, the internal microphone **360** may convert the acquired internal sound wave into an internal electrical signal.

For example, the internal microphone **360** may convert the internal sound wave, which is an acoustic signal, into an internal electrical signal, which is an electronic signal. For example, the internal microphone **360** may include a membrane and generate an internal electrical signal corresponding to the vibration of the membrane due to the internal sound wave.

[0078] According to an embodiment, the internal microphone **360** may digitize the converted internal electrical signal to convert it into an internal pulse coded modulation (PCM) signal. For example, the internal microphone **360** may convert the internal electrical signal, which is an analog signal, into an internal PCM signal, which is a digital signal. For example, the internal microphone **360** may generate an internal PCM signal by digitizing the internal electrical signal by sampling it into a uniform interval, quantizing it into a representative value of the interval, and encoding it into a digital binary code.

[0079] According to an embodiment, the processor **320** may convert the converted internal PCM signal, which is a time domain signal, into an internal frequency signal, which is a frequency domain signal. For example, the processor **320** may perform a fast Fourier transform (FFT) in the converted internal PCM signal to generate an internal frequency signal.

[0080] The memory **330** according to various embodiments may store various data (e.g., normalized least mean squares (NLMS) algorithm) for estimating a passive feature occurring according to actual wearing of the electronic device **300** based on an external input signal input through the external microphone **340** and an internal input signal input through the internal microphone **360**. For example, the estimated passive feature may represent a characteristic of a signal reduced and changed while a signal input through the external microphone **340** reaches a location of the internal microphone **360**. For example, the estimated passive feature may represent a filter that predicts a signal input to the internal microphone **360** based on a signal input through the external microphone **340**.

[0081] The memory **330** according to various embodiments may store a reference passive feature estimated through a wearing simulation (e.g., ear simulator) of the electronic device **300** based on a signal input through the external microphone **340** and a signal input through the internal microphone **360**. For example, the reference passive feature may be estimated based on NLMS with reference to a passive feature measured through a simulation.

[0082] The memory **330** according to various embodiments may store various data for identifying a target frequency response for an estimated passive feature based on a reference passive feature and designing or implementing a filter combination having the target frequency response.

[0083] The memory **330** according to various embodiments may store a learning model for deriving a final passive feature by compensating for an estimated passive feature. For example, the learning model may include a deep neural network learning model learned in advance so as to derive high frequency components of a passive feature based on low frequency components of the passive feature measured through a simulation.

[0084] The memory **330** according to various embodiments may store a learning model for deriving a frequency response of a signal changing through a path (external auditory canal) until a signal input through the external microphone **340** reaches the eardrum through a wearing simulation (e.g., ear simulator) of the electronic device **300**. For example, the learning model may include a deep neural network learning model learned in advance so that a frequency response of a signal measured at an eardrum location is derived through a simulation for a signal input through the external microphone **340**.

[0085] The memory **330** according to various embodiments may store filter data applied to remove noise of the internal microphone **360**. For example, the stored filter data may include information on a filter applied based on, for example, NLMS in order to remove noise when various voice signals such as a call event occur.

[0086] The external microphone **340** according to various embodiments may be located in an area exposed to the outside when wearing the electronic device **300** to acquire an external input signal.

According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may include at least a portion of a signal generating outside the electronic device **300**. According to an embodiment, the external microphone **340** may be installed in a location exposed to the outside from the external auditory canal when the user wears the electronic device **300** on his or her ear. According to an embodiment, the external microphone **340** may acquire an external input signal corresponding to a sound acquired from the outside of the electronic device **300**. For example, the sound acquired by the external microphone **340** from the outside may be a sound generating around the user while the user is wearing the electronic device **300**.

[0087] The speaker **350** according to various embodiments may output a signal in a direction of the eardrum of the user inside the external auditory canal without being exposed to the outside when wearing the electronic device **300**. According to an embodiment, the speaker **350** may be installed to be located between the inside of the external auditory canal and the eardrum when the electronic device **300** is worn on the ear. According to an embodiment, the speaker **350** may output an acoustic signal to the outside of the electronic device **300** based on a signal controlled by the processor **320**.

[0088] The internal microphone **360** according to various embodiments may be located in an inner region of the external auditory canal when wearing the electronic device **300** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360** and may include at least a portion of a signal output by the speaker **350**. According to an embodiment, the internal microphone **360** may be installed to be located between the external auditory canal and the eardrum when the electronic device **300** is worn on the ear. According to an embodiment, the internal microphone **360** may acquire an internal input signal corresponding to a sound acquired between the electronic device **300** and an external object (e.g., the eardrum). For example, the sound acquired by the internal microphone **360** may be a sound output from the speaker **350** and/or a sound output from the speaker **350** and reflected to an external object.

[0089] FIG. **4** is a flowchart illustrating a method of controlling a signal to be output from a speaker (e.g., the speaker **350** of FIG. **3**) based on signals acquired from an external microphone (e.g., the external microphone **340** of FIG. **3**) and an internal microphone (e.g., the internal microphone **360** of FIG. **3**) by a processor (e.g., the processor **320** of FIG. **3**) in an electronic device (e.g., the electronic device **300** of FIG. **3**) according to various embodiments disclosed in this document.

[0090] FIG. **4** is a flowchart illustrating a method of controlling a signal to be output from a speaker (e.g., the speaker **350** of FIG. **3**) based on signals acquired from an external microphone (e.g., the external microphone **340** of FIG. **3**) and an internal microphone (e.g., the internal microphone **360** of FIG. **3**) by a processor (e.g., the processor **320** of FIG. **3**) according to various embodiments disclosed in this document.

[0091] According to various embodiments, the processor **320** may control a signal output from the speaker **350** to enable a user wearing the electronic device **300** to hear external sounds in the surroundings.

[0092] According to various embodiments, in operation **401**, the processor **320** may estimate a passive feature based on an external input signal acquired through the external microphone **340** and an internal input signal acquired through the internal microphone **360**.

[0093] According to an embodiment, the external microphone **340** may be located in an area exposed to the outside from the ear inlet when wearing the electronic device **300** to acquire an external input signal. According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may correspond to at least a portion of a sound generating outside the electronic device **300**.

[0094] The internal microphone **360** according to various embodiments may be located between

the ear inlet and the eardrum within the external auditory canal when wearing the electronic device **300** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360**.
[0095] According to an embodiment, operation **401** may be performed, for example, in a situation where no signal is output by the speaker **350** and/or a situation where the user does not speak. To this end, for example, the electronic device **300** may identify whether the speaker **350** outputs. For example, the electronic device **300** may identify whether the user speaks using voice activity detection (VAD) technology for a signal input through the internal microphone **360**. For example, in the case that the electronic device **300** is equipped with a voice pickup unit (VPU), the electronic device **300** may identify whether the user speaks using the VPU.
[0096] According to various embodiments, the processor **320** may estimate a passive feature according to the wearing of the electronic device **300** based on an external input signal acquired through the external microphone **340** and an internal input signal acquired through the internal microphone **360**. Here, the passive feature may mean how much an external sound is attenuated and introduced into the external auditory canal. For example, the passive feature may be estimated based on the relationship (e.g., magnitude difference) between the external input signal acquired through the external microphone **340** and the internal input signal acquired through the internal microphone **360**. For example, the passive feature may be estimated using a normalized least mean squares (NLMS) algorithm, but embodiments are not limited thereto.
[0097] According to various embodiments, in operation **403**, the processor **320** may identify a target frequency response from the estimated passive feature with reference to the reference passive feature. According to an embodiment, the processor **320** may identify a gain difference between the estimated passive feature and the reference passive feature and identify a target frequency response based on the difference. For example, the reference passive feature may include a passive feature measured through a simulation (e.g., ear simulator).
[0098] According to various embodiments, in operation **405**, the processor **320** may estimate a filter based on the target frequency response. According to an embodiment, the estimated filter may be implemented by combining one or more finite impulse response/infinite impulse response (fir/iir) filters so as to have the target frequency response. For example, the implemented filter combination may be stored in a memory (e.g., the memory **330** of FIG. **3**). For example, an audio equalizer (EQ) value configured according to the implemented filter combination may be stored in the memory **330**.
[0099] FIG. **5** is a diagram illustrating an example of signal flow and a constitution of an electronic device for external signal transmission according to various embodiments.
[0100] An electronic device **500** (e.g., the electronic device **300** of FIG. **3**) according to various embodiments may include an external microphone **340**, a processor **320**, a memory **330**, a speaker **350**, and/or an internal microphone **360**.
[0101] According to an embodiment, the external microphone **340** may be located in an area exposed to the outside from the ear inlet when wearing the electronic device **300** to acquire an external input signal. According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may include at least a portion of a sound generating outside the electronic device **300**.
[0102] The internal microphone **360** according to various embodiments may be located between the ear inlet and the eardrum within an external auditory canal when wearing the electronic device **300** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360**.
[0103] According to an embodiment, a first filter **501** may include a filter designed by a simulation (e.g., ear simulator). For example, the first filter **501** may include a filter (fixed filter) having fixed filter coefficients. For example, the first filter **501** may include a filter designed based on a passive performance in an open state measured between the eardrum and the ear inlet of the simulator.

[0104] According to an embodiment, the electronic device **500** may be mounted on the ear simulator to measure passive features based on NLMS, and the first filter **501** may be tuned so that an active characteristic becomes a target frequency response with reference to the measured frequency response. For example, tuning of the first filter **501** may be performed during the manufacturing stage of the electronic device **500**.
[0105] According to an embodiment, the reference passive feature Hi_ref (f) may be estimated based on NLMS in a state in which the electronic device **500** is mounted on the ear simulator and stored in the memory **330**.
[0106] According to an embodiment, a passive feature estimation block **505** may estimate the passive feature Hi(f) according to the wearing of the electronic device **300** based on an external input signal acquired through the external microphone **340** and an internal input signal acquired through the internal microphone **360**. Here, the passive feature may mean how much an external sound is attenuated and introduced into the external auditory canal. For example, the passive feature may be estimated based on the relationship (e.g., magnitude difference) between the external input signal acquired through the external microphone **340** and the internal input signal acquired through the internal microphone **360**. For example, the passive feature may be estimated using a normalized least mean squares (NLMS) algorithm, but embodiments are not limited thereto.
[0107] According to an embodiment, the passive feature estimation block **505** may be operated in a situation where no signal is output by the speaker **350** and/or a situation where the user does not speak.
[0108] FIGS. **6**A and **6**B are graphs illustrating signals input through microphones of an electronic device and signal characteristics estimated based thereon and estimated filters according to various embodiments.
[0109] With reference to FIG. **6**A, an internal input signal **603** estimated from an external input signal may be represented based on a characteristic **601** of an external input signal acquired through an external microphone **340** and a characteristic **602** of an internal input signal acquired through an internal microphone **360**.
[0110] According to an embodiment, it is possible to model how much the internal input signal input to the internal microphone **360** is reduced relative to the external input signal input to the external microphone **340**, and a filter **604** may be estimated, as illustrated FIG. **6**B.
[0111] According to an embodiment, a relationship such as Equation 1 may be established between an external input signal X (f,t) acquired through the external microphone **340**, an internal input signal Y (f,t) input through the internal microphone **360**, and a filter H (f,t) that predicts the internal input signal Y (f,t) for the external input signal X (f,t).

Equation1

[00001]
$$E(f,t)=Y(f,t)-X(f,t)H(f,t) \quad \text{Eqn. 1}$$

[0112] Here, it is possible to model a converged filter H (f,t) representing how much the internal input signal is reduced compared to the external input signal by minimizing E (f,t) by applying NLMS.
[0113] According to an embodiment, a passive feature estimated by the passive feature estimation block **505** may be affected by various environmental changes occurring when the electronic device **500** is worn by an individual user, such as characteristics of the user's external auditory canal, a wearing state (e.g., including a tight or loose state), or a size of the eartip.
[0114] FIGS. **7**A and **7**B are graphs illustrating differences in passive features estimated by signals input through microphones according to various variables occurring when wearing an electronic device (e.g., the electronic device **300** or **500** of FIG. **3** or **5**) according to various embodiments.
[0115] According to an embodiment, with reference to FIG. **7**A, it may be seen that passive features estimated by signals input through microphones change according to a type and/or size of

an eartip applied for wearing the electronic device.

[0116] According to an embodiment, with reference to FIG. **7**B, it may be seen that passive features estimated by signals input through microphones change according to characteristics (e.g., characteristics of the external auditory canal) of the user wearing the electronic device.

[0117] According to various embodiments, a target frequency response identification block **507** may identify a target frequency response from the estimated passive feature with reference to a reference passive feature **508**. According to an embodiment, the target frequency response identification block **507** may identify a gain difference T(f) between an estimated passive feature Hi(f) and a reference passive feature Hi(f) and identify a target frequency response based on the gain difference T(f). For example, the target frequency response may include 1/T(f).

[0118] FIGS. **8**A and **8**B are graphs illustrating estimated signal characteristics based on signals input through microphones and deviations based on a reference signal characteristic when wearing an electronic device according to various embodiments.

[0119] According to an embodiment, with reference to FIGS. **8**A and **8**B, it may be seen that deviations (e.g., different eartip sizes/types) according to various variables may be compensated according to an identified target frequency response by applying a reference passive feature to estimated passive features based on signals input through microphones in a state of wearing an electronic device (e.g., the electronic device **300** or **500** of FIG. **3** or **5**). For example, in FIG. **8**A, an estimated passive feature **801** for a small eartip may be different from an estimated passive feature **802** for a mid eartip.

[0120] According to an embodiment, an identified frequency response by applying the reference passive feature to the estimated passive feature **801** for the small eartip may be approached to the estimated frequency response by applying the reference passive feature to the estimated passive feature **802** for the mid eartip.

[0121] According to an embodiment, with reference to FIG. **8**B, by applying and correcting a reference frequency response to a measured frequency response **803** for a small eartip in a state of wearing an electronic device, the frequency response **803** may be approached to an estimated frequency response **805** by applying the reference passive feature to a frequency response **804** according to a measured passive feature for a mid eartip.

[0122] According to an embodiment, a second filter **503** may be implemented by estimating based on the target frequency response. According to an embodiment, the second filter **503** may be a variable filter. According to an embodiment, the second filter **503** may be implemented by combining one or more finite impulse response/infinite impulse response (fir/iir) filters having the target frequency response. For example, filter coefficients may be calculated by performing inverse fast Fourier transform (IFT) in the target frequency response. For example, filter coefficients may be implemented by combining a plurality of biquad filters.

[0123] According to an embodiment, external sound acquired through the external microphone **340** may be filtered through the first filter **501** and the second filter **503** to be output through the speaker **350**.

[0124] With reference again to FIG. **5**, the passive feature estimation block **505** and the target frequency response identification block **507** may be implemented to operate as functional modules of the processor **320**. For example, a reference frequency response **508** may be stored in the memory **330**.

[0125] FIGS. **9**A to **9**C are graphs illustrating a signal characteristic estimated based on a signal input through microphones and a deviation based on a reference signal characteristic when wearing an electronic device (e.g., the electronic device **300** or **500** of FIG. **3** or **5**) according to various embodiments. With reference to the illustrated graphs, it may be seen that a frequency response estimated by correction based on a reference frequency response when wearing an electronic device is similar to a frequency response measured by a simulation when not wearing the electronic device according to various embodiments.

[0126] With reference to FIG. **9**A, it may be seen that a frequency response **902** estimated as a result corrected based on a reference frequency response **901** stored based on the simulation is similar to a frequency response **903** measured by a simulation according to various embodiments.
[0127] With reference to FIG. **9**B, it may be seen that a frequency response **905** estimated by correction based on a reference frequency response **904** stored based on a simulation is similar to a frequency response **906** measured by a simulation according to various embodiments.
[0128] With reference to FIG. **9**C, it may be seen that a frequency response **907** estimated by correction based on the reference frequency response **906** stored based on a simulation is similar to a frequency response **908** measured by a simulation according to various embodiments.
[0129] FIGS. **10**A and **10**B are graphs illustrating a signal characteristic estimated based on a signal input through microphones and a deviation compensated based on a reference signal characteristic when wearing an electronic device (e.g., the electronic device **300** or **500** of FIG. **3** or **5**) according to various embodiments.
[0130] With reference to FIG. **10**A, it may be seen that a gain **1003** for a frequency response estimated based on a reference signal characteristic with respect to a gain **1001** for a frequency response measured when a small eartip is applied is similar to a gain **1002** for a frequency response measured when a mid eartip is applied.
[0131] With reference to FIG. **10**B, it may be seen that a gain **1006** for a frequency response estimated based on a reference signal characteristic with respect to a gain **1004** for a frequency response measured when a small eartip is applied is similar to a gain **1005** for a frequency response measured when a mid eartip is applied.
[0132] With reference to FIG. **10**C, it may be seen that a gain **1009** for a frequency response estimated based on a reference signal characteristic with respect to a gain **1007** for a frequency response measured when a small eartip is applied is similar to a gain **1008** for a frequency response measured when a mid eartip is applied.
[0133] With reference to FIG. **10**D, it may be seen that a gain **1011** for a frequency response estimated based on a reference signal characteristic with respect to a gain **1009** for a frequency response measured when a small eartip is applied is similar to a gain **1010** for a frequency response measured when a mid eartip is applied.
[0134] FIG. **11** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments.
[0135] An electronic device **1100** (e.g., the electronic device **300** of FIG. **3** or the electronic device **500** of FIG. **5**) according to various embodiments may include an external microphone **340**, a processor **320**, a memory **330**, a speaker **350**, and/or an internal microphone **360**. Hereinafter, in the description of an operation of the electronic device **1100**, a detailed description of an operation identical or similar to the operation according to the constitution of the electronic device **300** of FIG. **3** or the electronic device **500** of FIG. **5** may be omitted.
[0136] According to an embodiment, the external microphone **340** may be located in an area exposed to the outside from the ear inlet when wearing the electronic device **1100** to acquire an external input signal. According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may include at least a portion of a sound generating outside the electronic device **300**.
[0137] The internal microphone **360** according to various embodiments may be located between the ear inlet and the eardrum within the external auditory canal when wearing the electronic device **1100** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360**.
[0138] According to an embodiment, a first filter **1101** may include a filter designed by a simulation (e.g., ear simulator). For example, the first filter **1101** may include a filter (fixed filter) having fixed filter coefficients. For example, the first filter **1101** may include a filter designed

based on a passive performance in an open state measured between the eardrum and the ear inlet of the simulator.

[0139] According to an embodiment, the electronic device **1100** may be mounted on the ear simulator to measure a passive feature based on NLMS, and the first filter **1101** may be tuned so that an active characteristic becomes a target frequency response with reference to the measured frequency response. For example, tuning of the first filter **1101** may be performed during the manufacturing stage of the electronic device **1100**.

[0140] According to an embodiment, a passive feature estimation block **1105** may estimate the passive feature according to the wearing of the electronic device **300** based on an external input signal acquired through the external microphone **340** and an internal input signal acquired through the internal microphone **360**. Here, the passive feature may mean how much an external sound is attenuated and introduced into the external auditory canal. For example, the passive feature may be estimated based on the relationship (e.g., magnitude difference) between the external input signal acquired through the external microphone **340** and the internal input signal acquired through the internal microphone **360**. For example, the passive feature may be estimated using a normalized least mean squares (NLMS) algorithm, but embodiments are not limited thereto.

[0141] According to an embodiment, the passive feature estimation block **1105** may be operated in a situation where no signal is output by the speaker **350** and/or a situation where the user does not speak.

[0142] According to an embodiment, a passive feature estimated by the passive feature estimation block **1105** may be affected by various environmental changes occurring when the electronic device **1100** is worn by an individual user, such as characteristics of the user's external auditory canal, a wearing state (e.g., including a tight or loose state), or a size of the eartip.

[0143] According to various embodiments, a target frequency response identification block **1107** may identify a target frequency response from the estimated passive feature with reference to a reference frequency response **1108**.

[0144] According to an embodiment, for a signal input through the external microphone **340**, the memory **330** may store a learning model for estimating a high frequency component of a passive feature based on the magnitude of a low frequency component of a passive feature estimated through a wearing simulation (e.g., ear simulator) of the electronic device **300** to further correct a high frequency component of a target frequency response. For example, the learning model may include a deep neural network learning model learned to estimate a passive feature for a signal input through the external microphone **340** in the ear simulator, and to estimate a high frequency component of the passive feature by inputting the magnitude of a low frequency component of the estimated passive feature and targeting a high frequency component of the passive feature measured in the ear simulator.

[0145] According to an embodiment, a target frequency response correction module **1109** may correct the target frequency response based on a learning model stored in the memory **330**.

[0146] According to an embodiment, a second filter **1103** may be implemented by estimating based on the corrected target frequency response. According to an embodiment, the second filter **1103** may be a variable filter. According to an embodiment, the second filter **1103** may be implemented by combining one or more finite impulse response/infinite impulse response (fir/iir) filters having a target frequency response. For example, filter coefficients may be calculated by performing inverse fast Fourier transform (IFT) in the target frequency response. For example, filter coefficients may be implemented by combining a plurality of biquad filters.

[0147] According to an embodiment, external sound acquired through the external microphone **340** may be compensated through the first filter **1101** and the second filter **1103** to be output through the speaker **350**.

[0148] With reference again to FIG. **11**, the passive feature estimation block **1105**, the target frequency response identification block **1107**, and the target frequency response correction block

1109 may be implemented to operate as functional modules of the processor **320**. The learning model for the reference frequency response **1108** and/or the target frequency response correction may be stored in the memory **330**.
[0149] FIG. **12** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments.
[0150] An electronic device **1200** (e.g., the electronic device **300** of FIG. **3**) according to various embodiments may include an external microphone **340**, a processor **320**, a memory **330**, a speaker **350**, and/or an internal microphone **360**. Hereinafter, in the description of an operation of the electronic device **1200**, a detailed description of an operation identical or similar to an operation according to the constitution of the electronic device **300** of FIG. **3** or the electronic device **500** of FIG. **5** may be omitted.
[0151] According to an embodiment, the external microphone **340** may be located in an area exposed to the outside from the ear inlet when wearing the electronic device **1200** to acquire an external input signal. According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may include at least a portion of a sound generating outside the electronic device **300**.
[0152] The internal microphone **360** according to various embodiments may be located between the ear inlet and the eardrum within the external auditory canal when wearing the electronic device **1200** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360**.
[0153] According to an embodiment, a first filter **1201** may include a filter designed by a simulation (e.g., ear simulator). For example, the first filter **1201** may include a filter (fixed filter) having fixed filter coefficients. For example, the first filter **1201** may include a filter designed based on a passive performance in an open state measured between the eardrum and the ear inlet of the simulator.
[0154] According to an embodiment, the electronic device **1200** may be mounted on the ear simulator to measure a passive feature based on NLMS, and the first filter **1201** may be tuned so that an active characteristic becomes a target frequency response with reference to the measured frequency response. For example, tuning of the first filter **1201** may be performed during the manufacturing stage of the electronic device **1200**.
[0155] According to an embodiment, a passive feature estimation block **1205** may estimate the passive feature according to the wearing of the electronic device **300** based on an external input signal acquired through the external microphone **340** and an internal input signal acquired through the internal microphone **360**. Here, the passive feature may mean how much an external sound is attenuated and introduced into the external auditory canal. For example, the passive feature may be estimated based on the relationship (e.g., magnitude difference) between the external input signal acquired through the external microphone **340** and the internal input signal acquired through the internal microphone **360**. For example, the passive feature may be estimated using a normalized least mean squares (NLMS) algorithm, but embodiments are not limited thereto.
[0156] According to an embodiment, the passive feature estimation block **1205** may be operated in a situation where no signal is output by the speaker **350** and/or a situation where the user does not speak.
[0157] According to an embodiment, a passive feature estimated by the passive feature estimation block **1205** may be affected by various environmental changes occurring when the electronic device **1200** is worn by an individual user, such as characteristics of the user's external auditory canal, a wearing state (e.g., including a tight or loose state), and a size of the eartip.
[0158] According to various embodiments, a target frequency response identification block **1207** may identify a target frequency response from the estimated passive features with reference to a reference frequency response **1208**.

[0159] According to an embodiment, the memory **330** may store a learning model for deriving a frequency response of a signal changing through a path (external auditory canal) until a signal input through the external microphone **340** reaches the eardrum through a wearing simulation (e.g., ear simulator) of the electronic device **300**. For example, the learning model may include a deep neural network learning model learned to estimate a passive feature of a signal input through the external microphone **340** in consideration of a signal input through the internal microphone **360** and to derive a frequency response of a signal measured at an eardrum location through a simulation.
[0160] According to an embodiment, a target frequency response correction module **1210** may correct the target frequency response based on a learning model stored in the memory **330**.
[0161] According to an embodiment, a second filter **1203** may be implemented by estimating based on the corrected target frequency response. According to an embodiment, the second filter **1203** may be a variable filter. According to an embodiment, the second filter **1203** may be implemented by combining one or more finite impulse response/infinite impulse response (fir/iir) filters having a target frequency response. For example, filter coefficients may be calculated by performing inverse fast Fourier transform (IFFT) in the target frequency response. For example, filter coefficients may be implemented by combining a plurality of biquad filters.
[0162] According to an embodiment, external sound acquired through the external microphone **340** may be compensated through the first filter **1201** and the second filter **1203** to be output through the speaker **350**.
[0163] With reference again to FIG. **12**, the passive feature estimation block **1205**, the target frequency response identification block **1207**, and a target frequency response correction block **1210** may be implemented to operate as functional modules of the processor **320**. The learning model for the reference frequency response **1208** and/or the target frequency response correction may be stored in the memory **330**.
[0164] FIG. **13** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments.
[0165] An electronic device **1300** (e.g., the electronic device **300** of FIG. **3**) according to various embodiments may include an external microphone **340**, a processor **320**, a memory **330**, a speaker **350**, and/or an internal microphone **360**. The electronic device **1300** according to an embodiment may further include a first acoustic echo canceller (AEC) **1311** and a second AEC **1313** at the rear end of the external microphone **340** and the internal microphone **360**. Hereinafter, in the description of an operation of the electronic device **1300**, a detailed description of an operation identical or similar to an operation according to the constitution of the electronic device **300** of FIG. **3** or the electronic device **500** of FIG. **5** may be omitted.
[0166] According to an embodiment, the external microphone **340** may be located in an area exposed to the outside from the ear inlet when wearing the electronic device **1300** to acquire an external input signal. According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may include at least a portion of a sound generating outside the electronic device **300**.
[0167] The internal microphone **360** according to various embodiments may be located between the ear inlet and the eardrum within the external auditory canal when wearing the electronic device **1300** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360**.
[0168] The first AEC **1311** and the second AEC **1313** that may be applied to the rear end of the external microphone **340** and the internal microphone **360** according to an embodiment may remove, for example, a signal output through the speaker **350** and/or noise input according to a user's speech from a signal input through the external microphone **340** and the internal microphone **360**. Accordingly, the electronic device **1300** may operate to filter external sounds and provide them to the speaker **350** even in a signal output situation and/or a user's speech situation through

the speaker **350**. For example, the first AEC **1311** may be implemented inside the external microphone **340**. For example, the second AEC **1313** may be implemented inside the internal microphone **360**.
[0169] According to an embodiment, a first filter **1301** may include a filter designed by a simulation (e.g., ear simulator). For example, the first filter **1301** may include a filter (fixed filter) having fixed filter coefficients. For example, the first filter **1301** may include a filter designed based on a passive performance in an open state measured between the eardrum and the ear inlet of the simulator.
[0170] According to an embodiment, the electronic device **1300** may be mounted on the ear simulator to measure a passive feature based on NLMS, and the first filter **1301** may be tuned so that an active characteristic becomes a target frequency response with reference to the measured frequency response. For example, tuning of the first filter **1301** may be performed during the manufacturing stage of the electronic device **1300**.
[0171] According to an embodiment, a passive feature estimation block **1305** may estimate the passive feature according to the wearing of the electronic device **300** based on an external input signal acquired through the external microphone **340** and an internal input signal acquired through the internal microphone **360**. Here, the passive feature may mean how much an external sound is attenuated and introduced into the external auditory canal. For example, the passive feature may be estimated based on the relationship (e.g., magnitude difference) between the external input signal acquired through the external microphone **340** and the internal input signal acquired through the internal microphone **360**. For example, the passive feature may be estimated using a normalized least mean squares (NLMS) algorithm, but embodiments are not limited thereto.
[0172] According to an embodiment, the passive feature estimation block **1305** may be performed in a situation where no signal is output by the speaker **350** and/or a situation where the user does not speak.
[0173] According to an embodiment, a passive feature estimated by the passive feature estimation block **1305** may be affected by various environmental changes occurring when the electronic device **1300** is worn by an individual user, such as characteristics of the user's external auditory canal, a wearing state (e.g., including a tight or loose state), and a size of the eartip.
[0174] According to various embodiments, a target frequency response identification block **1307** may identify a target frequency response from the estimated passive feature with reference to a reference frequency response **1308**.
[0175] According to an embodiment, a second filter **1303** may be implemented by estimating based on the identified target frequency response. According to an embodiment, the second filter **1303** may be a variable filter. According to an embodiment, the second filter **1303** may be implemented by combining one or more finite impulse response/infinite impulse response (fir/iir) filters having target frequency responses. For example, filter coefficients may be calculated by performing inverse fast Fourier transform (IFFT) in the target frequency response. For example, filter coefficients may be implemented by combining a plurality of biquad filters.
[0176] According to an embodiment, external sound acquired through the external microphone **340** may be compensated through the first filter **1301** and the second filter **1303** to be output through the speaker **350**.
[0177] With reference again to FIG. **13**, the passive feature estimation module **1305** and the target frequency response identification module **1307** may be implemented to operate as functional modules of the processor **320**. The reference frequency response **1308** may be stored in the memory **330**.
[0178] FIG. **14** is a diagram illustrating an example of learning a method of filtering and providing external sounds based on signals input through microphones of an electronic device (e.g., the electronic device **300** of FIG. **3**) according to a simulation according to various embodiments.
[0179] According to an embodiment, it is possible to learn a method of generating various sounds

through an external electronic device (e.g., the electronic device **101** of FIG. **1**) and filtering and providing external sounds of the electronic device **300** according to various embodiments based on the generated sounds.

[0180] According to an embodiment, an external electronic device **101** may receive an external sound provision function learning command of the electronic device **300** through a display (e.g., the display module **160** of FIG. **1**).

[0181] According to an embodiment, the external electronic device **101** may generate and output a test signal using an audio module (e.g., the audio module **170** of FIG. **1** or **2**) and/or a sound output module (e.g., the sound output module **155** of FIG. **1**).

[0182] According to an embodiment, the electronic device **300** may repeatedly perform operations of estimating passive features, identifying a target frequency response, and/or constituting a variable filter (e.g., the second filter **503**, **1103**, **1203**, or **1303** of FIG. **5**, **11**, **12**, or **13**) for microphone input signals according to the above description based on various test signals output from the external electronic device **101**, thereby enabling to update and learn filter coefficients of the variable filter.

[0183] FIG. **15** is a diagram illustrating an example of signal flow and a constitution of an electronic device that filters and provides external sounds based on signals input through microphones when wearing the electronic device according to various embodiments.

[0184] An electronic device **1500** (e.g., the electronic device **300** of FIG. **3**) according to various embodiments may include an external microphone **340**, a processor **320**, a memory **330**, a speaker **350**, and/or an internal microphone **360**. Hereinafter, in the description of an operation of the electronic device **1500**, a detailed description of an operation identical or similar to an operation according to the constitution of the electronic device **300** of FIG. **3** or the electronic device **500** of FIG. **5** may be omitted.

[0185] According to an embodiment, the external microphone **340** may be located in an area exposed to the outside from the ear inlet when wearing the electronic device **1500** to acquire an external input signal. According to an embodiment, the external input signal is a signal acquired by the external microphone **340** and may include at least a portion of a sound generating outside the electronic device **300**.

[0186] The internal microphone **360** according to various embodiments may be located between the ear inlet and the eardrum within the external auditory canal when wearing the electronic device **1500** to acquire an internal input signal. According to an embodiment, the internal input signal is a signal acquired by the internal microphone **360**.

[0187] According to an embodiment, a first filter **1501** may include a filter designed by a simulation (e.g., ear simulator). For example, the first filter **1501** may include a filter (fixed filter) having fixed filter coefficients. For example, the first filter **1501** may include a filter designed based on the measured passive performance of an open state between the eardrum and the ear inlet of the simulator.

[0188] According to an embodiment, the electronic device **1500** may be mounted on the ear simulator to measure passive features based on NLMS, and the first filter **1501** may be tuned so that an active characteristic becomes a target frequency response with reference to the measured frequency response. For example, tuning of the first filter **1501** may be performed during the manufacturing stage of the electronic device **1500**.

[0189] According to an embodiment, a passive feature estimation block **1505** may estimate the passive feature according to the wearing of the electronic device **300** based on an external input signal acquired through the external microphone **340** and an internal input signal acquired through the internal microphone **360**. Here, the passive feature may mean how much an external sound is attenuated and introduced into the external auditory canal. For example, the passive feature may be estimated based on the relationship (e.g., magnitude difference) between the external input signal acquired through the external microphone **340** and the internal input signal acquired through the

internal microphone **360**. For example, the passive feature may be estimated using a normalized least mean squares (NLMS) algorithm, but embodiments are not limited thereto.
[0190] According to an embodiment, the passive feature estimation block **1505** may estimate the passive feature by additionally referring to filter data **1515** stored in the memory **330**. For example, the filter data **1515** may include various filter data converged, i.e., applied and updated in order to remove noise of the internal microphone **360** according to the operation of the electronic device **1500**. For example, the filter data **1515** may include filter data converged according to a voice call solution including an NLMS-based filter (e.g., adaptive filter) operating in order to remove noise of the internal microphone **360** when a call is performed in the electronic device **1500**.
[0191] According to an embodiment, the passive feature estimation block **1505** may be performed in a situation where no signal is output by the speaker **350** and/or a situation where the user does not speak.
[0192] According to an embodiment, a passive feature estimated by the passive feature estimation block **1505** may be affected by various environmental changes occurring when the electronic device **1500** is worn by an individual user, such as characteristics of the user's external auditory canal, a wearing state (e.g., including a tight or loose state), or a size of the eartip.
[0193] According to various embodiments, a target frequency response identification block **1507** may identify a target frequency response from the estimated passive feature with reference to a reference frequency response **1508**.
[0194] According to an embodiment, the memory **330** may store a learning model for deriving a frequency response of a signal changing through a path (external auditory canal) until a signal input through the external microphone **340** reaches the ear drum through a wearing simulation (e.g., ear simulator) of the electronic device **300**. For example, the learning model may include a deep neural network learning model learned to estimate a passive feature for a signal input through the external microphone **340** and to derive a frequency response of a signal measured at an eardrum location through a simulation.
[0195] According to an embodiment, a target frequency response correction module **1510** may correct the target frequency response based on a learning model stored in the memory **330**.
[0196] According to an embodiment, a second filter **1503** may be implemented by estimating based on the corrected target frequency response. According to an embodiment, the second filter **1503** may be a variable filter. According to an embodiment, the second filter **1503** may be implemented by combining one or more finite impulse response/infinite impulse response (fir/iir) filters having a target frequency response. For example, filter coefficients may be calculated by performing inverse fast Fourier transform (IFFT) in the target frequency response. For example, filter coefficients may be implemented by combining a plurality of biquad filters.
[0197] According to an embodiment, external sound acquired through the external microphone **340** may be compensated through the first filter **1501** and the second filter **1503** to be output through the speaker **350**.
[0198] With reference again to FIG. **15**, the passive feature estimation block **1505**, the target frequency response identification block **1507**, and the target frequency response correction block **1510** may be implemented to operate as functional modules of the processor **320**. The learning model for the reference frequency response **1508** and/or the target frequency response correction may be stored in the memory **330**.
[0199] According to various embodiments, an electronic device (e.g., the electronic device **101** of FIG. **1**, the electronic device **300**, **500**, **1100**, **1200**, **1300**, or **1500** of FIG. **3**, **5**, **11**, **12**, **13**, or **15**) may include a speaker (e.g., the speaker **350** of FIG. **3**), an external microphone (e.g., the external microphone **340** of FIG. **3**), an internal microphone (e.g., the internal microphone **360** of FIG. **3**), a first filter (e.g., the first filter **501**, **1101**, **1201**, **1301**, or **1501** of FIG. **5**, **11**, **12**, **13**, or **15**), a second filter (e.g., the second filter **503**, **1103**, **1203**, **1303**, **1503** of FIG. **5**, **11**, **12**, **13**, or **15**), a processor (e.g., the processor **120** or **320** of FIG. **1** or **3**) operatively connected to the speaker, the external

microphone and the internal microphone, wherein the processor may be configured to control to estimate a passive feature based on a signal acquired through the external microphone and a signal acquired through the internal microphone, to identify a target frequency response for the estimated passive feature based on a reference passive feature, to implement the second filter based on the identified target frequency response, and to sequentially filter a signal input through the external microphone through the first filter and the second filter to output the signal through the speaker.

[0200] According to various embodiments, the processor may be configured to estimate the passive feature in the case that no signal is output through the speaker and that the user wearing the electronic device does not speak.

[0201] According to various embodiments, the processor may be configured to estimate the passive feature based on a normalized least mean squares (NLMS) algorithm.

[0202] According to various embodiments, the first filter may be implemented by a simulation in a non-wearing state of the electronic device, and the second filter may be implemented based on the identified frequency response by estimating the passive feature in a wearing state of the electronic device.

[0203] According to various embodiments, the second filter may be configured by combining one or more finite impulse response or infinite impulse response (fir or iir) filters having the target frequency response.

[0204] According to various embodiments, the processor may be configured to learn by updating a constitution of the second filter based on various signals output from an external electronic device.

[0205] According to various embodiments, the electronic device may further include a memory storing the reference passive feature, wherein the reference passive feature may be estimated based on a simulation to be stored in the memory.

[0206] According to various embodiments, the memory may store a learning model for additionally correcting a high frequency component of the target frequency response by estimating a high frequency component of the passive feature based on a magnitude of a low frequency component of the passive feature estimated through a simulation, and the processor may be configured to correct the target frequency response based on the learning model.

[0207] According to various embodiments, the memory may store a learning model learned so that a frequency response changing through an external auditory canal is derived until a signal input through the external microphone reaches an eardrum location through a simulation, and the processor may be configured to correct the target frequency response based on the learning model.

[0208] According to various embodiments, the electronic device may further include a first acoustic echo canceller (AEC) connected to the external microphone and a second AEC connected to the internal microphone, wherein the processor may control the first AEC and the second AEC to remove noise input according to a signal output through the speaker or a speech of a user wearing the electronic device.

[0209] According to various embodiments, a method of operating an electronic device (e.g., the electronic device **101** of FIG. **1**, the electronic device **300**, **500**, **1100**, **1200** or **1300** of FIG. **3**, **5**, **11**, **12**, or **13**) may include estimating a passive feature based on a signal acquired through an external microphone (e.g., the external microphone **340** of FIG. **3**) of the electronic device and a signal acquired through an internal microphone of the electronic device; identifying a target frequency response for the estimated passive feature based on a reference passive feature; and filtering a signal input through the external microphone through a first filter (e.g., the first filter **501**, **1101**, **1201** or **1301** of FIG. **5**, **11**, **12**, or **13**) and additionally filtering the signal through a second filter (e.g., the second filter **503**, **1103**, **1203**, or **1303** of FIG. **5**, **11**, **12**, or **13**) implemented based on the identified target frequency response and outputting the signal through a speaker of the electronic device.

[0210] According to various embodiments, the passive feature estimation operation may be performed in the case that no signal is output through the speaker and that a user wearing the

electronic device does not speak.
[0211] According to various embodiments, the passive feature may be estimated based on a normalized least mean squares (NLMS) algorithm.
[0212] According to various embodiments, the first filter may be designed by a simulation in a non-wearing state of the electronic device, and the second filter may be implemented according to the target frequency response identified by estimating the passive feature in a wearing state of the electronic device.
[0213] According to various embodiments, the second filter may be configured by combining one or more finite impulse response or infinite impulse response (fir or iir) filters having the target frequency response.
[0214] According to various embodiments, the method may further learning by updating a constitution of the second filter based on various signals output from an external electronic device.
[0215] According to various embodiments, the reference passive feature may be estimated based on a simulation and stored in advance.
[0216] According to various embodiments, the method may further include correcting a high frequency component of the target frequency response based on a pre-stored learning model that estimates a high frequency component of a passive feature based on the magnitude of a low frequency component of the passive feature estimated through a simulation.
[0217] According to various embodiments, the method may further include correcting the target frequency response based on a pre-stored learning model learned so that a frequency response changing through an external auditory canal is derived until a signal input through the external microphone reaches an eardrum location through a simulation.
[0218] According to various embodiments, the passive feature estimation operation may estimate the passive feature based on filter data applied to remove noise of the internal microphone in the electronic device.
[0219] It should be understood that various embodiments of this document and terms used therein are not intended to limit the technical features described in this document to specific embodiments, but include various modifications, equivalents, or substitutions of the embodiments.
[0220] In connection with the description of the drawings, like reference numerals may be used for similar or related components. The singular form of the noun corresponding to the item may include one or more of the item, unless the relevant context clearly dictates otherwise.
[0221] In this document, each of phrases such as “A or B”, “at least one of A and B”, “at least one of A or B”, “A, B, or C”, “at least one of A, B, and C”, and “at least one of A, B, or C” may include any one of or all possible combinations of items listed together in the corresponding one of the phrases. Terms such as “first” or “second” may be simply used for distinguishing a corresponding component from other corresponding components, and do not limit the corresponding components in other aspects (e.g., importance or order). In the case that one (e.g., first) component is referred to as “coupled” or “connected” to another (e.g., second) component, with or without the terms “functionally” or “communicatively”, it means that the one component may be connected to the other component directly (e.g., by wire), wirelessly, or through a third component.
[0222] The embodiments disclosed in this document disclosed in this specification and drawings only present a specific example in order to easily describe the technical contents according to an embodiment disclosed in this document and to help an understanding of the embodiments disclosed in this document, and they do not intend to limit the scope of the embodiments disclosed in this document. Accordingly, all changes or modifications derived from the technical idea of various embodiments disclosed in this document in addition to the embodiments disclosed herein should be interpreted as being included in the scope of various embodiments disclosed in this document.

Claims

1. An electronic device comprising: at least one speaker; an external microphone; an internal microphone; a first filter; a second filter; and at least one processor operatively connected to the at least one speaker, the external microphone, and the internal microphone, wherein the at least one processor is configured to: estimate a passive feature based on a first signal acquired through the external microphone and a second signal acquired through the internal microphone, identify a target frequency response for the passive feature based on a reference passive feature, and filter a third signal acquired through the external microphone through the first filter and the second filter sequentially and output the filtered third signal through the at least one speaker, wherein the second filter is based on the target frequency response.
2. The electronic device of claim 1, wherein the at least one processor is further configured to, based on no signal being output through the at least one speaker and a user wearing the electronic device not speaking, estimate the passive feature based on the first signal and the second signal.
3. The electronic device of claim 1, wherein the at least one processor is further configured to estimate the passive feature based on a normalized least mean squares (NLMS) algorithm.
4. The electronic device of claim 1, wherein the first filter is based on a simulation in a non-wearing state of the electronic device, and wherein the second filter is based on the target frequency response identified by estimating the passive feature in a state of wearing the electronic device.
5. The electronic device of claim 4, wherein the second filter is based on a combination of one or more finite impulse response or infinite impulse response filters having the target frequency response.
6. The electronic device of claim 4, wherein the at least one processor is further configured to update a constitution of the second filter based on various signals output from an external electronic device.
7. The electronic device of claim 1, further comprising a memory configured to store the reference passive feature, wherein the reference passive feature is estimated based on a reference passive feature simulation, and the reference passive feature is stored in the memory.
8. The electronic device of claim 7, wherein the memory is further configured to store a learning model for correcting a high frequency component of the target frequency response by estimating a high frequency component of the passive feature based on a magnitude of a low frequency component of the passive feature estimated through a passive feature simulation, and wherein the at least one processor is further configured to correct the target frequency response based on the learning model.
9. The electronic device of claim 7, wherein the memory is further configured to store a learning model learned to derive a frequency response changing through an external auditory canal until a signal input through the external microphone reaches an eardrum location through a simulation, and wherein the at least one processor is further configured to correct the target frequency response based on the learning model.
10. The electronic device of claim 1, further comprising: a first acoustic echo canceller (AEC) operatively connected to the external microphone; and a second AEC operatively connected to the internal microphone, wherein the at least one processor is further configured to control the first AEC and the second AEC to remove noise input based on a signal output through the at least one speaker or a speech of a user wearing the electronic device.
11. A method of operating an electronic device, the method comprising: estimating a passive feature based on a first signal acquired through an external microphone of the electronic device and a second signal acquired through an internal microphone of the electronic device; identifying a target frequency response for the passive feature based on a reference passive feature; filtering a third signal acquired through the external microphone through a first filter and a second filter sequentially, wherein the second filter is based on the identified target frequency response; and

outputting the filtered third signal through at least one speaker of the electronic device.
12. The method of claim 11, wherein the estimating the passive feature comprises, based on no signal being output through the at least one speaker and based on a user wearing the electronic device not speaking, estimating the passive feature based on the first signal and the second signal.
13. The method of claim 11, wherein the first filter is based on a simulation in a non-wearing state of the electronic device, and wherein the second filter is based on the target frequency response identified by estimating the passive feature in a state of wearing the electronic device.
14. The method of claim 13, wherein the second filter is based on a combination of one or more finite impulse response or infinite impulse response filters having the target frequency response.
15. The method of claim 13, further comprising updating a constitution of the second filter based on various signals output from an external electronic device.