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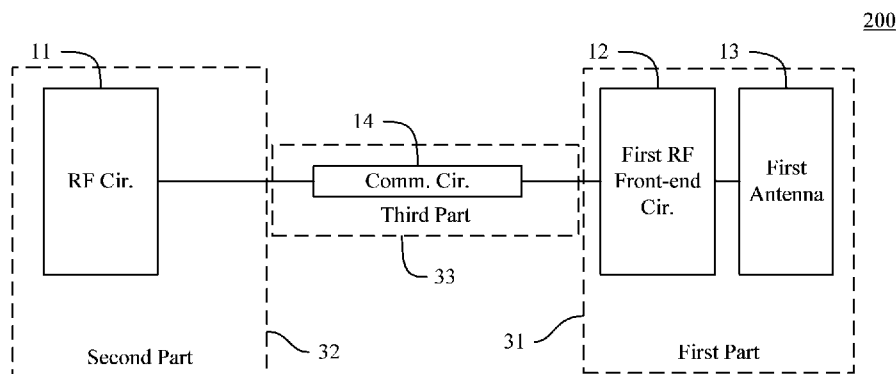


Figure 2b

(57) Abstract: A wireless electronic device, a method for transmitting wireless signals, and a method for receiving wireless signals. The wireless electronic device comprises: RF circuitry configured to transmit/receive first electronic signals to/from an first antenna, via first RF front-end circuitry and communication circuitry; the first RF front-end circuitry configured to amplify the first electronic signals; the first antenna electrically connected to first RF front-end circuitry and configured to implement conversion between the first electronic signals and first wireless signals; and the communication circuitry electrically connected between the RF circuitry and the first RF front-end circuitry. An insertion loss of the first electronic signals on the communication circuitry is larger than an insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry, when the first electronic signals are transmitted between the first antenna and the RF circuitry.



WIRELESS ELECTRONIC DEVICE HAVING RF FRONT-END CIRCUITRY

TECHNICAL FIELD

[0001] The present application relates to the technical field of wireless communications, and in particular, to a wireless electronic device having radio-frequency front-end circuitry, a method for transmitting wireless signals, and a method for receiving wireless signals.

BACKGROUND

[0002] Recent decades have witnessed prosperity of electronic wearable devices. Being designed properly, these devices are generally not handheld during usage, but are "worn" as accessories or even apparel on body parts of a user, i.e., a wearer. Hence, it is quite convenient for the wearer to interact with the outside world simultaneously in various manners. For example, the virtual reality (VR) or augmented reality (AR) technology may apply electronic headwear to provide visual and/or acoustic information, while the wearer is able to operate a keyboard or a gamepad by hand. For another example, an electronic wristband may collect electro-cardio signals of the wearer, while not interrupting daily activities of the wearer. For another example, electronic eyeglasses may prompt the wearer with detailed content of instant messages, even when both bands of the wearer are occupied. Since visual signals and acoustic signals are most common among all kinds of information received by human beings, many electronic wearable devices are head-mounted to facilitate interaction with the eyes, the ears, and the vocal organs of the wearers, or to provide a vivid imitation on wearers' real perception.

[0003] Rapid development of the batteries and the integrated circuits renders electronic wearable devices smaller sizes and more compact structures, which aims at merging them into each application scenario in people's daily life. Therefore, an increasing requirement on convenient "anytime and anywhere" accesses to the Internet and WLANs demands the electronic wearable devices wireless and portable. A prospect is that the electronic wearable devices are capable to provide high-quality wireless accesses within limited power budget and limited space budget, that is, not increasing power consumption significantly and not becoming an inconvenient burden of an ordinary wearer. Such objective raises great challenges on a proper and fine layout of components inside the electronic wearable devices, especially the head-mounted devices.

SUMMARY

[0004] In view of the above, following technical solutions are provided according to

embodiments of the present disclosure, in order to address at least an issue of limited power budget and limited space budget for wireless communication components in a wireless electronic device.

[0005] In an aspect, a wireless electronic device is provided according to embodiments of the present disclosure. The wireless electronic device comprises: radio-frequency (RF) circuitry; first RF front-end circuitry; a first antenna, electrically connected to first RF front-end circuitry, where the first antenna is configured to implement conversion between first electronic signals and first wireless signals; and communication circuitry, comprising one or more communication lines, where the RF circuitry is electrically connected to the first RF front-end circuitry via the communication circuitry; where the RF circuitry is configured to transmit the first electronic signals to the first antenna, or receive the first electronic signals from the first antenna, via the first RF front-end circuitry and the communication circuitry; where the first RF front-end circuitry is configured to amplify the first electronic signals; and where an insertion loss of the first electronic signals on the communication circuitry is larger than an insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry, when the first electronic signals are transmitted between the first antenna and the RF circuitry.

[0006] In one embodiment, the RF circuitry comprises: a first transmitting terminal, configured to transmit the first electronic signals from the RF circuitry to the RF front-end circuitry via the communication circuitry; and a first receiving terminal, configured to receive the first electronic signals transmitted from the first RF front-end circuitry via the communication circuitry.

[0007] In one embodiment, the wireless electronic device further comprises one or both of: a pre-amplifier, configured to amplify the first electronic signals transmitted from the RF circuitry to the communication circuitry; and a post-amplifier, configured to amplify the first electronic signals transmitted from the communication circuitry to the RF circuitry; where the first transmitting terminal is electrically connected to the communication circuitry via the pre-amplifier, and the first receiving terminal is electrically connected to the communication circuitry via the post low noise amplifier.

[0008] In one embodiment, the first RF front-end circuitry comprises: a first duplexer or a first switch, comprising: a first terminal and a second terminal which are electrically connected to the communication circuitry, and a third terminal electrically connected to the first antenna, where the first terminal is configured to receive the first electronic signals transmitted from the RF circuitry to the first RF front-end circuitry, and the second terminal is configured to transmit the first electronic signals from the first RF front-end circuitry to the RF circuitry, and where the first duplexer is configured to couple the first electronic signals

from the first terminal to the third terminal and couple the first electronic signals from the third terminal to the second terminal, and the first switch is configured to couple either the first terminal or the second terminal to the third terminal; and one or both of a first power amplifier and a first low noise amplifier, where: the first power amplifier is electrically connected between the communication circuitry and the first terminal, wherein the first power amplifier is configured to amplify the first electronic signals transmitted from the RF circuitry to the first antenna; and the first low noise amplifier is electrically connected between the communication circuitry and the second terminal, wherein the first power amplifier is configured to amplify the first electronic signals transmitted from the first antenna to the RF circuitry.

[0009] In one embodiment, the wireless electronic device further comprises second RF front-end circuitry, electrically connected to the first antenna, where: the RF circuitry is electrically connected to the second RF front-end circuitry via the communication circuitry; the first antenna is further configured to implement conversion between second electronic signals and second wireless signals, and a frequency of the second wireless signals is different from a frequency of the first wireless signals; the RF circuitry is further configured to transmit the second electronic signals to the first antenna, or receive the second electronic signals from the first antenna, via the second RF front-end circuitry and the communication circuitry; and the second RF front-end circuitry is configured to amplify the second electronic signals.

[0010] In one embodiment, an insertion loss of the second electronic signals on the communication circuitry is larger than an insertion loss of the second electronic signals between the first antenna and the second RF front-end circuitry, when the second electronic signals is transmitted between the first antenna and the RF circuitry.

[0011] In one embodiment, the wireless electronic device further comprises one or both of a first diplexer and a second diplexer, where both the first RF front-end circuitry and the second RF front-end circuitry are electrically connected to the first antenna via the first diplexer, and both the first RF front-end circuitry and the second RF front-end circuitry are electrically connected to the communication circuitry via the second diplexer.

[0012] In one embodiment, the RF circuitry comprises: a second transmitting terminal, configured to transmit the second electronic signals from the RF circuitry to the second RF front-end circuitry via the communication circuitry; and a second receiving terminal, configured to receive the second electronic signals transmitted from the second RF front-end circuitry via the communication circuitry.

[0013] In one embodiment, the second RF front-end circuitry comprises: a second diplexer or a second switch, comprising: a fourth terminal and a fifth terminal which are electrically connected to the communication circuitry, and a sixth terminal electrically connected to the

second antenna, where the fourth terminal is configured to receive the second electronic signals transmitted from the RF circuitry to the second RF front-end circuitry, and the fifth terminal is configured to transmit the second electronic signals from the second RF front-end circuitry to the RF circuitry, and where the second duplexer is configured to couple the second electronic signals from the fourth terminal to the sixth terminal and couple the second electronic signals from the sixth terminal to the fifth terminal, and the second switch is configured to couple either the fourth terminal or the fifth terminal to the third terminal; and one or both of a second power amplifier and a second low noise amplifier, where: the second power amplifier is electrically connected between the communication circuitry and the fourth terminal, wherein the second power amplifier is configured to amplify the second electronic signals transmitted from the RF circuitry to the first antenna; and the second low noise amplifier is electrically connected between the communication circuitry and the fifth terminal, wherein the second low noise amplifier is configured to amplify the second electronic signals transmitted from the first antenna to the RF circuitry.

[0014] In one embodiment, the communication circuitry further comprises first switch circuitry and second switch circuitry, where: the RF circuitry is electrically connected to a communication line of the one or more communication lines via the first switch circuitry, and the first RF front-end circuitry and the second RF front-end circuitry is electrically connected to the communication line via the second switch circuitry; the first switch circuitry and the second switch circuitry are configured to select one of candidate pairs and establish electrical connection between the selected candidate pair, or duplex communication among at least two of the candidate pairs via the communication line, and the candidate pairs comprise at least two of: the first transmitting terminal and the first power amplifier, the first receiving terminal and the first low noise amplifier, the second transmitting terminal and the second power amplifier, and the second receiving terminal and the second low noise amplifier.

[0015] In one embodiment, the one or more communication lines comprise at least one of: a first communication line, configured to connect the first power amplifier electrically to the first transmitting terminal; and a second communication line, configured to connect the first low noise amplifier electrically to the first receiving terminal; a third communication line, configured to connect the second power amplifier electrically to the second transmitting terminal; and a fourth communication line, configured to connect the second low noise amplifier electrically to the second receiving terminal.

[0016] In one embodiment, the wireless electronic device further comprises: third RF front-end circuitry, electrically connected to the RF circuitry; and a second antenna, electrically connected to third RF front-end circuitry, where the second antenna is configured to implement conversion between third electronic signals and third wireless signals; where the RF circuitry is configured to transmit the third electronic signals to the second antenna, or

receive the third electronic signals from the second antenna, via the third RF front-end circuitry.

[0017] In one embodiment, a frequency of the third wireless signals is different from a frequency of the first wireless signals.

5 **[0018]** In one embodiment, the third RF front-end circuitry is electrically connected to the RF circuitry not via the communication circuitry.

[0019] In one embodiment, the wireless electronic device further comprises a controller, configured to: control the RF front-end circuitry, and control the first RF front-end circuitry via control signals.

10 **[0020]** In one embodiment, the wireless electronic device further comprises: an auxiliary controller, electrically connected to the controller and the first RF front-end circuitry, where the auxiliary controller is configured to: receive a channel of control signals from the controller, convert the received channel of the control signals into multiple channels of control signals, and control the first RF front-end circuitry based on the multiple channels of control
15 signals.

[0021] In one embodiment, a communication line among the one or more communication lines is configured to transmit both the first electronic signals and the control signals.

[0022] In one embodiment, the wireless electronic device further comprises one or both of first filter circuitry and second filter circuitry, where: the communication line is electrically
20 connected to the RF circuitry and the controller via the first filter circuitry, and is electrically connected to a communication terminal and a control terminal of the first RF front-end circuitry via the second filter circuitry; the communication terminal is configured to transmit the first electronic signals to the RF circuitry or receive the first electronic signals from the RF circuitry, and the control terminal is configured to receive the control signals from the
25 controller; the first filter circuitry is configured to reduce interference of the first electronic signals on the controller and reduce interference of the control signals on the RF circuitry; and the second filter circuitry is configured to reduce interference of the first electronic signals on the control terminal and reduce interference of the control signals on the receiving terminal.

[0023] In one embodiment, the wireless electronic device further comprises housing, where
30 at least a part of the housing is formed by: a first part, configured to accommodate the first antenna and the first RF front-end circuitry; a second part, configured to accommodate the RF circuitry; and a third part, configured to accommodate the communication circuitry, where the third part is located between the first part and the third part.

[0024] In one embodiment, neither the first part nor the second part is spatially sufficient
35 for accommodating the RF circuitry, the first RF front-end circuitry, and the first antenna; and

the third part is not spatially sufficient for accommodating either the RF circuitry or the RF front-end circuitry.

[0025] In one embodiment, the second part of the housing is further configured to accommodate the second antenna.

5 **[0026]** In one embodiment, the third RF front-end circuitry comprises: a third duplexer or a third switch, where: the third duplexer is configured to couple the third electronic signals transmitted from the RF circuitry electrically to the second antenna and couple the third electronic signals transmitted from the second antenna electrically to the RF circuitry, and the third switch is configured to couple either a terminal for transmitting the third electronic
10 signals or a terminal for receiving the third electronic signals, of the RF circuitry, to the second antenna.

[0027] In one embodiment, the first part of the housing is further configured to accommodate the second RF front-end circuitry.

[0028] In one embodiment, the second part of the housing is further configured to
15 accommodate the auxiliary controller.

[0029] In one embodiment, the wireless electronic device is a wearable device, and the first part and the second part are configured to be located at two sides of a body part of a user when the user wears the wireless electronic device.

[0030] In one embodiment, the wireless electronic device is electronic eyeglasses, where:
20 the first part comprises at least a part of a temple bar of the electronic eyeglasses, the second part comprises at least a part of another temple bar of the electronic eyeglasses, and the third part comprises at least a part of a bridge and at least a part of a lens frame of the electronic eyeglasses.

[0031] In one embodiment, the wireless electronic device is a headset, where: the first part
25 or the second part comprises at least a part of a speaker cup of the headset, and the third part comprises at least a part of a headband of the headset.

[0032] In another aspect, a method for transmitting wireless signals is provided according to embodiments of the present disclosure. The method is applicable to an electronic device comprising: RF circuitry, first RF front-end circuitry, a first antenna electrically connected to
30 first RF front-end circuitry, and communication circuitry electrically connected between the RF circuitry and the first RF front-end circuitry, and comprises: transmitting, by the RF circuitry, first electronic signals to the first RF front-end circuitry via the communication circuitry; amplifying, by the first RF front-end circuitry, the first electronic signals transmitted from the RF circuitry; transmitting, by the first RF front-end circuitry, the amplified first
35 electronic signals to the first antenna; and converting, by the first antenna, the amplified first

electronic signals transmitted from the first RF front-end circuitry into first wireless signals; where an insertion loss of the first electronic signals on the communication circuitry is larger than an insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry.

5 [0033] In another aspect, a method for receiving wireless signals is provided according to embodiments of the present disclosure. The method is applicable to an electronic device comprising: RF circuitry, first RF front-end circuitry, a first antenna electrically connected to first RF front-end circuitry, and communication circuitry electrically connected between the RF circuitry and the first RF front-end circuitry, and comprises: converting, by the first
10 antenna, first wireless signals into first electronic signals; transmitting, by the first antenna, the first electronic signals to the first RF front-end circuitry; amplifying, by the first RF front-end circuitry, the first electronic signals transmitted from the first antenna; and transmitting, by the first RF front-end circuitry, the amplified first electronic signals to the RF circuitry via the communication circuitry; where an insertion loss of the first electronic
15 signals on the communication circuitry is larger than an insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry

[0034] Therefore, the wireless electronic devices are provided according to embodiments of the present disclosure. The wireless electronic device comprises the RF circuitry, the first RF front-end circuitry, the first antenna electronically connected to the first RF front-end
20 circuitry, and communication circuitry comprising one or more communication lines. The first antenna is configured to implement conversion between the first electronic signals and the first wireless signals. The RF circuitry is electrically connected to the first RF front-end circuitry via the communication circuitry. The RF circuitry is configured to transmit the first electronic signals to the first antenna, or receive the first electronic signals from the first
25 antenna, via the first RF front-end circuitry and the communication circuitry. The first RF front-end circuitry is configured to amplify the first electronic signals. The insertion loss of the first electronic signals on the communication circuitry is larger than the insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry, when the first electronic signals are transmitted between the first antenna and the RF circuitry.
30 During the transmission process in which a strength of the transmitted first electronic signals is of more interest, the first electronic signals has passed the communication circuitry having the larger insertion when being amplified, and hence an output power of the RF front-end circuitry need not be increased too much, which reduces the power consumption of the amplification of the first electronic signals. During the receiving process in which a quality
35 of the to-be-recognized first electronic signals is of more interest, the first electronic signals has been amplified before being transmitted via the communication circuitry, and hence a total noise figure of the whole receiving path is lowered, which improves the signal-to-noise

ratio at the RF circuitry. Therefore, the wireless electronic device is capable to transmit electronic signals with less power consumption and is more robust to noises in the received electronic signals when compared with its counterparts in conventional technology.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0035] For clearer illustration of the technical solutions according to embodiments of the present disclosure or conventional techniques, hereinafter briefly described are the drawings to be applied in embodiments of the present disclosure or conventional techniques. Apparently, the drawings in the following descriptions are only some embodiments of the present disclosure, and other drawings may be obtained by those skilled in the art based on the provided drawings without creative efforts.

[0036] Figure 1 is a schematic structural diagram of a wireless electronic device having limited space budget in conventional technology.

[0037] Figure 2a is a schematic structural diagram with signal flows of a wireless electronic device according to an embodiment of the present disclosure.

[0038] Figure 2b is a schematic structural diagram of a wireless electronic device having limited space budget according to an embodiment of the present disclosure.

[0039] Figure 3 is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure.

[0040] Figures 4a and 4b are schematic structural diagrams of a first radio-frequency (RF) front-end circuitry according to embodiments of the present disclosure.

[0041] Figure 5a is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure.

[0042] Figure 5b is a schematic structural diagram of a wireless electronic device having limited space budget according to another embodiment of the present disclosure.

[0043] Figure 6 is a schematic structural diagram with signal flows of a part of a wireless electronic device according to an embodiment of the present disclosure.

[0044] Figure 7 is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure.

[0045] Figures 8a and 8b are schematic structural diagrams of a second RF front-end circuitry according to embodiments of the present disclosure.

[0046] Figures 9a to 9c are schematic structural diagrams of communication circuitry according to embodiments of the present disclosure.

[0047] Figure 10a is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure.

[0048] Figure 10b is a schematic structural diagram of a wireless electronic device having limited space budget according to another embodiment of the present disclosure.

5 [0049] Figure 11a is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure.

[0050] Figure 11b is a schematic structural diagram of a wireless electronic device having limited space budget according to another embodiment of the present disclosure.

10 [0051] Figure 12a is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure.

[0052] Figure 12b is a schematic structural diagram of a wireless electronic device having limited space budget according to another embodiment of the present disclosure.

[0053] Figure 13 is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure.

15 [0054] Figure 14 is a schematic structural diagram with signal flows of a part of a wireless electronic device according to another embodiment of the present disclosure.

[0055] Figure 15 is a schematic structural diagram of housing of a wireless electronic device according to an embodiment of the present disclosure.

20 DETAILED DESCRIPTION OF THE EMBODIMENTS

[0056] Hereinafter technical solutions in embodiments of the present disclosure are described clearly and completely in conjunction with the drawings in embodiments of the present disclosure. Apparently, the described embodiments are only some rather than all of the embodiments of the present disclosure. Any other embodiments obtained based on the
25 embodiments of the present disclosure by those skilled in the art without any creative effort fall within the scope of protection of the present disclosure.

[0057] The relationship terms such as "first", "second" and the like are only used herein to distinguish one entity or operation from another, rather than to necessitate or imply that an actual relationship or order exists between the entities or operations. Furthermore, the terms
30 such as "include", "comprise" or any other variants thereof means to be non-exclusive. Therefore, a process, a method, an article or a device including a series of elements include not only the disclosed elements but also other elements that are not clearly enumerated, or further include inherent elements of the process, the method, the article or the device. Unless expressively limited, the statement "including a..." does not exclude the case that other

similar elements may exist in the process, the method, the article or the device other than enumerated elements.

[0058] As described in the above background, the development of the wireless electronic devices demands achieving same or even better performances within limited power budget or limited space budget. As an example, a wearable wireless electronic device, such as a headset, electronic glasses, an electronic wrist band, a head-mounted display, should be as compact as possible such that the wearer would not feel it as a burden in daily usage. As another example, the wearable wireless electronic device should consume power as slow as possible such that the wearer need not take it off frequently for charging. At the same time, more and more components such as antenna, sensors, circuitry, display panels, speakers, and microphones are crammed into housing to enrich the functions of wearable wireless electronic devices. For examples, nowadays many wireless electronic devices have two or more antennas such that more frequency bands can be utilized and/or more directions can be covered for wireless communications. Generally, the two or more antennas are coupled to the same radio-frequency (RF) circuitry to save space in housing of the wireless electronic devices. Herein the RF circuitry refer to circuitry configured to transmit generated electronic signals or process received electronic signals, for example, may be a transmitter, a receiver, or a transceiver.

[0059] Placing the antenna in proximity of the RF circuitry would reduce a signal loss therebetween, and thereby is beneficial for improving signal quality at the RF circuitry (when receiving) and reducing power consumption (when transmitting). Nevertheless, it is preferable that not all the antennas are placed in proximity of the RF circuitry. In one aspect, the adjacency among the antennas would be hazardous because interference between the different frequency bands is significantly increased. In another aspect, the adjacency means that the antennas are distributed in the same region inside the device, and hence the coverage of the antennas would be far from ideal. In some cases, the larger the distance among the antennas is, the better the performances of the wireless electronic device are. Thus, in practice, at least one antenna is preferably disposed far from the RF circuitry in the housing. Generally, the communications between the RF circuitry and a "far-away" antenna is linked via a communication line, such as a cable, a wire, or wiring on a circuitry board. The larger the distance between the RF circuitry and such antenna is, the larger a length of the communication need to be, and thereby the larger an insertion loss may be introduced between the RF circuitry and the antenna. In order to compensate the insertion loss and thereby maintain a quality of the communication between the RF circuitry and the antenna, RF front-end circuitry such as a RF front-end module (FEM) may be provided to amplify signals transmitted between the RF circuitry and the antenna.

[0060] The miniaturization of electronic devices usually renders a space budget for the

communication function rather limited. For example, some spaces in housing of the wireless electronic device, which are reserved for the components for wireless communication may only allow a wire to run through and may be too narrow to accommodate a circuitry board. Therefore, locations of each component for wireless communication should be wisely
5 designed. In most cases, the RF circuitry and the RF front-end circuitry are integrated on a same circuitry board to save spaces, and the communication line extending from such circuit board to the antenna may run through narrow spaces.

[0061] Reference is made to Figure 1, which is a schematic structural diagram of a wireless electronic device 10 having limited space budget in conventional technology. The wireless
10 electronic device 10 comprises a first circuit board 4 carrying circuitry 1, which comprises a transceiver and a RF front-end module, and a second circuitry board 5 carrying an antenna 2. The first circuit board 4 and the second circuit board 5 are accommodated in two parts of housing of the wireless device 10, and a space defined by the housing between the two part forms a narrow "bottleneck" 6 which allows a wire 3 connecting the circuitry 1 and the
15 antenna 2 to run through. During a transmission process, electronic signals are generated by the transceiver, amplified by the RF FEM, then transmitted to the antenna 2 via the wire 3, and converted into wireless signals at the antenna 2. During a receiving process, wireless signals are converted into electronic signals at the antenna 2, and the electronic signals are transmitted to the RF FEM via the wire 3, amplified by the RF FEM, and then processed (e.g.,
20 demodulated) at the transceiver. For conciseness, herein the electronic signals refer to RF electronic signals which are embodied as, for example, oscillating current flowing in circuitry, and the wireless signals refer to RF wireless signals which are embodied as, for example, electronic magnetic waves.

[0062] Generally, an insertion loss of the electronic signals on the wire 3 is greater than that
25 between the transceiver and the RF FEM, because an internal connection such as wiring on the first circuit board introduces negligible impedance in comparison with the wire 3. The architecture as shown in Figure 1 adopts an "amplification before wire loss" scheme in transmission and a "wire loss before amplification" scheme in reception. The inventor has recognized and appreciated that such architecture is deficient in at least following aspects.
30 First, the RF FEM should raise the electronic signals to high power in transmission, in order to pre-compensate a large insertion loss on the wire 3, and thus would cause large power consumption at the RF FEM. Second, in reception, the signal-to-noise ratio (SNR) of the electronic signals has been degraded on the wire 3 before the electronic signals being amplified at the FEM, and thus would result in low signal quality at the transceiver.

[0063] The inventor has recognized and appreciated that moving the RF FEM from the
35 transceiver side to the antenna side is capable to overcome the above deficiencies. On a basis of at least the above considerations, a wireless electronic device is provided according to

embodiments of the present disclosure. Reference is made to Figure 2a, which is a schematic structural diagram with signal flows of a wireless electronic device 200 according to an embodiment of the present disclosure.

[0064] As shown in Figure 2a, the wireless electronic device comprises RF circuitry 11, first front-end circuitry 12, a first antenna 13, and communication circuitry 14. The first antenna 13 is electrically connected to the first front-end circuitry 12, and is configured to implement conversion between first electronic signals and first wireless signals. The communication circuitry 14 comprises one or more communication lines 141 (not depicted), and the RF circuitry 11 is electrically connected to the first RF front-end circuitry 14 via the communication circuitry 14. The RF circuitry 11 is configured to transmit the first electronic signals to the first antenna 13 via the first RF front-end circuitry 12 and the communication circuitry 14, and/or receive the first electronic signals from the first antenna 13 via the communication circuitry 14 and the first RF front-end circuitry 12. The first RF front-end circuitry 12 is configured to amplify the first electronic signals. An insertion loss of the first electronic signals on the communication circuitry 14 is larger than an insertion loss of the first electronic signals between the first antenna 13 and the first RF front-end circuitry 12, when the first electronic signals are transmitted between the first antenna 13 and the RF circuitry 11.

[0065] The RF circuitry 11 may be transmitter circuitry, receiver circuitry, or a combination of the both (i.e., the transceiver circuitry). When serving as the transmitter circuitry, the RF circuitry 11 may be capable to generate the first electronic signals that are transmitted to the first antenna 13, or may be electrically connected to an RF source generating the first electronic signals and capable to modulate data into the first electronic signals received from the RF source. Alternatively or additionally, when serving as the receiver circuitry, the RF circuitry 11 may be capable to demodulate data from the first electronic signals received from the first antenna 13 itself, or may be capable to forward the first electronic signals received from the first antenna 13 to processing circuitry which is capable to demodulate data from the first electronic signals. The RF circuitry 11 herein is not limited to any specific case.

[0066] The first RF front-end circuitry 12 may be an amplifier, for example, comprising at least one of a power amplifier, an operational amplifier, or a low-noise amplifier. Generally, the amplification at the first RF front-end circuitry 12 is bi-directional, that is, both the first electronic signals transmitting from the RF circuitry 11 to the first antenna 13 and those transmitting from the first antenna 13 to the RF circuitry 11 would be amplified. In some embodiments, the amplification may be unidirectional, that is, only the first electronic signals transmitting from the RF circuitry 11 to the first antenna 13 or only those transmitting from the first antenna 13 to the RF circuitry 11 is amplified to the first RF front-end circuitry 12. In the latter case, another amplifier may be provided for the direction along which the

transmitted first electronic signals are not amplified at the first RF front-end circuitry 12.

[0067] The first antenna 13 is capable to transmit first wireless signals converted from the first electronic signals. Generally, the electronic signals are carried by oscillating currents or oscillating voltages, and the wireless signals are carried by electromagnetic waves having a frequency within a frequency band defined in a wireless communication standard. The frequency band and the wireless communication standard are not specifically limited herein, and may be determined according to an actual requirement. For example, the wireless communication standard is Wireless Fidelity (Wi-Fi), and the frequency band ranges from 2.4GHz to 2.48GHz, or from 5.15GHz to 7.15GHz. For another example, the wireless communication standard is Bluetooth®, and the frequency band ranges from 2.4GHz to 2.485GHz. For another example, the wireless communication standard is a wireless communication standard for cellular network, such as the 2G, 3G, 4G or 5G standard. Herein a type and a shape of the first antenna 13 are not specifically limited. For example, the first antenna 13 may be a monopole antenna, a dipole antenna, a loop antenna, a slot antenna, a meander antenna, or the like, and may be provided on a flexible printed circuit, manufactured through laser-direct-structuring, or simply be a piece of electrode. During operation, the first antenna 13 may serve as an independent antenna, that is, may transmit and/or receive the first wireless signals solely. Alternatively, the first antenna 13 may form an independent antenna along with another component, for example, an additional electrode or a body part of a user. In such case, the other component is also capable to transmit and/or receive the first wireless signals when cooperating with the first antenna. The other component may be an internal component or an external component of the wireless electronic device 200, which is not specifically limited herein.

[0068] The communication circuitry 14 may refer to only the one or more communication lines 141, or may further include a circuit board carrying the one or more communication lines 141. Each communication line may be a wire, a cable, or wiring printed on the circuit board, which is not limited herein.

[0069] The insertion loss refers to an amount of energy that a signal loses as it travels along an electrical link. That is, the insertion loss of the first electronic signals on the communication circuitry 14 refers to the amount of energy the first electronic signals lose as they pass the communication circuitry 14, and the insertion loss of the first electronic signals between the first antenna 13 and the first RF front-end circuitry 12 refers to the amount of energy the first electronic signals lose as they travels from the first antenna 13 to the first RF front-end circuitry 12 or inversely. In this embodiment, the first electronic signals flowing in both directions lose more energy due to the communication circuitry 14, i.e., the link between the RF circuitry 11 and the first RF front-end circuitry 12, than due to the link between the first antenna 13 and the first RF front-end circuitry 12.

[0070] In some embodiments, the insertion losses may be controlled by a length of an electrical link in the communication circuitry 14 (e.g., one of the one or more communication lines 141) and a length an electrical link between the first RF front-end circuitry 12 and the first antenna 13 (e.g., a wire, a cable, or wiring printed on the circuit board). The lengths may be substantially determined by a corresponding physical distance. In one embodiment, a distance between the RF circuitry 11 and the RF front-end circuitry 12 is larger than a distance between the first antenna 13 and the RF front-end circuitry 12. It is further appreciated that the insertion loss may not be solely determined by the physical distances. For example, a structure, a material, a shape, or a specific component of the electrical links may also influence the insertion losses.

[0071] Figure 2a further shows the signal flows during wireless transmission and reception. As shown in Figure 2a, during the transmission, the first electronic signals flows from the RF circuitry 11 to the communication circuitry 14, then to the first RF front-end circuitry 12, and finally to the first antenna 13 and is converted into first wireless signals. During the reception, the first wireless signals are converted into first electronic signals at the first antenna 13, and the first electronic signals flows from the first antenna 13 to the first front-end circuitry 12, then to the communication circuitry 14, and then to the RF circuitry 11. Although both the transmission and the reception are depicted in Figure 2a, it is appreciated that the wireless electronic device 200 may performs only the transmission or the reception, may not perform the transmission or the reception at the same time.

[0072] Hereinafter an example is provided for comparing performances of the structures as shown in Figure 1 and Figure 2a. It is assumed that the RF circuitry 11, the first RF front-end circuitry 12, the first antenna 13, and the communication circuitry 14 are same as the transceiver, the RF FEM, the antenna 2, and the wire 3, respectively, as shown in Figure 1. That is, a difference between the two structures may be treated as switching between the positions of the wire 3 and the RF FEM.

[0073] For the transmission path, the first electronic signals generated by the wireless electronic device itself have little noise without external inferences, and should have adequate power to generate first wireless signals which are strong enough to be picked by a target of the wireless communication. Hence, the power consumption is of more interests than the signal-to-noise ratio. It is assumed that the first electronic signals at an output of the transceiver has a power of P_0 dBm, and a net gain at the RF FEM is G dB, and an insertion loss at the wire 3 is L dB. In such case, switching positions of the wire 3 and the RF FEM would not influence a power of the first electronic signals at an input of the antenna, which is equal to $(P_0 + G_1 - L)$ dBm. The difference lies in power of the first electronic signals at the RF FEM: in the structure as shown in Figure 1, the RF FEM raises the power of the first electronic signals from P_0 dBm to $(P_0 + G_1)$ dBm, while in the structure as shown in Figure

2a, the RF FEM raises the power of the first electronic signals from $(P_0 - L)$ dBm to $(P_0 + G_1 - L)$ dBm. Since dBm is a 10-based logarithm unit, the RF FEM as shown in Figure 1 would consume more power to implement the power increase of G dBm. For example, assuming the power efficiency of amplification at the RF FEM is 40%, raising power from 0dBm to 26dBm would consume around 995mW, while raising power from -4dBm to 22dBm would consume 396mW. Hence, the transmission path in the structure as shown in Figure 2a is much friendlier to a limited power budget, especially when a gain of the RF front-end circuitry 12 is high, for example, to compensate a large insertion loss of the communication circuitry 14.

[0074] For the reception path, the received first wireless signals is generally subject to various noises introduced by the channel and external inferences, while a power level required at an input of the transceiver is much lower than that at the antenna for transmission. Hence, the signal-to-noise ratio is of more interests than the power consumption. It is assumed that a noise figure of the transceiver is N_1 dB, a noise figure of the RF FEM is N_2 dB, a gain at the RF FEM is G_2 dB, a loss due to components (which may be located in upstream of the amplifier) in the RF FEM is L' dB, and insertion loss at the wire 3 is still L dB. In such case, a total noise figure from the antenna to the input of the transceiver is equal to $(L' + N_2 + L + \frac{N_2 - 1}{G_2})$ dB in the structure as shown in Figure 1, and is equal to $(L' + N_2 + \frac{N_2 + L - 1}{G_2})$ dB in the structure as shown in Figure 2a. In most cases, G_2 is much greater than 1dB, which ensures that the structure as shown in Figure 2a has a lower total noise figure. That is, the total noise figure is greatly suppressed in comparison with the structure as shown in Figure 1, especially when a gain of the RF front-end circuitry 12 is high, for example, to compensate a large insertion loss of the communication circuitry 14.

[0075] Therefore, no matter in the transmission or the reception, the performances of the structure as shown in Figure 2a is superior that that as shown in Figure 1. During the transmission process in which a strength of the transmitted first electronic signals is of more interest, the first electronic signals has passed the communication circuitry 14 having the larger insertion when being amplified, and an output power of the RF front-end circuitry 12 need not be increased too much, which reduces the power consumption of the amplification of the first electronic signals. During the receiving process in which a quality of the to-be-recognized first electronic signals is of more interest, the first electronic signals has been amplified before being transmitted via the communication circuitry 14, and a total noise figure of the whole receiving path is lowered, which improves the signal-to-noise ratio at the RF circuitry 11. Therefore, the wireless electronic device 200 is capable to transmit the first electronic signals with less power consumption and is more robust to noises in the received first electronic signals when compared with its counterparts in conventional technology.

[0076] The structure as shown in Figure 2a can be applied to an application scenario in

which a space budget for the function of the wireless communication is limited. In comparison with the structure as shown in Figure 1, a difference may lie in that the RF FEM is moved to a side of the antenna 2. Reference is further made to Figure 2b, which is a schematic structural diagram of the wireless electronic device 200 having limited space budget according to an embodiment of the present disclosure. As shown in Figure 2b, the wireless electronic device 200 further comprises housing 30, and at least a part of the housing 30 is formed by a first part 31, a second part 32, and a third part 33. The first part 31 is configured to accommodate the first antenna 13 and the first RF front-end circuitry 12, the second part 32 is configured to accommodate the RF circuitry 11, and the third part 33 is configured to accommodate the communication circuitry 14. The third part 33 is located between the first part 31 and the second part 32. In this embodiment, both the first RF front-end circuitry 12 and the first antenna 13 are disposed at the same part, i.e., the first part 31, which facilitates a small insertion loss between the two. A material and a shape of the first part 31, the second part 32, or the third part 33 is not limited herein, and may vary based on a design and a function of the wireless electronic device 200. The accommodation may refer to that circuitry is located in a space enclosed or surrounded by the corresponding part of the housing 30 encloses a space in which, that the circuitry is at least partially embedded in the corresponding part of the housing 30, or that the circuitry is attached to a surface of the corresponding part of the housing 30. The circuitry may or may not be in direct contact with the corresponding part of the housing 30. For example, the circuitry may be located on a circuit board fixed at such part, mounted on a chassis fixed at such part, or attached to such part via one or more films, membranes, or layers. Although both the first antenna 13 and the first RF front-end circuitry 12 are accommodated by the first part 31, it is appreciated that they may or may not be located on a same circuit board or supported by a same chassis.

[0077] The third part 33 being located between the first part 31 and the second part 32 does not necessarily means being physically connected to the first part 31 and the second part 32. There may be an intermediate part between the third part 33 and either of the first part 31 or the second part 32. Alternatively, the housing 30 may not be integral, and either of the first part 31 or the second part 32 may be physically separated from the third part 33. Moreover, when there is physical connection, such connection may be fixed, flexible, or even detachable. It is appreciated that in some embodiments, the third part 33 may not be located between the first part 31 and the second part 32, as long as it serves as an "electrical connection" between the two. For example, a communication line connecting the RF circuitry 11 and the first RF front-end circuitry 12 may follow a detour in the housing due to a requirement of a function or a design of the wireless electronic device 200.

[0078] In some embodiments, neither the first part 31 nor the second part 32 is spatially sufficient for accommodating the RF circuitry 11, the first RF front-end circuitry 12, and the

first antenna 13, and the third part 33 is not spatially sufficient for accommodating either the RF circuitry or the RF front-end circuitry. That is, the housing 30 is provided in such a manner the RF circuitry 11, the first RF front-end circuitry 12, and the first antenna 13 should be separated into the first part 31 and the second part 32. In such application scenario, disposing the first RF front-end circuitry 12 at the side of the first antenna 13 rather than the RF circuitry 11 would be more crucial, because it is inevitable to introduce a large insertion loss either between the RF circuitry 11 and the first RF front-end circuitry 12 or between the first RF front-end circuitry 12 and the first antenna 13.

[0079] Although each electrical link in Figures 2a and 2b is depicted as a single line, it is appreciated that the electrical link may be implemented via multiple channels. For example, the electrical link between the RF circuitry 11 and the communication circuitry 14 may have at least two channels when the RF circuitry 11 operates as a transceiver. In such case, one channel may be configured to transmit first electronic signals from the RF circuitry 11 to the communication circuitry 14, while another channel is configured to transmit first electronic signals inversely. Reference is made to Figure 3, which is a schematic structural diagram with signal flows of a wireless electronic device 300 according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2a, the RF circuitry 11 as shown in Figure 3 comprises a first transmitting terminal TX and a first receiving terminal RX. The first transmitting terminal TX is configured to transmit the first electronic signals from the RF circuitry 11 to the RF front-end circuitry 12 via the communication circuitry 14, and the second receiving terminal RX is configured to receive the first electronic signals transmitted from the first RF front-end circuitry 12 via the communication circuitry 14. In this embodiment, different terminals TX1 and RX2 are used to establish different channels for the first electronic signals flow in different directions, which is capable to reduce interference between the two directions effectively at the RF circuitry 11. Accordingly, a quality of the wireless communication can be improved.

[0080] The RF front end may be not entirely moved to the side of the antenna due to, for example, difficulties of supply adequate power to such side. In such case, an auxiliary amplifier may be provided between the communication circuitry 14 and the RF circuitry 11, and is configured to amplify the first electronic signals transmitted from the RF circuitry 11 to the communication circuitry 14 and/or amplify the first electronic signals transmitted from the communication circuitry 14 to the RF circuitry 11. As an example, on a basis of the structure as shown in Figure 3, the wireless electronic device 300 further comprises a pre-amplifier and/or a post-amplifier (which are not depicted). The pre-amplifier is configured to amplify the first electronic signals transmitted from the RF circuitry 11 to the communication circuitry 14. The post-amplifier is configured to amplify the first electronic signals transmitted from the communication circuitry 14 to the RF circuitry 11. In practice,

the pre-amplifier may be a power amplifier (PA), and the post-amplifier may be a low-noise amplifier (LNA).

[0081] Different channels for the first electronic signals flowing in different directions may be also provided in the first RF front-end circuitry 12. Generally, an antenna usually has only one feed point, and hence the difference channels needs to be combined through, for example, duplexing or switching, before connected to the antenna. Reference is made to Figures 4a and 4b, which are schematic structural diagrams of the first RF front-end circuitry 12 according to embodiments of the present disclosure. As shown in Figure 4a, the first RF front-end circuitry 12 comprises a first power PA 121, a first LNA 122, and a first duplexer/switch 123. The first PA 121 is electrically connected to the communication circuitry 14, and is configured to amplify the first electronic signals transmitted from the RF circuitry 11 to the first antenna 13. The first LNA 122 is electrically connected to the communication circuitry 14, and is configured to amplify the first electronic signals transmitted from the first antenna 13 to the RF circuitry 11. The first duplexer/switch 123 is electrically connected to the first PA 121, the first LNA 122, and the first antenna 13, which may be a first duplexer or a first switch. The first duplexer/switch 123 is provided such that the first electronic signals flowing in different directions would not interfere with each other at the first front-end circuitry 12. As an example, the first duplexer is configured to couple the first electronic signals amplified by the first PA 121 to the first antenna 13 and couple the first electronic signals transmitted from the first antenna 13 to the first LNA 122. As another example, the first switch is configured to couple either the first LNA 122 or first PA 151 to the first antenna 13. A control signal may be provided to the first switch such that the selective coupling is performed under control of, for example, a controller or a processor. In some embodiments, either the first PA 121 or the first LNA 122 may be omitted. It may not be necessary to amplify the first electronic signals transmitting from the RF circuitry 11 to the first antenna 13 because, for example, the first electronic signals at an output of the RF circuitry 11 has such high power that the first antenna 13 is capable to transmit the first wireless signals strong enough for the wireless communication, even without amplification. It may not be necessary to amplify the first electronic signals transmitting from the first antenna 13 to the RF circuitry 11 because, for example, the first wireless signals received by the first antenna 13 has such low noises that the RF circuitry is capable to recognize the data carried in the first electronic signals even without amplification. The arrows in Figure 4a indicate flows of the first electronic signals. During the transmission process, the first electronic signals flows from the communication circuitry 14 (not depicted) to the first PA 121 for amplification, then to the first duplexer/switch 123, and then to the first antenna 13 (not depicted). During the reception process, the first electronic signals flows from the first antenna 13 to the first duplexer/switch 123, then to the first LNA 122, and then to the

communication circuitry 14.

[0082] In one embodiment, an additional filter may be further provided on a basis of the first RF front-end circuitry 12 as shown in Figure 4a. Reference is further made to Figure 4b, in which an additional filter 124 is electrically connected to the first duplexer/switch 123, and is configured to filter the first electronic signals flowing between the first duplexer/switch 123 and the antenna 13. In this embodiment, the additional filter is configured to remove noises in the first electronic signals, especially those flowing from the antenna 13 to the first duplexer/switch 123 in the reception process. The additional filter 124 may be a passive filter, such as a surface acoustic wave filter or a bulk acoustic wave filter. The additional filter 124 may be a high-pass filter, a low-pass filter, or a band-pass filter, where a passband of the additional filter 124 is not specifically limited herein, as long as it can improve the signal-to-noise ratio of the first electronic signals. It is appreciated that the additional filter 124 may not be a component of the first RF front-end circuitry 12 but provided at a side of the first antenna 13.

[0083] It is appreciated that the additional filter 124 may be provided only the transmission path, e.g., between the first PA 121 and the first duplexer/switch 123, or the reception path, e.g., between the first LNA 122 and the first duplexer/switch 123. Additionally or alternatively, there may be two additional filters in both paths, e.g., one is located between the first PA 121 and the first duplexer/switch 123 and another is located between the first LNA 122 and the first duplexer/switch 123. It is further appreciated that either the first PA 121 or the first LNA 122 in Figures 4a and 4b may be replaced by an amplifier of another type. For example, the first LNA 122 may be replaced by another power amplifier.

[0084] In some embodiments, the wireless electronic device may reuse the first antenna 13 for wireless communication under two frequency bands. For example, two kinds of electronic signals having different oscillating frequencies are generated, and then converted into two kinds of wireless signals having different frequencies at the first antenna 13. Since a change of the frequency the electronic signal also influences a gain and a loss at the RF front end, the RF front-end circuitry need have different functional parts to handle the electronic signals having different frequencies.

[0085] Reference is made to Figure 5a, which is a schematic structural diagram with signal flows of a wireless electronic device 500 according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2a, the wireless electronic device 500 further comprises second RF front-end circuitry 15 which is electrically connected to the first antenna 13. The RF circuitry 11 is electrically connected to the second RF front-end circuitry 15 via the communication circuitry 14. That is, the second RF front-end circuitry 15 serves as a parallel branch of the first RF front-end circuitry 12. In this embodiment, the

first antenna 13 is further configured to implement conversion between second electronic signals and second wireless signals, and a frequency of the second wireless signals is different from a frequency of the first wireless signals. Correspondingly, the RF circuitry 11 is further configured to transmit the second electronic signals to the first antenna 13, or receive the second electronic signals from the first antenna 13, via the second RF front-end circuitry 15 and the communication circuitry 14. The second RF front-end circuitry 15 is configured to amplify the second electronic signals. Herein the first wireless signals and the second wireless signals may be conformed to different protocols or standards, such as Bluetooth[®] and Wi-Fi.

[0086] As shown in Figure 5a, during the transmission, the second electronic signals flows from the RF circuitry 11 to the communication circuitry 14, then to the second RF front-end circuitry 15 for amplification, and then to the first antenna 13, and is converted into the second wireless signals at the first antenna 13. During the reception, the second wireless signals are converted into the second electronic signals at the first antenna 13, and the second electronic signals are transmitted from the first antenna 13 to the second RF front-end circuitry 15 for amplification, then to the communication circuitry 14, and then to the RF circuitry 11 for processing. That is, a path of the second electronic signals is substantially same as that of the first electronic signals, except that it passes the second RF front-end circuitry 15 instead of the first RF front-end circuitry 12. Similar to the first electronic signals, the first electronic signals has been amplified before being transmitted via the communication circuitry 14 during the transmission process, and a total noise figure of the whole receiving path is lowered for the reception process, which improves the signal-to-noise ratio at the RF circuitry 11. In some embodiments, an insertion loss of the second electronic signals on the communication circuitry 14 is larger than an insertion loss of the first electronic signals between the first antenna 13 and the second RF front-end circuitry 15, when the first electronic signals are transmitted between the first antenna 13 and the RF circuitry 11. In such case, the wireless electronic device 500 is further capable to transmit the second electronic signals with less power consumption and is more robust to noises in the received second electronic signals.

[0087] Reference is further made to Figure 5b, which is a schematic structural diagram of the wireless electronic device 500 having limited space budget according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2b, the first part 31 of the housing 30 is further configured to accommodate the second RF front-end circuitry 15, which facilitates a small insertion loss between the second RF front-end circuitry 15 and the first antenna 13. It is appreciated that the second RF front-end circuitry 15 may alternatively be accommodated by another part of the housing, for example, the third part 33, as long as it can serve as an electrical "bridge" for the second electronic signals flowing from

the communication circuitry 14 to the first antenna 13.

[0088] Since the paths for the first electronic signals and for the second electronic signals are combined between the front-end circuitry 12, 15 and the first antenna 13, it may be desirable to reduce an interference between the two paths, such that the wireless communication under two difference frequency bands can be smoothly performed via the first antenna 13. Reference is made to Figure 6, which is a schematic structural diagram with signal flows of a part of a wireless electronic device according to an embodiment of the present disclosure. On a basis the structure as shown in Figure 5a, the wireless electronic device further comprises a diplexer 16, and both the first RF front-end circuitry 12 and the second RF front-end circuitry 15 are electrically connected to the first antenna 13 via the diplexer. The diplexer 16 is capable to split the first electronic signals and the second electronic signals flowing from the first antenna 13 according to the different frequencies. Hence, the first RF front-end circuitry 12 would not be influenced by the second electronic signals, and the second RF front-end circuitry 15 would not be influenced by the first electronic signals. Similarly, another diplexer 16' (not depicted) may be provided between the RF front-end circuitry 12, 15 and the communication circuitry 14. That is, both the first RF front-end circuitry 12 and the second RF front-end circuitry 15 are electrically connected to the first antenna 13 via the diplexer 16'. The diplexer 16 is capable to split the first electronic signals and the second electronic signals flowing from the RF circuitry 11 according to the different frequencies, which can also reduce mutual interference between the first electronic signals and the second electronic signals. It is appreciated that the electronic device disclosed herein may comprise one or both of the diplexer 16 and the diplexer 16'.

[0089] Moreover, the interference may further be reduced by configuring the electrical link between the front-end circuitry 12, 15 and the RF circuitry 11. For example, when the RF circuitry 11 operates as a transceiver, the electrical link between the RF circuitry 11 and the communication circuitry 14 may further have at least two channels for the second electronic signals. One channel may be configured to transmit the second electronic signals from the RF circuitry 11 to the communication circuitry 14, while another channel is configured to transmit the second electronic signals inversely. Reference is made to Figure 7, which is a schematic structural diagram with signal flows of a wireless electronic device 700 according to another embodiment of the present disclosure. As shown in Figure 7, on a basis of the structure as shown in Figure 5a, the RF circuitry comprises a first transmitting terminal TX1, a first receiving terminal RX1, a second transmitting terminal TX2, and a second receiving terminal RX2. Details concerning the first transmitting terminal TX1 and the first receiving terminal RX1 may refer to their counterparts as shown in Figure 3, and are not repeated herein. The second transmitting terminal TX2 is configured to transmit the second electronic signals from the RF circuitry 11 to the second RF front-end circuitry 15 via the

communication circuitry 14, and the second receiving terminal RX2 is configured to receive the second electronic signals transmitted from the second RF front-end circuitry 15 via the communication circuitry 14. In this embodiment, different terminals are used to establish different channels not only for different directions but also for different electronic signals, which is capable to further reduce interference. Accordingly, a quality of the wireless communication can be further improved.

[0090] Still similar to the first electronic signals, different channels for the second electronic signals flowing in different directions may be provided in the second RF front-end circuitry 15. Reference is made to Figures 8a and 8b, which are schematic structural diagrams of the second RF front-end circuitry 15 according to embodiments of the present disclosure. As shown in Figure 8a, the second RF front-end circuitry 15 comprises a second PA 151, a second LNA 152, and a second duplexer/switch 153. The second PA 151 is electrically connected to the communication circuitry 14, and is configured to amplify the second electronic signals transmitted from the RF circuitry 11 to the first antenna 13. The second LNA 152 is electrically connected to the communication circuitry 14, and is configured to amplify the second electronic signals transmitted from the first antenna 13 to the RF circuitry 11. The second duplexer/switch 153 is electrically connected to the second PA 151, the second LNA 152, and the second antenna 153, which may be a second duplexer or a second switch. As an example, the second duplexer is configured to couple the second electronic signals amplified by the second PA 151 to the first antenna 13 and couple the second electronic signals transmitted from the first antenna 13 to the second LNA 152. As another example, the second switch is configured to couple either the second LNA 152 or second PA to the first antenna 13. As shown in 8b, an additional filter 154 electrically connected to the second duplexer/switch 153 may be further provided on a basis of the second RF front-end circuitry 15 as shown in Figure 8a. In some embodiments, either the second PA 151 or the second LNA 152 may be omitted. Details of the second PA 151, the second LNA 152, the second duplexer/switch 153, and the additional filter 154 may refer to the description concerning the first PA 121, the first LNA 122, the first duplexer/switch 123, and the additional filter 124, respectively, and are not repeated herein.

[0091] When the RF circuitry 11 has all the foregoing terminals TX1, RX1, TX2, RX2 and the RF front-end circuitry 12, 15 each comprises the corresponding PA, LNA, and duplexer/switch as described above, it is desirable that the four terminals TX1, RX1, TX2, RX2 are capable to be coupled to the first PA 121, the first LNA 122, the second PA 151, and the second LNA 152, respectively, to form four channels with mutual interference as little as possible. In some embodiments, the four channels may correspond to four communication lines, respectively, in the communication circuitry. That is, the one or more communication lines 141 comprises a first communication line, a second communication line, a third

communication line, and a fourth communication line. The first communication line is configured to connect the first PA 121 electrically to the first transmitting terminal TX1, the second communication line is configured to connect the first LNA 122 electrically to the first receiving terminal RX1, the third communication line is configured to connect the second PA 151 electrically to the second transmitting terminal TX2, and the fourth communication line is configured to connect the second LNA 152 electrically to the second receiving terminal RX2. In such case, the four communications is beneficial to keep the four channels stable.

[0092] In other embodiments, it may be difficult or undesirable to provide all the four communication lines between the RF circuitry 11 and the RF front-end circuitry 12, 15 due to, for example, a rather narrow space in the third part 33. In such case, at least two of the four channels may reuse a same communication line of the one or more communication lines 141. The communication circuitry further comprises first switch circuitry 142 and second switch circuitry 143. The RF circuitry 11 is electrically connected to a communication line of the one or more communication lines 141 via the first switch circuitry 142, and the RF front-end circuitry 12, 15 is electrically connected to the communication line via the second switch circuitry 143. The first switch circuitry 142 and the second switch circuitry 143 are configured to select one of candidate pairs and establish electrical connection between the selected candidate pair. Additionally or alternatively, the first switch circuitry 142 and the second switch circuitry 143 are configured to diplex communication among at least two of the candidate pairs via the communication line. The candidate pairs comprise at least two of: the first transmitting terminal TX1 and the first PA 121, the first receiving terminal RX1 and the first LNA 122, the second transmitting terminal TX2 and the second PA 151, and the second receiving terminal RX2 and the second low noise amplifier LNA 2. In a case that a quantity of the candidate pairs is equal to four, it means that all four channels share such communication line. In a case that a quantity of the candidate pairs is less than four, it means that only a part of the four channels share such communication line, and the communication circuitry 14 may further comprise additional communication line(s) for the remaining channel(s). That is, the one or more communication lines 141 comprises the additional communication line(s), which is at least one of the first communication line, the second communication line, the third communication line, and the fourth communication line. Herein the first switch circuitry 142 and the second switch circuitry 143 each may be implemented in various forms, such as a diplexer or a single-pole N-throw switch, where N stands for an integer and corresponds to how many channels share the communication line. It is appreciated that the first switch circuitry 142 and the second switch circuitry 143 each may be controlled by a processor or a controller when selecting the one of the candidate pairs.

[0093] Reference is made to Figures 9a to 9c, which are schematic structural diagrams of communication circuitry according to embodiments of the present disclosure. In Figure 9a,

there is only one communication line 141 in the communication circuitry 14, and the communication line is shared by all the four channels. The first switch circuitry 142 and the second switch circuitry 143 each comprise a single-pole four-throw switch. In Figure 9b, there are two communication lines 141 in the communication circuitry 14, one is shared by the two channels corresponding to the first electronic signals, and the other is shared by the two channels corresponding to the second electronic signals. The first switch circuitry 142 and the second switch circuitry 143 each comprise two single-pole double-throw switches. In Figure 9c, there are also two communication lines 141 in the communication circuitry 14, one is the fourth communication line corresponding to the channel between the second receiving terminal RX2 and the second LNA 152, and the other is shared by the other three channels. The first switch circuitry 142 and the second switch circuitry 143 each comprise a single-pole three-throw switch. It is appreciated that the present disclosure are not limited to the examples as shown in Figures 9a to 9c. For example, the four channels may be arbitrarily divided into two groups to use two communication lines 141, and may arbitrarily divided into three groups to use three communication lines 141. For example, the four channels may adopt a "diplexer" scheme instead of the "switch" schemes as shown in Figures 9a to 9c. In a case that a group comprises a channel for the first electronic signals and a channel for the second electronic signals, the switch circuitry 142, 143 may provide a diplexer for such group, and the diplexer is capable to split the first electronic signals and the second electronic signals coming from one communication line into the two channels at the RF circuitry 11 (in case of the first switch circuitry) or at the RF front-end circuitry 12, 15 (in case of the second switch circuitry). In one embodiment, the switch circuitry 142, 143 may use a "diplexer-and-switch" scheme, in which one or more diplexers are configured to separate electrical signals flowing in a same direction but having different frequencies, and one or more switches are configured to separate electrical signals flowing in a same direction and having identical frequencies. A quantity and a structure of the switches or diplexers in the switch circuitry may depend on a quantity of the groups and a quantity of channels comprised in each group.

[0094] As discussed above, the wireless electronic device may be provided with multiple antennas such that more frequency bands can be utilized and/or more directions can be covered in wireless communications. In some embodiments, the forgoing wireless electronic device may have another antenna besides the first antenna 13. The other antenna may be configured to transmitting or receive the first wireless signals, and operate in parallel with the first antenna 13 during the wireless communication. In such case, the frequencies of electronic signals are identical for the two antennas, and the other antenna may be directly coupled to the first RF front-end circuitry 12. Since the other antenna share the same front-end circuitry, i.e., the first front-end circuitry 12, with the first antenna 13, the two

antennas should be disposed not far from each other, and otherwise an inserted loss between the other antenna and the first front-end circuitry would be too large and cause degradation of the wireless communication at the other antenna. Such adjacency between the two antennas hinders an ideal coverage for the wireless communication. Therefore, when it is desirable to improve coverage between different antennas, or when the different antennas are configured to perform wireless communication under different frequencies, the different antennas may be connected to the RF circuitry 11 via different front-end circuitry.

[0095] Reference is made to Figure 10a, which is a schematic structural diagram with signal flows of a wireless electronic device 1000 according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2a, the wireless electronic device 1200 further comprises third RF-front end circuitry 18 and a second antenna 17. The third front-end circuitry 18 is electrically connected to the RF circuitry 11. The second antenna 17 is electrically connected to third RF front-end circuitry 18, and is configured to implement conversion between third electronic signals and third wireless signals. The RF circuitry 11 is further configured to transmit the third electronic signals to the second antenna 17, or receive the third electronic signals from the second antenna 17, via the third RF front-end circuitry.

[0096] Details of the third antenna 17 may refer to those of the first antenna 13 in the foregoing description, which is not repeated herein. A type and/or a shape of the third antenna may be identical to or different from that of the first antenna 13, and may be determined based on an actual application scenario. Similarly, details of the third wireless signals and of the third electronic signals may refer to those of the first wireless signals and of the first electronic signals in the foregoing description, which is not repeated herein. A frequency of the third wireless signals may be identical or different from a frequency of the first wireless signals. In case of being different, the third wireless signals and the first wireless signals may use different wireless protocols or different frequency bands under a same wireless communication protocol, such as the 2.4GHz and 5GHz bands of Wi-Fi.

[0097] In some embodiments as shown in Figure 10a, the third RF front-end circuitry 18 is electrically connected to the RF circuitry 11 not via the communication circuitry 14. That is, the third RF front-end circuitry 18 may be directly connected to the RF circuitry 11, or may be connected to the RF circuitry 11 via an electrical link other than the communication circuitry 11. During the transmission process, the third electronic signals flow from the RF circuitry 11 to the third RF front-end circuitry 18, and then to the second antenna 17, and are converted into the third wireless signals at the second antenna 17. During the reception process, the third wireless signals are converted into the third electronic signals at the second antenna 17, and third electronic signals flow from the second antenna 17 to the third RF front-end circuitry 18, and then to the RF circuitry 11 for processing. In these embodiments, the second antenna 17 may be located closer to the RF circuitry than the first antenna 13.

Reference is made to Figure 10b, which is a schematic structural diagram of a wireless electronic device having limited space budget according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2b, the second part 32 of the housing is further configured to accommodate the second antenna 17. The third RF front-end circuitry 18 may be also accommodated in the second part 32, as shown in Figure 10b, or may be accommodated outside the second part 32, such as in the third part 33. As an example, the third RF front-end circuitry 18 and/or the second antenna 17 may be located on the same circuitry board as the RF circuitry 11, or may be supported by a same chassis within the second part 32. In such case, the second antenna 17 and the first antenna 13 are apart from each other in order to increase the coverage and prevent interference (in case of the first wireless signals and the third wireless signals having different frequencies), while save the space budget as such as possible. It is appreciated that the third RF front-end circuitry 18 and/or the second antenna 17 may alternatively be accommodated in another part of the housing 30 as long as the space budget permits. For example, the third RF front-end circuitry 18 and/or the second antenna 17 may be disposed at a different side of the RF circuitry 11 in view of first RF front-end circuitry 12 and the first antenna 13, so as to ensure a large distance between the two antennas.

[0098] In other embodiments, as the first front-end circuitry 12, the third RF front-end circuitry 18 is electrically connected to the RF circuitry 11 via the communication circuitry 14. During the transmission process, the third electronic signals flow from the RF circuitry 11 to the communication circuitry 14, then to the third RF front-end circuitry 18, and then to the second antenna 17, and are converted into the third wireless signals at the second antenna 17. During the reception process, the third wireless signals are converted into the third electronic signals at the second antenna 17, and third electronic signals flow from the second antenna 17 to the third RF front-end circuitry 18, and then to the communication circuitry 14, and then to the RF circuitry 11 for processing. The communication circuitry 14 may provide separate electrical links for the first electronic signals and the third electronic signals, respectively, or provide a shared link which allows the first electronic signals or the third electronic signals are to pass selectively. The selective passing may be implemented via switch circuitry with reference to that for the first electronic signals and the second electronic signals, e.g., as shown in Figures 9a to 9c, and is not illustrated in details herein. Since the difference between these embodiments and the foregoing embodiment only lies in whether the electrical link between the RF circuitry 11 and the third RF front-end circuitry 18 passes the communication circuitry 14, details of physical locations of the third RF front-end circuitry 18 and the second antenna 17 may refer to the foregoing embodiments, and are not repeated herein.

[0099] The third RF front-end circuitry 18 may have the same structure as shown in Figures

4a, 4b, 8a, and 8b. Thus, some details of the third RF front-end circuitry 18 may refer to those of the first RF front-end circuitry 12 and the second RF front-end circuitry 15, and are not repeated herein. As discussed in the foregoing embodiments, the second antenna 17 and the third RF front-end circuitry 18 may be close to the RF circuitry 11, and thus an insertion
5 loss of the third electronic signals between the third RF front-end circuitry 18 and the RF circuitry 11 may be small or even negligible in compared with that of the first electronic signals on the communication circuitry 14. In such case, the PA and/or the LNA in the structure as shown in Figures 4a, 4b, 8a, and 8b may be omitted, so as to further save the space budget and the power budget of the wireless electronic device. That is, in some
10 embodiments, the third RF front-end circuitry 18 may comprise a third duplexer/switch. The third duplexer is configured to couple the third electronic signals transmitted from the RF circuitry 11 electrically to the second antenna 17 and couple the third electronic signals transmitted from the second antenna 17 electrically to the RF circuitry 11. The third switch is configured to couple either a terminal for transmitting the third electronic signals or a
15 terminal for receiving the third electronic signals, of the RF circuitry 11, to the second antenna 17.

[0100] The RF circuitry, the RF front-end circuitry, as well as the switch circuitry in the foregoing embodiments may operate under control of, for example, a controller or a processor. For example, the RF circuitry may be controlled to modulate and or demodulate the electronic
20 signals, the RF front-end circuitry may be controlled to amplify the electronic signals with an appropriate factor, and the switch circuitry may be controlled to select a candidate electrical link on requirement. Reference is made to Figure 11a, which is a schematic structural diagram with signal flows of a wireless electronic device according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2a, the wireless
25 electronic device 1100 further comprises a controller 21. The controller 21 is configured to control the RF front-end circuitry 11 and the first front-end circuitry 12. The dashed lines in Figure 11a refer to control links between the controller 21 and the RF circuitry 11 and between the controller 21 and the first RF front-end circuitry. Generally, the control link may be implemented in a wired manner, that is, through a control line that carries control
30 signals. The control line may be a cable, a wire, wiring on a circuit board, or the like. The control link may alternatively be implemented in a wireless manner.

[0101] Reference is further made to Figure 11b, which is a schematic structural diagram of a wireless electronic device having limited space budget according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2b, the controller 21
35 may be accommodated in the second part 32 along with the RF circuitry 11, and the control line between the controller 21 and the first RF front-end circuitry 12 may be accommodated in the third part 14 along with the communication circuitry, so as to further save the space

budget for the wireless communication. In such case, the controller 21 may be located on a same circuit board as the RF circuitry 11, or may be supported by a same chassis as the RF circuitry 11. A position of the controller is not limited to what is shown in Figure 11b. The controller may alternatively be accommodated in another part. As an example, the controller
5 21 is accommodated in the first part 31 along with the first front-end circuitry 12 and/or the first antenna 13. As another example, the controller 21 is accommodated in the third part 33 along with the communication circuitry 14.

[0102] Since the first RF front-end circuitry 12 may comprise multiple components having different functions, as shown in Figures 4a, 4b, 8a, and 8b, it may be necessary to provide
10 multiple control lines between the controller 21 and the first RF front-end circuitry 12 to transmit different signals for different components. The multiple control lines may require a large space within the housing 30 (such as within the third part 33). In such case, an auxiliary controller may be provided between the controller 21 and the first RF front-end circuitry to simplify a layout of the control lines. Reference is made to Figure 12a, which is
15 a schematic structural diagram with signal flows of a wireless electronic device 1200 according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 11a, the wireless electronic device 1200 further comprises an auxiliary controller 22. The auxiliary controller is electrically connected to the controller 21 and the first RF front-end circuitry 12, configured to receive a channel of control signals from the
20 controller 21, convert the received channel of the control signals into multiple channels of control signals, and control the first RF front-end circuitry based on the multiple channels of control signals. In practice, the auxiliary controller 22 may receive a serial input from the controller 21, and convert the serial input into multiple parallel outputs, and may be
25 implemented via multiple general-purpose input/outputs (GPIOs). For example, when the first RF front-end circuitry 12 has a structure as shown in Figure 4a, the single serial input are converted into three channels for the first PA 121, the first LNA 122, and the first duplexer/switch 123, and thus the auxiliary controller 22 may be implement via 4 GPIOs having one input and three outputs. Similarly, when the first RF front-end circuitry 12 has a
30 structure as shown in Figure 4b, the auxiliary controller 22 may be implemented via 5 GPIOs having one input and four outputs due to an addition channel for the first filter 124. As shown in Figure 2a, adding the auxiliary controller 22 can reduce a quantity of the control lines at least between the controller 21 and the auxiliary controller 22. In a case that the auxiliary controller 22 is directly coupled to the first RF front-end circuitry via, for example,
wiring on a circuitry board or a designated connector, there may be only one control line
35 between the controller 21 and the first RF front-end circuitry 12. Hence, it is preferable that the auxiliary controller 22 is placed close to the first RF front-end circuitry 12.

[0103] Reference is made to Figure 12b, which is a schematic structural diagram of a

wireless electronic device 1200 having limited space budget according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 2b, the second part 32 of the housing 30 is further configured to accommodate the auxiliary controller 22. Such configuration can reduce a total length of the control line(s) as much as possible while saving the space budget. The controller 21 may be located on a same circuit board or may be supported by a same chassis as the first front-end circuitry 12 and/or the first antenna 13. It is appreciated that the auxiliary controller 22 may alternatively be accommodated in another part, such as the second part 32 or the third part 33, as long as it is in the control link between the controller 21 and the first RF front-end circuitry 12.

[0104] When the control line between the controller 21 and the first RF front-end circuitry 12 is accommodated by the third part 33, such control line may be a part of the communication circuitry 14. That is, the control signals between the controller 21 and the first RF front-end circuitry 12 is transmitted by the communication circuitry 14. In one embodiment, one of the one or more communication lines 141 in the communication circuitry 14 is reused for both the communication link and the control link, that is, such communication line is configured to transmit both the first electronic signals and the control signals. Reference is made to Figure 13, which is a schematic structural diagram with signal flows of a wireless electronic device 1300 according to another embodiment of the present disclosure. On a basis of the structure as shown in Figure 11a, a part of the control line between the controller 21 and the first RF front-end circuitry 12 is combined into a communication line 141, and the wireless electronic device 1300 further comprises first filter circuitry 23 and second filter circuitry 24. As shown in Figure 13, the communication line 141 is electrically connected to the RF circuitry 11 and the controller 21 via the first filter circuitry 23, and is electrically connected to a communication terminal and a control terminal of the first RF front-end circuitry 12 via the second filter circuitry 24. The communication terminal is configured to transmit the electronic signals to the RF circuitry 11 or receive the first electronic signals from the RF circuitry 11, and the control terminal is configured to receive the control signals from the controller 21. The first filter circuitry 23 is configured to reduce interference of the first electronic signals on the controller 21 and reduce interference of the control signals on the RF circuitry 11. The second filter circuitry 24 is configured to reduce interference of the first electronic signals on the control terminal and reduce interference of the control signals on the receiving terminal. The first filter circuitry 23 and the second filter circuitry 24 may be implemented in various forms. In some embodiments, the filter circuitry may be implemented as a single-pole double-through switch under control of, for example, the controller 21. For example, the controller 21 may control the first filter circuitry 23 to connect the communication line 141 to either the RF circuitry 11 or the controller 12 in a time division manner, and control the second filter circuitry 24 to connect the communication line

141 to either the communication terminal or the control terminal in a time division manner. In other embodiments, the filter circuitry may be implemented by one or more filters that separate the control signals and the first electronic signals through their different frequencies.

[0105] Generally, the control signals (e.g., ~ MHz or lower) do not have a frequency as high as the wireless signals (e.g., GHz). In such case, the different signals can be separated using a high-pass filter (HPF) and a low-pass filter (LPF). Reference is made to Figure 14, which is a schematic structural diagram with signal flows of a part of a wireless electronic device according to another embodiment of the present disclosure. As shown in Figure 14, the first filter circuitry 23 and the second filter circuitry 24 each has a HPF and a LPF. The HPF is capable to remove the control signals from the mixed signals (i.e., the first electronic signals plus the control signals), while the LPF is capable to remove the first electronic signals from the mixed signals. It is appreciated that the HPF and the LPF are merely exemplary filters in the filter circuitry, and each may be replaced with a filter of another type, for example, a band-pass filter (BPF), as long as the desired signals can be separated from the undesired ones in the mixed signals.

[0106] It is appreciated the first filter circuitry 23 and the second filter circuitry 24 may have different structures or different parameters. For example, the corresponding HPFs, BPFs, or LPFs may have different pass bands. For example, one may be implemented as filters while the other is implemented as a switch. Moreover, the first filter circuitry 23 may be omitted in a case that the RF circuitry 11 merely transmits the first electronic signals to the antenna while not receiving the first electronic signals from the antenna, and the second filter circuitry 24 may be omitted in a case that the RF circuitry 11 merely receives the first electronic signals from the antenna while not transmitting the first electronic signals to the antenna.

[0107] Details of a control link between the controller 21 and the second RF front-end circuitry 15 and a control link between the controller 21 and the third RF front-end circuitry 18 may refer to those of the control link between the controller 21 and the first RF front-end circuitry 12 as described in the foregoing embodiments, and are not repeated herein.

[0108] Herein the wireless electronic devices, e.g., the wireless electronic device 200, 300, 500, 700, 1000, 1100, 1200, or 1300, may be implemented in various forms. Specifically, the wireless electronic devices may be configured as a wearable device, since the wearable wireless devices has particularly strict requirements on the power consumption and signal quality of wireless communication. The wearable device may be worn at a body part, such as the head, a limb, the torso, of the user. For example, the wearable device may be electronic glasses worn on the head of the user, may be an electronic watch worn on the wrist of the user, or may a game pad held by at least one hand of the user. In a case the housing 30

of the head-mounted device comprises the first part 31 and the second part 32 as described in the foregoing embodiments, the first part 31 and the second part 32 may be disposed at different sides of the body part, so as to keep a compact design that facilitates wearing. Reference is made to Figure 15, which is a schematic structural diagram of housing of a wireless electronic device according to an embodiment of the present disclosure. As shown in Figure 5, the first part 31 and the second part 32 are configured to be located at two sides of a body part of a user when the user wears the wireless electronic device. Herein the two sides may refer to, for example, a left side and a right side, a front side and a rear side, a left-front side and a right-front side, or the like, which is not limited herein. The third part 33 may be disposed at any side of the head as long as it is capable to accommodate the communication circuitry 14. For example, the third part 33 may be disposed at another side of the body part and connecting the first part 31 and the second part 32.

[0109] In some embodiments, the wireless electronic device may be a head-mounted device, for example, a head-mounted display, a head-mounted camera, electronic eyeglasses, a headset, or the like. As an example, the head-mounted device is eyeglasses. The first part 31 comprises at least a part of a temple bar of the electronic eyeglasses, the second part 32 comprises at least a part of another temple bar of the electronic eyeglasses, and the third part 33 comprises at least a part of a bridge and at least a part of a lens frame of the electronic eyeglasses. As another example, the head-mounted device is a headset. The first part 31 or the second part 32 comprises at least a part of a speaker cup of the headset, and the third part 33 comprises at least a part of a headband of the headset. In a case that only one of the first part 31 or the second part 32 is the speaker cup, the other of the two parts may be a T-pad or another component configured to fix the headset on an ear of the user.

[0110] Hereinabove illustrated are embodiments of the wireless electronic devices. Correspondingly, a method for transmitting wireless signals and a method for receiving wireless signals are further provided according to embodiments of the present disclosure. Both methods are applicable to an electronic device comprising RF circuitry, first RF front-end circuitry, a first antenna electrically connected to first RF front-end circuitry, and communication circuitry electrically connected between the RF circuitry and the first RF front-end circuitry. It is appreciated that the wireless electronic device may be any foregoing wireless electronic device, e.g., 200, 300, 500, 700, 1000, 1100, 1200, or 1300.

[0111] In one embodiment, the method for transmitting wireless signals comprises following steps S11 to S14. In step S11, the RF circuitry transmits first electronic signals to the first RF front-end circuitry via the communication circuitry. In step S12, the first RF front-end circuitry amplifies the first electronic signals transmitted from the RF circuitry. In step S13, the first RF front-end circuitry transmits the amplified first electronic signals to the first antenna. In step S14, the first antenna converts the amplified first electronic signals

transmitted from the first RF front-end circuitry into first wireless signals. An insertion loss of the first electronic signals on the communication circuitry is larger than an insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry.

[0112] In another embodiment, the method for receiving wireless signals comprises following steps S21 to S24. In step S21, the first antenna converts first wireless signals into first electronic signals. In step S22, the first antenna transmitted the first electronic signals to the first RF front-end circuitry. In step S23, the first RF front-end circuitry amplifies the first electronic signals transmitted from the first antenna. In step S24, the first RF front-end circuitry transmits the amplified first electronic signals to the RF circuitry via the communication circuitry. An insertion loss of the first electronic signals on the communication circuitry is larger than an insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry.

[0113] Details of the above method may refer to those of the wireless electronic devices in the foregoing embodiments, especially those concerning the signal flows in each structure. These details are not repeated herein. The steps of the method or algorithm described according to the embodiments disclosed herein can be implemented in forms of hardware, a software module executed by a processor or the combination of the both. The software module may be stored in a Random Access Memory (RAM), a memory, a Read-Only Memory (ROM), an electrically programmable ROM, an electrically erasable programmable ROM, a register, a hardware disk, a movable magnetic disk, CD-ROM or any other forms of storage medium well known in the art.

[0114] The embodiments of the present disclosure are described in a progressive manner, and each embodiment places emphasis on the difference from other embodiments. Therefore, one embodiment can refer to other embodiments for the same or similar parts. Since the methods disclosed in the embodiments corresponds to the devices disclosed in the embodiments, the description of the method embodiments is simple, and reference may be made to the relevant part of the device embodiments.

[0115] The signal flows and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer readable media according to various embodiments. In this regard, each block in the block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). The method, computer system, and computer readable medium may include additional blocks, fewer blocks, different blocks, or differently arranged blocks than those depicted in the Figures. In some alternative implementations, the functions noted in the blocks may occur out of the order noted in the Figures. It will also be noted that each block of the block

diagrams, and combinations of blocks in the block diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

[0116] It will be apparent that systems and/or methods, described herein, may be implemented in different forms of hardware, firmware, or a combination of hardware and software. The actual specialized control hardware or software code used to implement these systems and/or methods is not limiting of the implementations. Thus, the operation and behavior of the systems and/or methods were described herein without reference to specific software code—it being understood that software and hardware may be designed to implement the systems and/or methods based on the description herein.

[0117] No element, act, or instruction used herein should be construed as critical or essential unless explicitly described as such. Also, as used herein, the articles "a" and "an" are intended to include one or more items, and may be used interchangeably with "one or more". Furthermore, as used herein, the term "set" is intended to include one or more items (e.g., related items, unrelated items, a combination of related and unrelated items, etc.), and may be used interchangeably with "one or more". Where only one item is intended, the term "one" or similar language is used. Also, as used herein, the terms "has", "have", "having", or the like are intended to be open-ended terms. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise.

[0118] The aforementioned embodiments are only intended to describe the technical solutions of the present disclosure, and not to limit the present disclosure. Although the present disclosure is described in detail with reference to the above embodiments, those skilled in the art should understand that, modifications can be made to the technical solutions recorded in the above embodiments, or equivalent replacements can be made to some of the technical features thereof, and the modifications and the replacements will not make the corresponding technical solutions deviate from the spirit and the scope of the technical solutions of the embodiments of the present disclosure.

CLAIMS

1. A wireless electronic device, comprising:

radio-frequency (RF) circuitry;

first RF front-end circuitry;

5 a first antenna, electrically connected to first RF front-end circuitry, wherein the first antenna is configured to implement conversion between first electronic signals and first wireless signals; and

communication circuitry, comprising one or more communication lines, wherein the RF circuitry is electrically connected to the first RF front-end circuitry via the communication circuitry;

10 wherein the RF circuitry is configured to transmit the first electronic signals to the first antenna, or receive the first electronic signals from the first antenna, via the first RF front-end circuitry and the communication circuitry;

15 wherein the first RF front-end circuitry is configured to amplify the first electronic signals; and

wherein an insertion loss of the first electronic signals on the communication circuitry is larger than an insertion loss of the first electronic signals between the first antenna and the first RF front-end circuitry, when the first electronic signals are transmitted between the first antenna and the RF circuitry.

20 2. The wireless electronic device according to claim 1, wherein the RF circuitry comprises:

a first transmitting terminal, configured to transmit the first electronic signals from the RF circuitry to the RF front-end circuitry via the communication circuitry; and

25 a first receiving terminal, configured to receive the first electronic signals transmitted from the first RF front-end circuitry via the communication circuitry.

3. The wireless electronic device according to claim 2, further comprising one or both of:

a pre-amplifier, configured to amplify the first electronic signals transmitted from the RF circuitry to the communication circuitry; and

30 a post-amplifier, configured to amplify the first electronic signals transmitted from the communication circuitry to the RF circuitry;

wherein the first transmitting terminal is electrically connected to the communication circuitry via the pre-amplifier, and the first receiving terminal is electrically connected to the communication circuitry via the post low noise amplifier.

35 4. The wireless electronic device according to any one of claims 1 to 3, wherein the first RF front-end circuitry comprises:

a first duplexer or a first switch, comprising:

a first terminal and a second terminal which are electrically connected to the

communication circuitry, and

a third terminal electrically connected to the first antenna,

wherein the first terminal is configured to receive the first electronic signals transmitted from the RF circuitry to the first RF front-end circuitry, and the second terminal is configured to transmit the first electronic signals from the first RF front-end circuitry to the RF circuitry, and

wherein the first duplexer is configured to couple the first electronic signals from the first terminal to the third terminal and couple the first electronic signals from the third terminal to the second terminal, and the first switch is configured to couple either the first terminal or the second terminal to the third terminal; and

one or both of a first power amplifier and a first low noise amplifier, wherein:

the first power amplifier is electrically connected between the communication circuitry and the first terminal, wherein the first power amplifier is configured to amplify the first electronic signals transmitted from the RF circuitry to the first antenna; and

the first low noise amplifier is electrically connected between the communication circuitry and the second terminal, wherein the first power amplifier is configured to amplify the first electronic signals transmitted from the first antenna to the RF circuitry.

5. The wireless electronic device according to any one of claims 1 to 4, further comprising second RF front-end circuitry, electrically connected to the first antenna, wherein: the RF circuitry is electrically connected to the second RF front-end circuitry via the communication circuitry;

the first antenna is further configured to implement conversion between second electronic signals and second wireless signals, and a frequency of the second wireless signals is different from a frequency of the first wireless signals;

the RF circuitry is further configured to transmit the second electronic signals to the first antenna, or receive the second electronic signals from the first antenna, via the second RF front-end circuitry and the communication circuitry; and

the second RF front-end circuitry is configured to amplify the second electronic signals.

6. The wireless electronic device according to claim 5, wherein an insertion loss of the second electronic signals on the communication circuitry is larger than an insertion loss of the second electronic signals between the first antenna and the second RF front-end circuitry, when the second electronic signals is transmitted between the first antenna and the RF circuitry.

7. The wireless electronic device according to claim 5 or 6, further comprising one or both of a first duplexer and a second duplexer, wherein:

both the first RF front-end circuitry and the second RF front-end circuitry are electrically connected to the first antenna via the first duplexer; and

both the first RF front-end circuitry and the second RF front-end circuitry are electrically connected to the communication circuitry via the second diplexer.

8. The wireless electronic device according to any one of claim 5 to 7, wherein the RF circuitry comprises:

5 a second transmitting terminal, configured to transmit the second electronic signals from the RF circuitry to the second RF front-end circuitry via the communication circuitry; and
a second receiving terminal, configured to receive the second electronic signals transmitted from the second RF front-end circuitry via the communication circuitry.

9. The wireless electronic device according to any one of claims 5 to 8, wherein the
10 second RF front-end circuitry comprises:

a second diplexer or a second switch, comprising:

a fourth terminal and a fifth terminal which are electrically connected to the communication circuitry, and

a sixth terminal electrically connected to the second antenna,

15 wherein the fourth terminal is configured to receive the second electronic signals transmitted from the RF circuitry to the second RF front-end circuitry, and the fifth terminal is configured to transmit the second electronic signals from the second RF front-end circuitry to the RF circuitry, and

wherein the second diplexer is configured to couple the second electronic signals
20 from the fourth terminal to the sixth terminal and couple the second electronic signals from the sixth terminal to the fifth terminal, and the second switch is configured to couple either the fourth terminal or the fifth terminal to the third terminal; and
one or both of a second power amplifier and a second low noise amplifier, wherein:

25 the second power amplifier is electrically connected between the communication circuitry and the fourth terminal, wherein the second power amplifier is configured to amplify the second electronic signals transmitted from the RF circuitry to the first antenna; and

30 the second low noise amplifier is electrically connected between the communication circuitry and the fifth terminal, wherein the second low noise amplifier is configured to amplify the second electronic signals transmitted from the first antenna to the RF circuitry.

10. The wireless electronic device according to any one of claims 4 to 9, wherein the communication circuitry further comprises first switch circuitry and second switch circuitry, wherein:

35 the RF circuitry is electrically connected to a communication line of the one or more communication lines via the first switch circuitry, and the first RF front-end circuitry and the second RF front-end circuitry is electrically connected to the communication line via the second switch circuitry;

the first switch circuitry and the second switch circuitry are configured to select one of candidate pairs and establish electrical connection between the selected candidate pair, or duplex communication among at least two of the candidate pairs via the communication line, wherein the candidate pairs comprise at least two of:

the first transmitting terminal and the first power amplifier,
the first receiving terminal and the first low noise amplifier,
the second transmitting terminal and the second power amplifier, and
the second receiving terminal and the second low noise amplifier.

11. The wireless electronic device according to any one of claims 4 to 10, wherein the one or more communication lines comprise at least one of:

a first communication line, configured to connect the first power amplifier electrically to the first transmitting terminal; and

a second communication line, configured to connect the first low noise amplifier electrically to the first receiving terminal;

a third communication line, configured to connect the second power amplifier electrically to the second transmitting terminal; and

a fourth communication line, configured to connect the second low noise amplifier electrically to the second receiving terminal.

12. The wireless electronic device according to any one of claims 1 to 11, further comprising:

third RF front-end circuitry, electrically connected to the RF circuitry; and

a second antenna, electrically connected to third RF front-end circuitry, wherein the second antenna is configured to implement conversion between third electronic signals and third wireless signals;

wherein the RF circuitry is configured to transmit the third electronic signals to the second antenna, or receive the third electronic signals from the second antenna, via the third RF front-end circuitry.

13. The wireless electronic device according to claim 12, wherein a frequency of the third wireless signals is different from a frequency of the first wireless signals.

14. The wireless electronic device according to claim 12 or 13, wherein the third RF front-end circuitry is electrically connected to the RF circuitry not via the communication circuitry.

15. The wireless electronic device according to any one of claims 1 to 14, further comprising a controller, configured to:

control the RF front-end circuitry, and

control the first RF front-end circuitry via control signals.

16. The wireless electronic device according to claim 15, further comprising:

an auxiliary controller, electrically connected to the controller and the first RF front-end

circuitry, wherein the auxiliary controller is configured to:

receive a channel of control signals from the controller, convert the received channel of the control signals into a plurality of channels of control signals, and control the first RF front-end circuitry based on the plurality of channels of control signals.

5 17. The wireless electronic device according to claim 15 or 16, wherein a communication line among the one or more communication lines is configured to transmit both the first electronic signals and the control signals.

18. The wireless electronic device according to claim 17, further comprising one or both of first filter circuitry and second filter circuitry, wherein:

10 the communication line is electrically connected to the RF circuitry and the controller via the first filter circuitry, and is electrically connected to a communication terminal and a control terminal of the first RF front-end circuitry via the second filter circuitry;

the communication terminal is configured to transmit the first electronic signals to the RF circuitry or receive the first electronic signals from the RF circuitry, and the control terminal is configured to receive the control signals from the controller;

15 the first filter circuitry is configured to reduce interference of the first electronic signals on the controller and reduce interference of the control signals on the RF circuitry; and

the second filter circuitry is configured to reduce interference of the first electronic signals on the control terminal and reduce interference of the control signals on the receiving terminal.

19. The wireless electronic device according to any one of claims 1 to 18, further comprising housing, wherein at least a part of the housing is formed by:

a first part, configured to accommodate the first antenna and the first RF front-end circuitry;

25 a second part, configured to accommodate the RF circuitry; and

a third part, configured to accommodate the communication circuitry, wherein the third part is located between the first part and the third part.

20. The wireless electronic device according to claim 19, wherein:

30 neither the first part nor the second part is spatially sufficient for accommodating the RF circuitry, the first RF front-end circuitry, and the first antenna; and

the third part is not spatially sufficient for accommodating either the RF circuitry or the RF front-end circuitry.

21. The wireless electronic device according to claim 19 or 20, wherein in a case that the wireless electronic device comprises the second antenna, the second part of the housing is further configured to accommodate the second antenna,.

22. The wireless electronic device according to claim 21, wherein the third RF front-end circuitry comprises:

a third duplexer or a third switch, wherein:

the third duplexer is configured to couple the third electronic signals transmitted from the RF circuitry electrically to the second antenna and couple the third electronic signals transmitted from the second antenna electrically to the RF circuitry, and

the third switch is configured to couple either a terminal for transmitting the third electronic signals or a terminal for receiving the third electronic signals, of the RF circuitry, to the second antenna.

23. The wireless electronic device according to any one of claims 19 to 22, wherein in a case that the wireless electronic device comprises the second RF front-end circuitry, the first part of the housing is further configured to accommodate the second RF front-end circuitry.

24. The wireless electronic device according to any one of claims 19 to 23, wherein in a case that the wireless electronic device comprises the auxiliary controller, the second part of the housing is further configured to accommodate the auxiliary controller.

25. The wireless electronic device according to any one of claims 19 to 24, being a wearable device, and the first part and the second part are configured to be located at two sides of a body part of a user when the user wears the wireless electronic device.

26. The wireless electronic device according to any one of claims 19 to 24, being electronic eyeglasses, wherein:

the first part comprises at least a part of a temple bar of the electronic eyeglasses, the second part comprises at least a part of another temple bar of the electronic eyeglasses, and the third part comprises at least a part of a bridge and at least a part of a lens frame of the electronic eyeglasses.

27. The wireless electronic device according to any one of claims 19 to 24, being a headset, wherein:

the first part or the second part comprises at least a part of a speaker cup of the headset, and the third part comprises at least a part of a headband of the headset.

28. A method for transmitting wireless signals, applicable to an electronic device, wherein:

the electronic device comprises: RF circuitry, first RF front-end circuitry, a first antenna electrically connected to first RF front-end circuitry, and communication circuitry electrically connected between the RF circuitry and the first RF front-end circuitry;

the method comprises:

transmitting, by the RF circuitry, first electronic signals to the first RF front-end circuitry via the communication circuitry;

amplifying, by the first RF front-end circuitry, the first electronic signals transmitted from the RF circuitry;

transmitting, by the first RF front-end circuitry, the amplified first electronic signals to the first antenna; and

converting, by the first antenna, the amplified first electronic signals transmitted

from the first RF front-end circuitry into first wireless signals; and
an insertion loss of the first electronic signals on the communication circuitry is larger
than an insertion loss of the first electronic signals between the first antenna and the first RF
front-end circuitry.

5 29. A method for receiving wireless signals, applicable to an electronic device,
wherein:

the electronic device comprises: RF circuitry, first RF front-end circuitry, a first antenna
electrically connected to first RF front-end circuitry, and communication circuitry electrically
connected between the RF circuitry and the first RF front-end circuitry;

10 the method comprises:

converting, by the first antenna, first wireless signals into first electronic signals;

transmitting, by the first antenna, the first electronic signals to the first RF front-end
circuitry;

amplifying, by the first RF front-end circuitry, the first electronic signals

15 transmitted from the first antenna; and

transmitting, by the first RF front-end circuitry, the amplified first electronic signals
to the RF circuitry via the communication circuitry; and

an insertion loss of the first electronic signals on the communication circuitry is larger
than an insertion loss of the first electronic signals between the first antenna and the first RF
20 front-end circuitry.

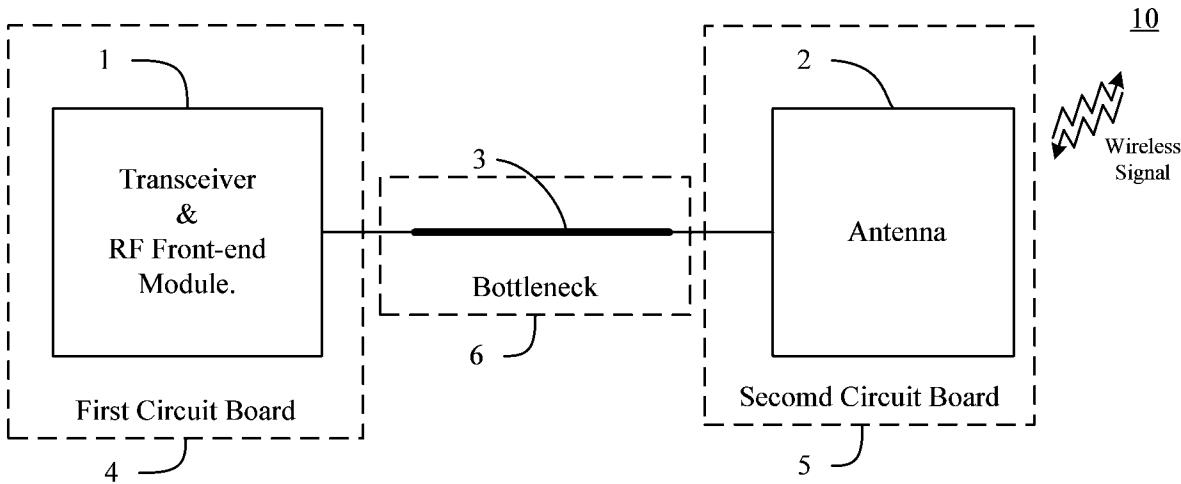


Figure 1

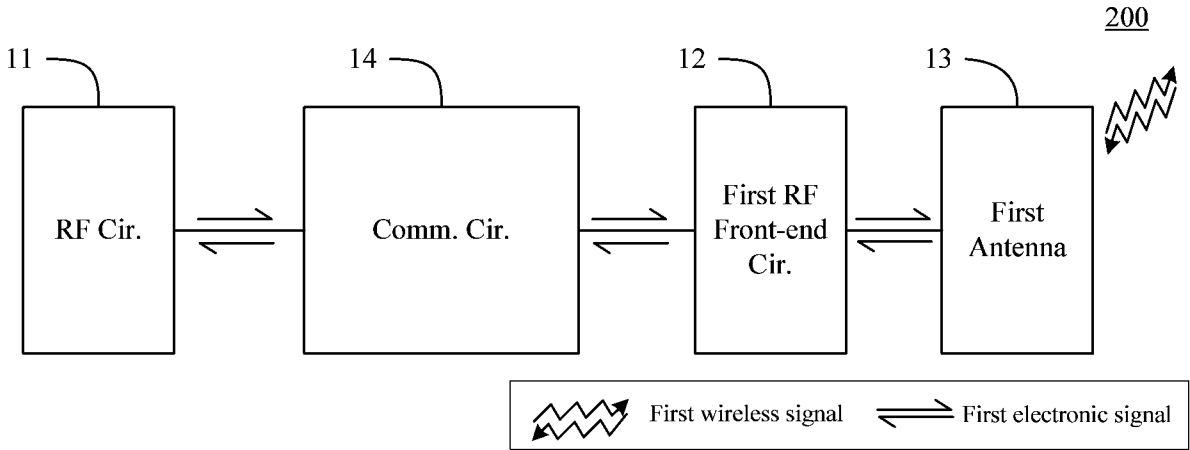


Figure 2a

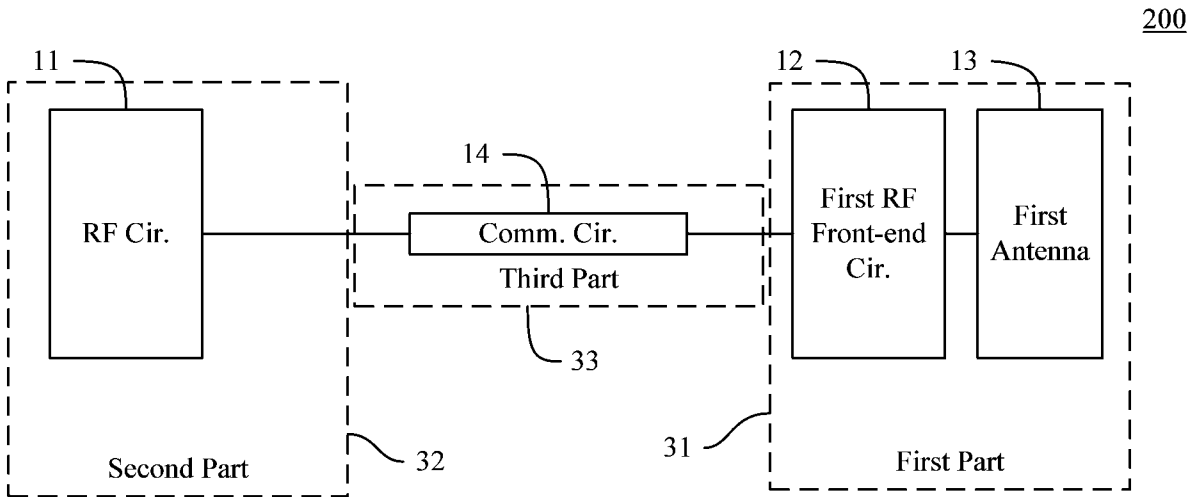


Figure 2b

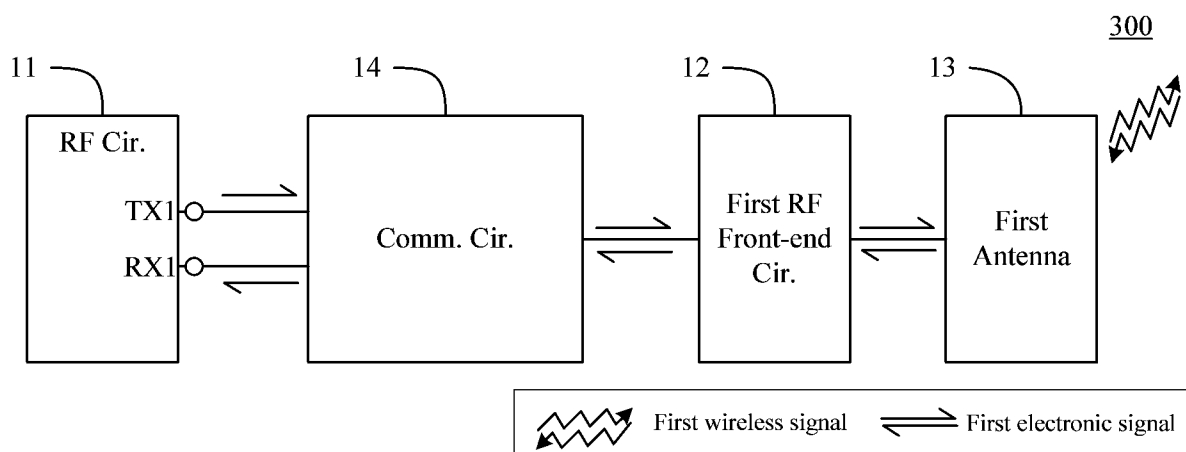


Figure 3

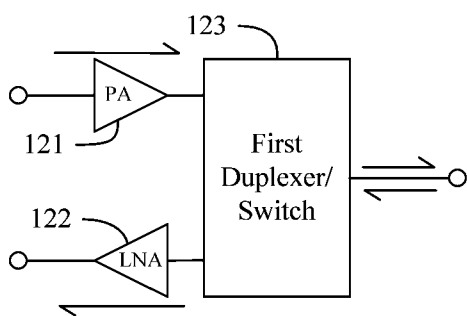


Figure 4a

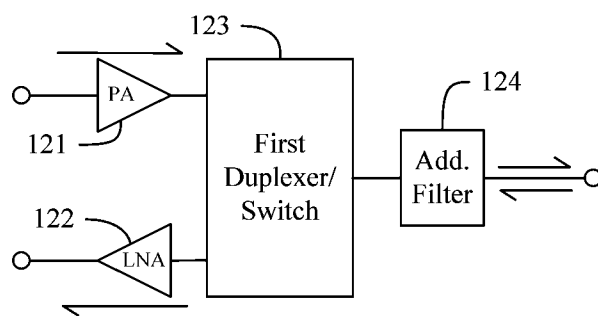


Figure 4b\

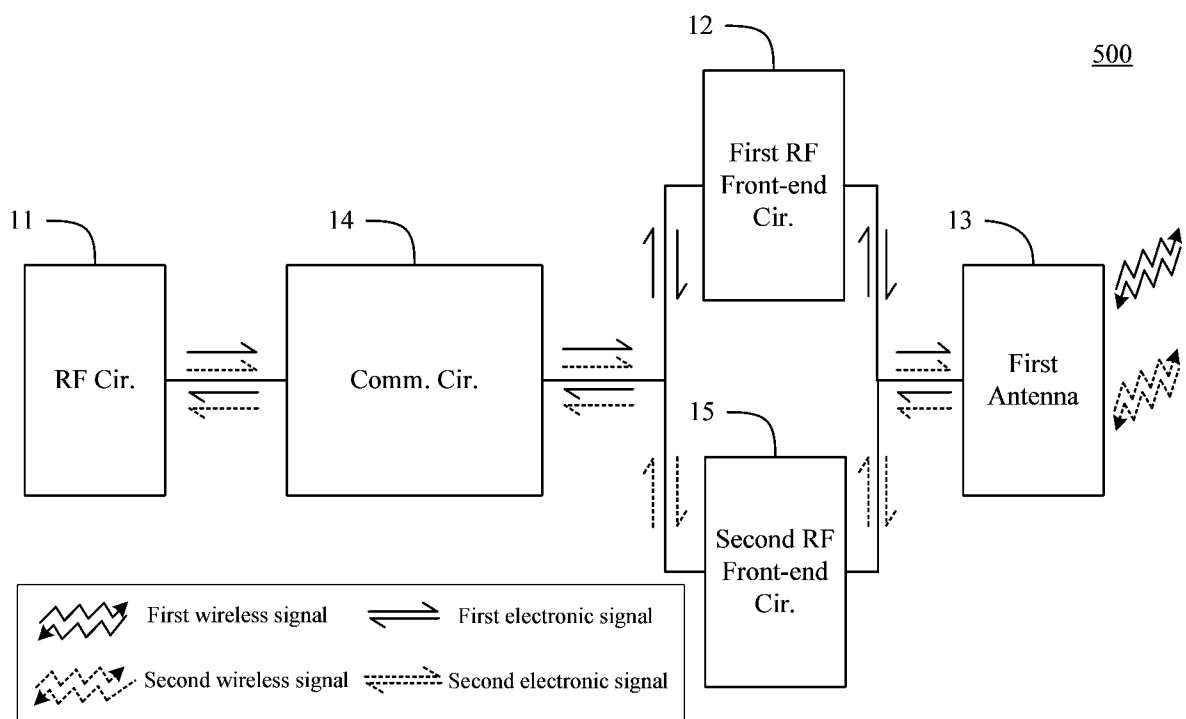


Figure 5a

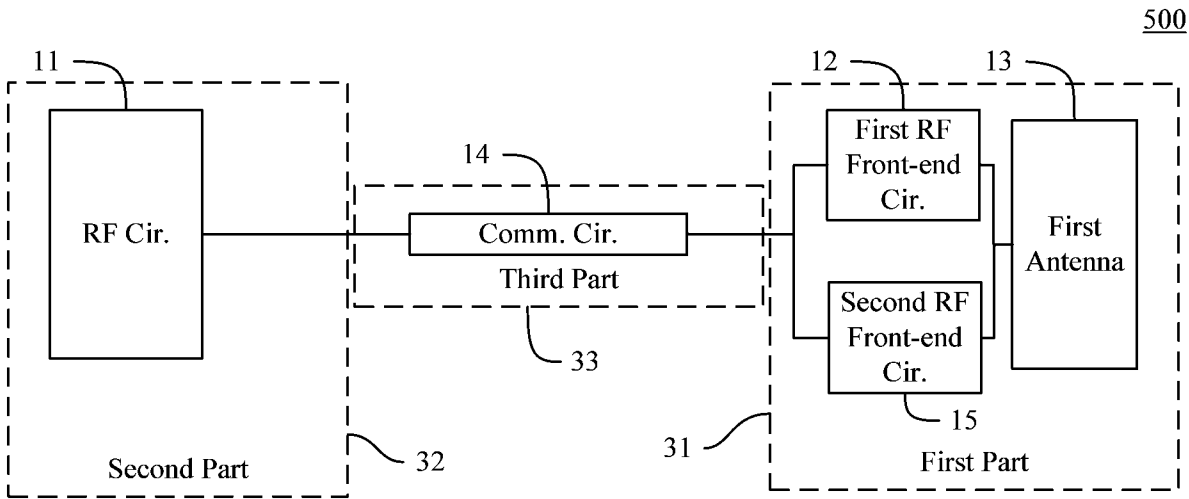


Figure 5b

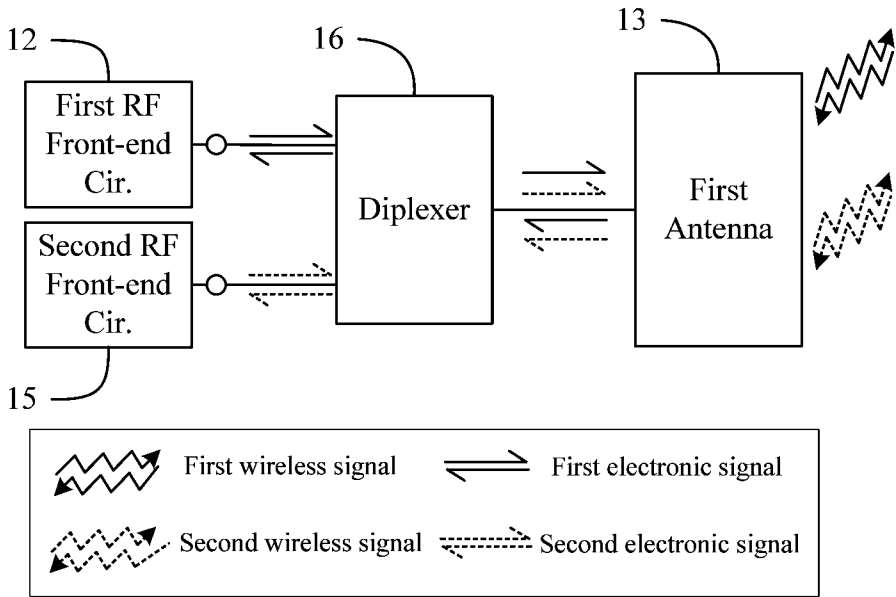


Figure 6

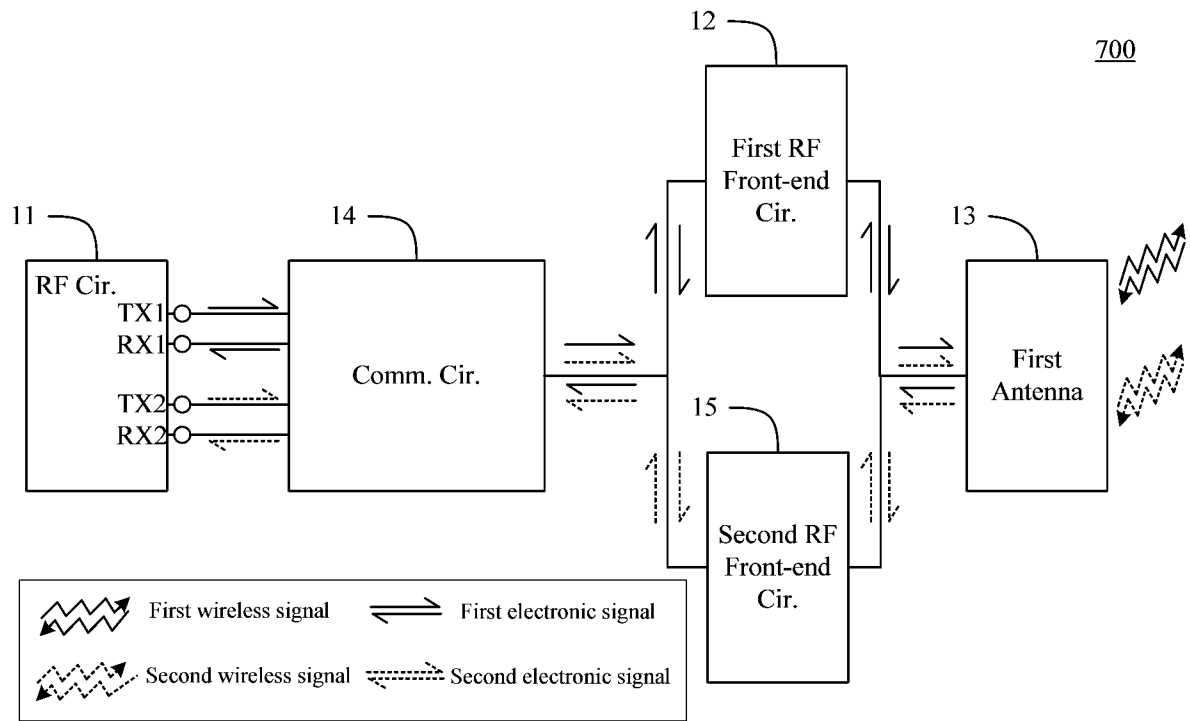


Figure 7

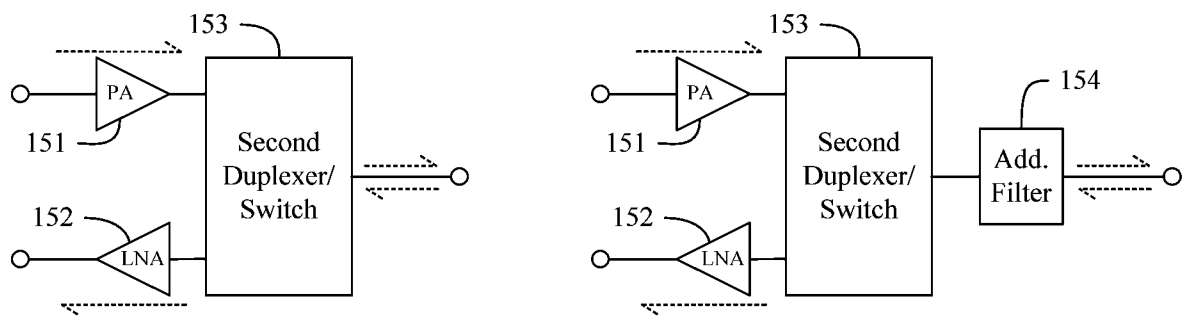


Figure 8a

Figure 8b

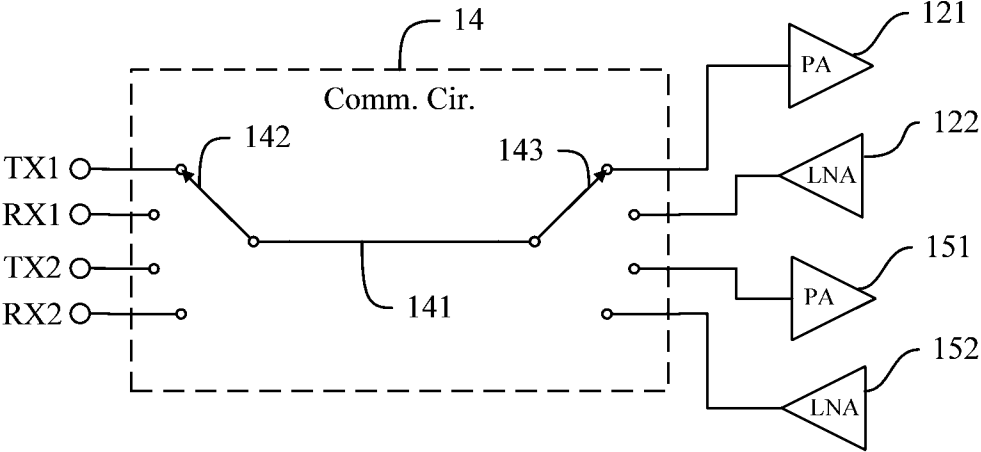


Figure 9a

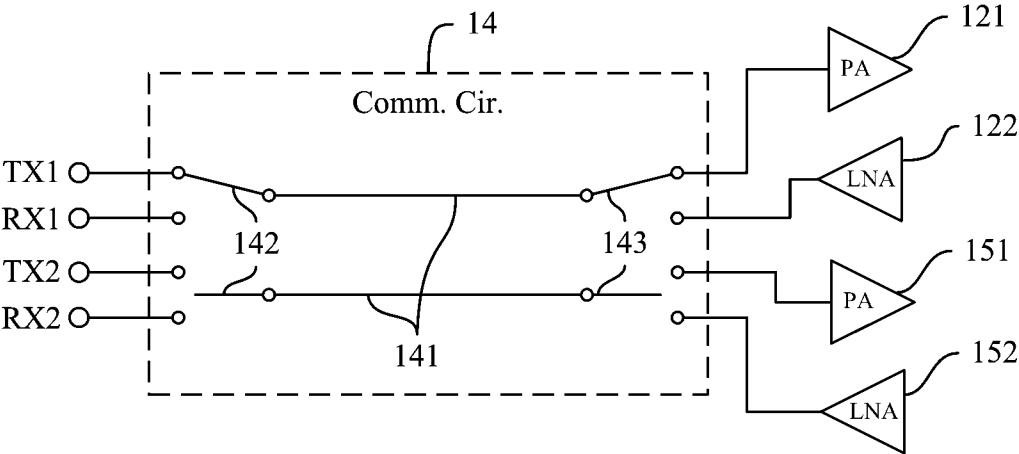


Figure 9b

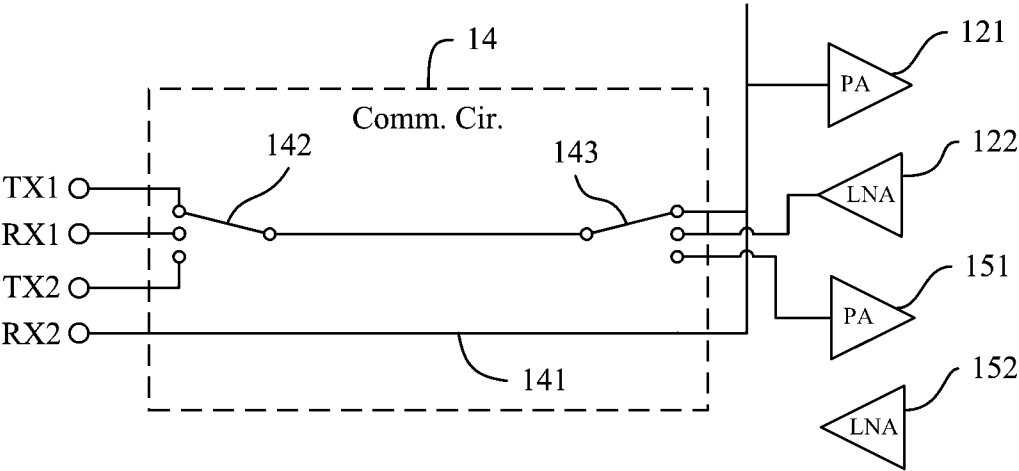


Figure 9c

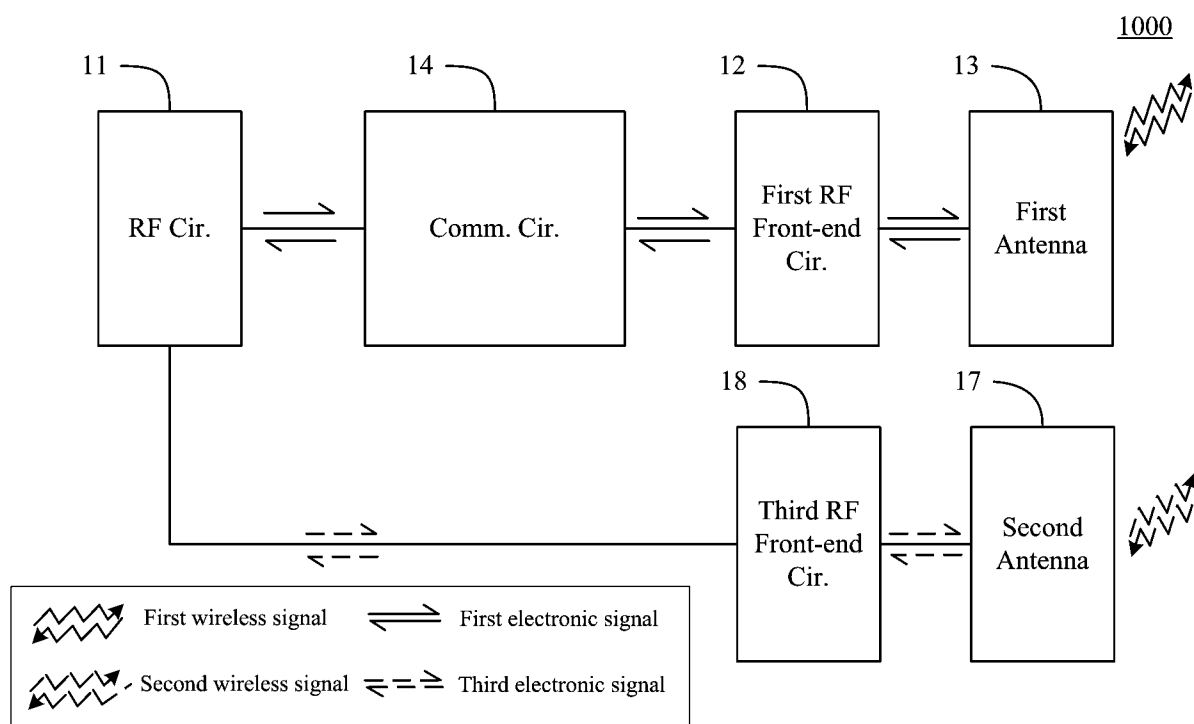


Figure 10a

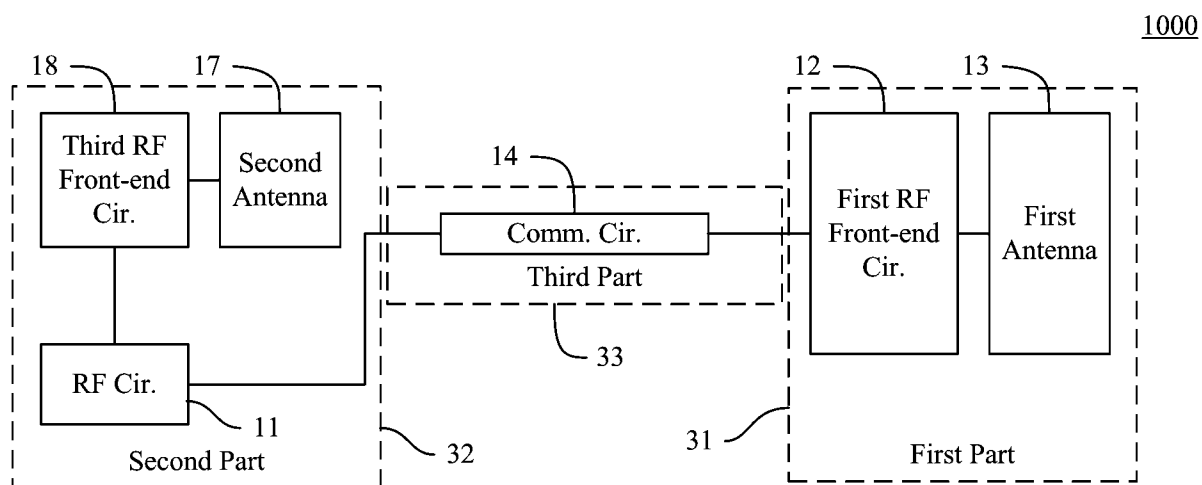
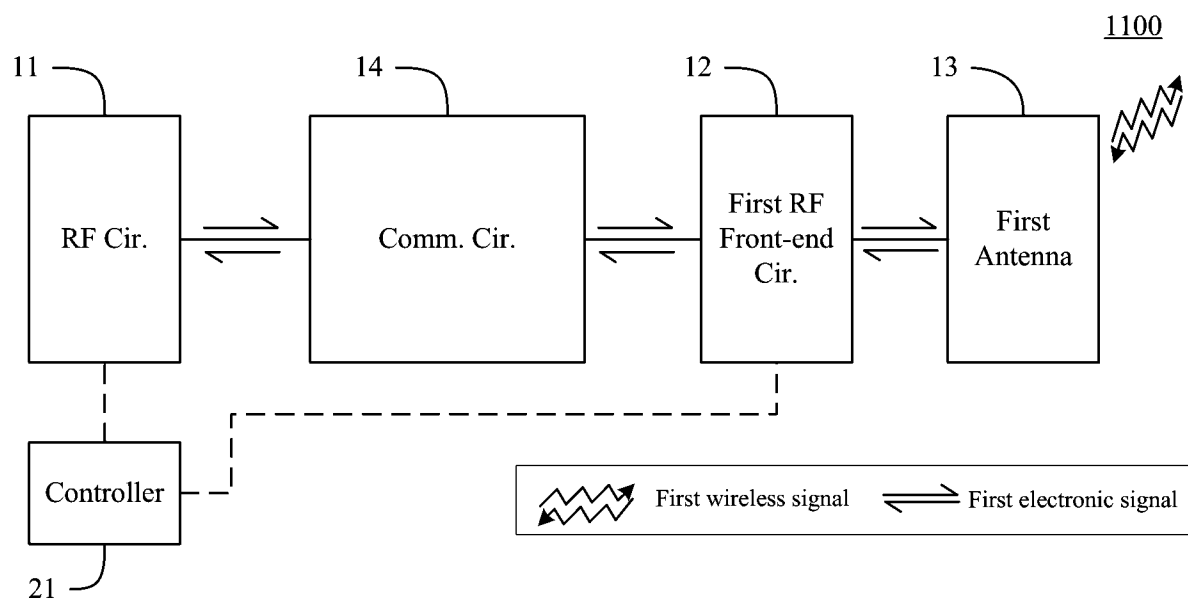
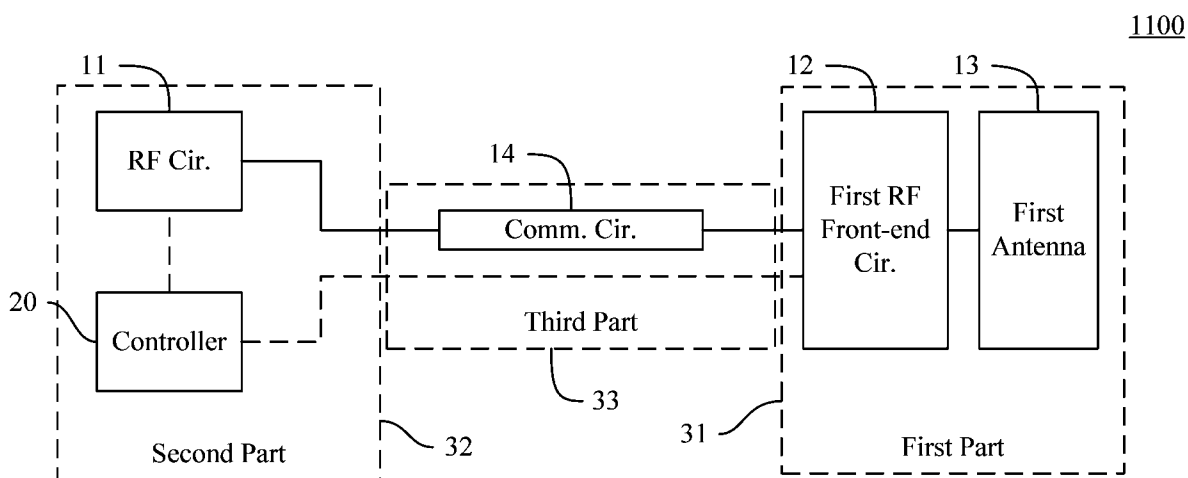


Figure 10b

**Figure 11a****Figure 11b**

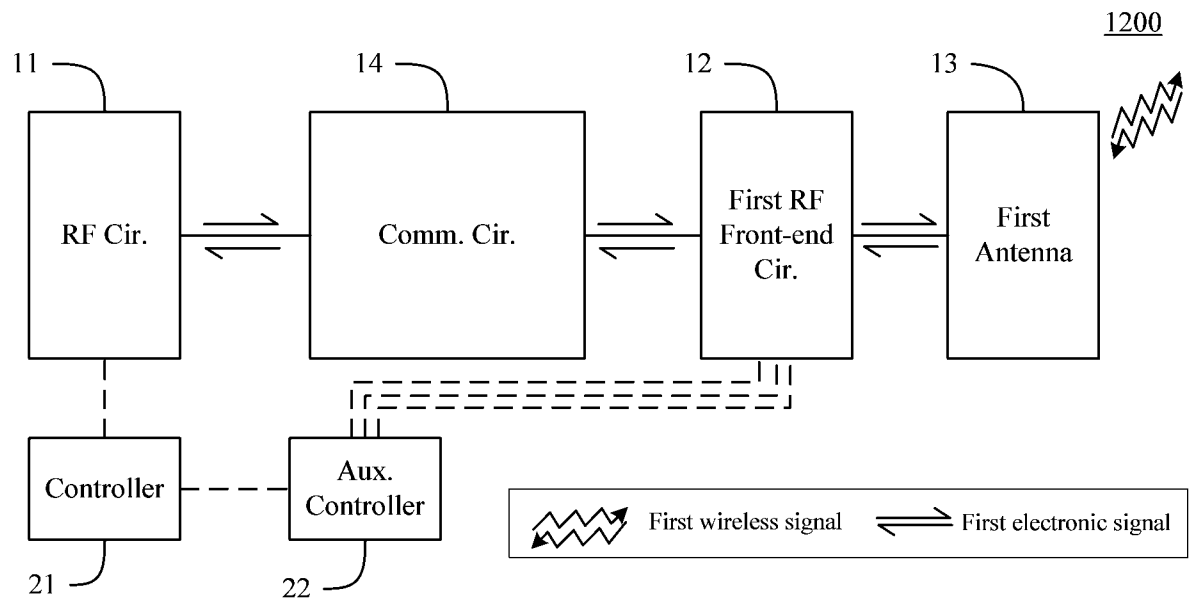


Figure 12a

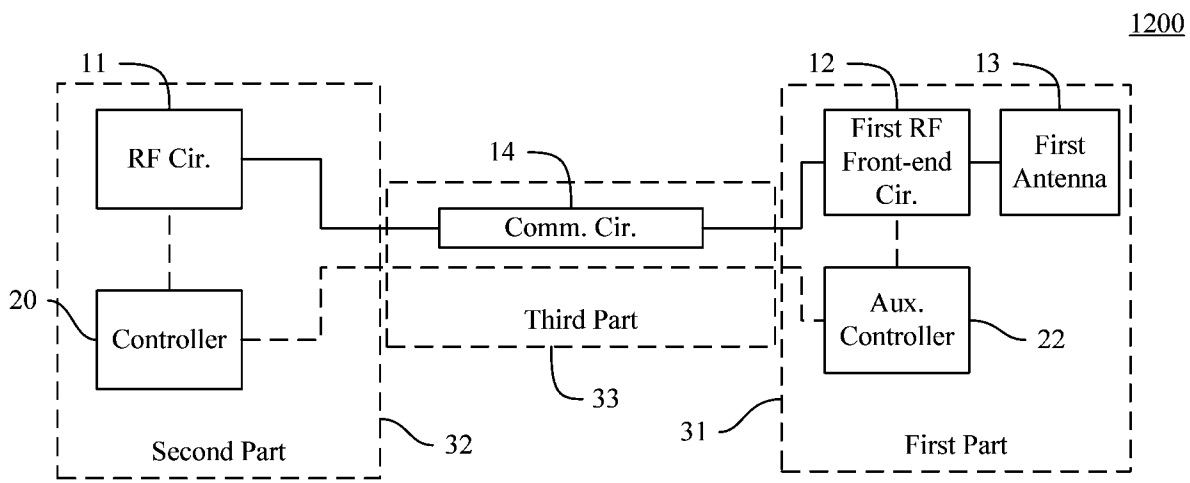


Figure 12b

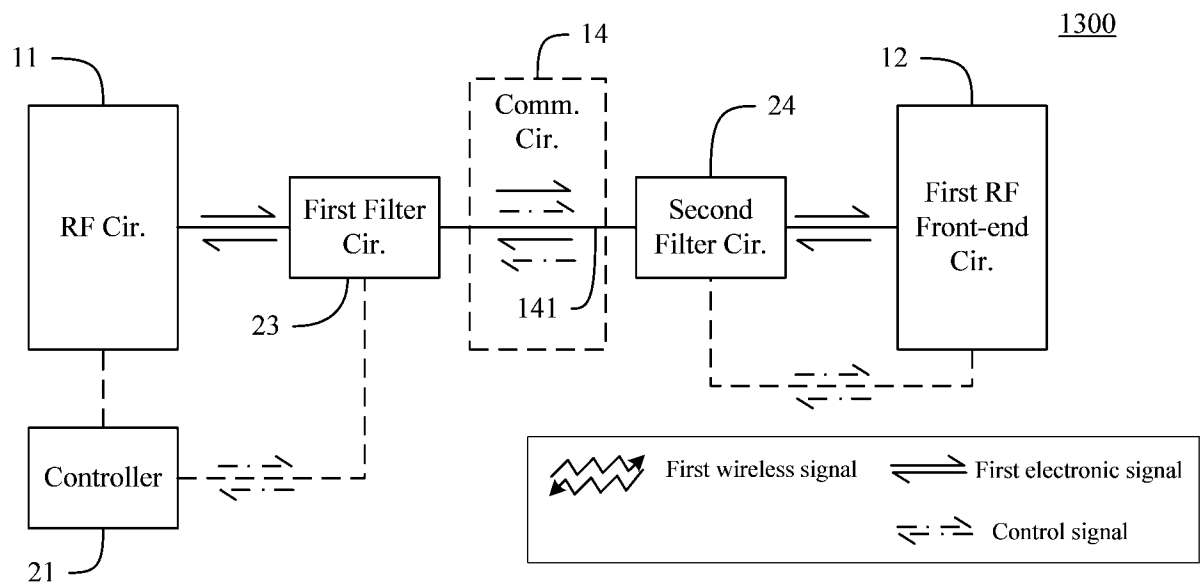


Figure 13

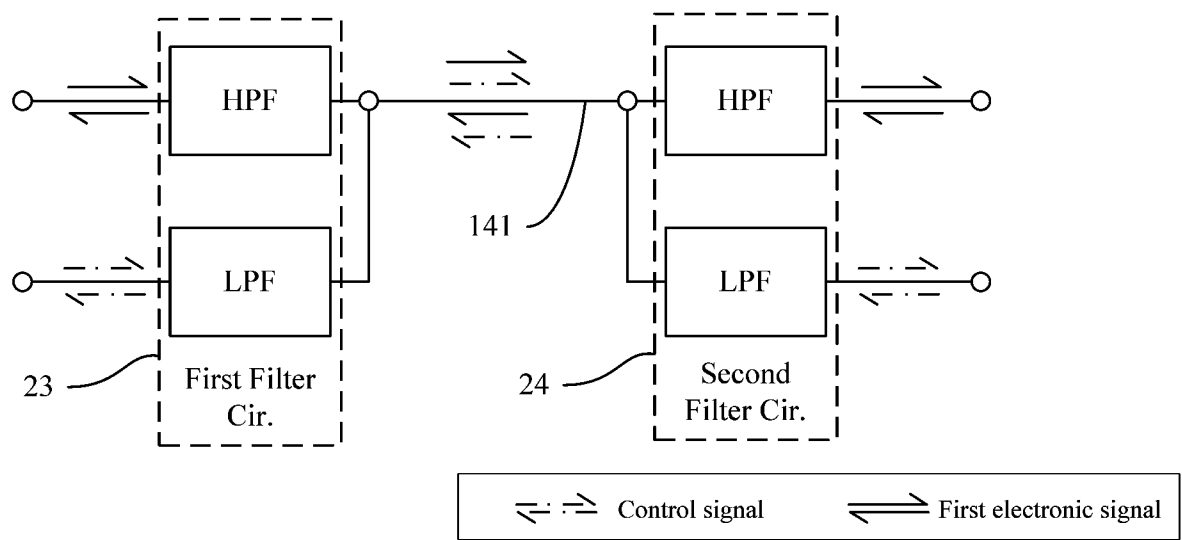


Figure 14

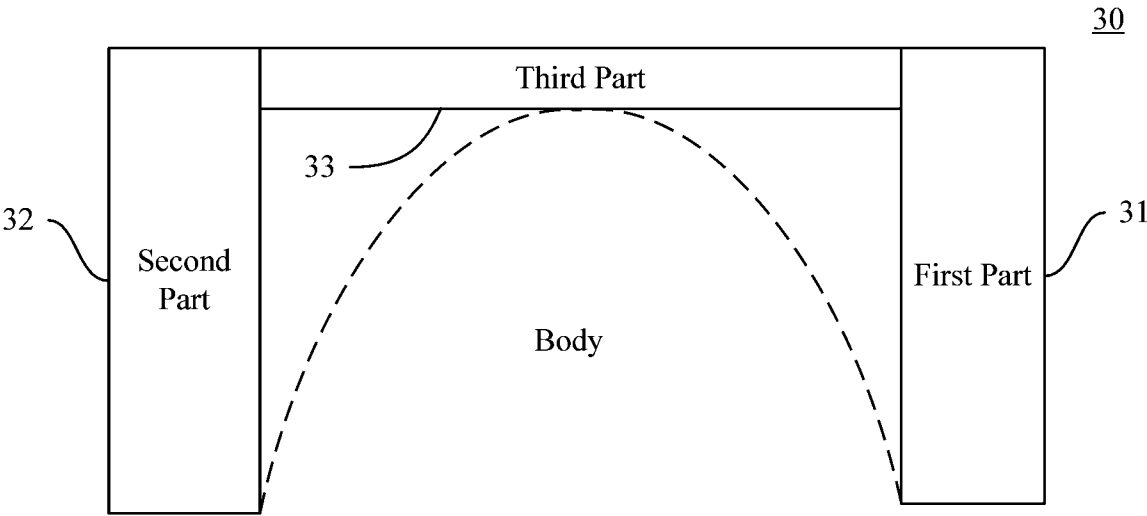


Figure 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/078907

A. CLASSIFICATION OF SUBJECT MATTER H04B 1/401(2015.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC:H04B,H04W Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNTXT,DWPI,ENTXTC,VEN,WPABSC,VCN:RF front back end circuitry antenna amplify insertion loss		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019363453 A1 (SAMSUNG ELECTRONICS CO., LTD.) 28 November 2019 (2019-11-28) description, paragraphs 21–95, and figures 1-11	1-29
A	US 2017126953 A1 (NETGEAR, INC.) 04 May 2017 (2017-05-04) the whole document	1-29
A	WO 2021244226 A1 (ZTE CORP.) 09 December 2021 (2021-12-09) the whole document	1-29
A	CN 103813431 A (WISTRON CORP.) 21 May 2014 (2014-05-21) the whole document	1-29
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 30 October 2023		Date of mailing of the international search report 03 November 2023
Name and mailing address of the ISA/CN CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China		Authorized officer LI,TingTing Telephone No. (+86) 010-53961728

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/078907

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US	2019363453	A1	28 November 2019	US	2021021052	A1	21 January 2021
				DE	102019107258	A1	28 November 2019
				CN	110534870	A	03 December 2019
				KR	20190134435	A	04 December 2019
				TW	202005178	A	16 January 2020

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WO	2021244226	A1	09 December 2021	US	2023128757	A1	27 April 2023
				EP	4117198	A1	11 January 2023
				CN	113765558	A	07 December 2021

CN	103813431	A	21 May 2014	USRE	47978	E	05 May 2020
				US	2014135054	A1	15 May 2014
				TW	201419905	A	16 May 2014
