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| United States Patent Application Publication | 20250266853 |
| Kind Code | A1 |
| Publication Date | August 21, 2025 |
| Inventor(s) | HSU; Chang-Yi et al. |

## WIRELESS COMMUNICATION DEVICE

### Abstract

A wireless communication device is provided. The wireless communication device includes a first radio frequency circuit, a second radio frequency circuit, a third radio frequency circuit, a first antenna, a second antenna, a first switch including a first end, a second end, a third end, and a fourth end, and a second switch including a fifth end, a sixth end, and a seventh end. The first end connects to the first radio frequency circuit. The second end connects to the second radio frequency circuit. The third end connects to the first antenna. The fourth end connects to the fifth end. The sixth end connects to the third radio frequency circuit. The seventh end connects to the second antenna.

**Inventors:** **HSU; Chang-Yi (Hsinchu City, TW), HUANG; Po-Hsun (Hsinchu City, TW), CHUANG; Chia-Hsuan (Hsinchu City, TW), LI; Yi-Yan (Hsinchu City, TW), LIAO; Shen-Yi (Hsinchu City, TW)**

**Applicant:** **MEDIATEK INC.** (Hsinchu City, TW)

**Family ID:** **1000008198103**

**Appl. No.:** **18/917435**

**Filed:** **October 16, 2024**

### Related U.S. Application Data

us-provisional-application US 63555476 20240220
us-provisional-application US 63648736 20240517

### Publication Classification

**Int. Cl.:** **H04B1/00** (20060101); **H04B1/44** (20060101); **H04B7/0404** (20170101)

**U.S. Cl.:**

CPC **H04B1/0064** (20130101); **H04B1/44** (20130101); **H04B7/0404** (20130101);

## Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application claims priority of U.S. Provisional Application Ser. No. 63/555,476, filed on 2024 Feb. 20 and U.S. Provisional Application Ser. No. 63/648,736, filed on 2024 May 17, the entirety of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION
Field of the Invention
[0002] The present invention relates to a wireless communication device, and, in particular, it relates to a wireless communication device with multiple radio frequency circuits sharing multiple antennas.
Description of the Related Art
[0003] When a device has more radio frequency circuits than antennas, some radio frequency circuits will have to share an antenna. However, if the connections between the radio frequency circuits and the antennas aren't well-configured, there may be some unused antennas when the radio frequency circuit is idle. Thus, a wireless communication device that can fully use every antenna is required.
BRIEF SUMMARY OF THE INVENTION
[0004] An embodiment of the present invention provides a wireless communication device. The wireless communication device comprises a first radio frequency circuit, a second radio frequency circuit, a third radio frequency circuit, a first antenna, a second antenna, a first switch, and a second switch. The first switch comprises a first end, a second end, a third end, and a fourth end. The second switch comprises a fifth end, a sixth end, and a seventh end. The first end connects to the first radio frequency circuit. The second end connects to the second radio frequency circuit. The third end connects to the first antenna. The fourth end connects to the fifth end. The sixth end connects to the third radio frequency circuit. The seventh end connects to the second antenna. The first switch is configured to connect the first end to the third end and to connect the second end to the fourth end, or to connect the first end to the fourth end and to connect the second end to the third end. The second switch is configured to connect either the fifth end or the sixth end to the seventh end.

## Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0005] The present invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:
[0006] FIG. **1** is a block diagram of a wireless communication device **100** in accordance with the embodiments of the present disclosure;
[0007] FIG. **2** is a schematic diagram illustrating one of the embodiments of the present disclosure;
[0008] FIG. **3** is a schematic diagram illustrating one of the embodiments of the present disclosure;
[0009] FIG. **4** is a schematic diagram illustrating one of the embodiments of the present disclosure;
[0010] FIG. **5** is a schematic diagram illustrating one of the embodiments of the present disclosure;
[0011] FIG. **6** is a block diagram of the wireless communication device in accordance with the embodiments of the present disclosure;
[0012] FIG. **7** is a block diagram of the wireless communication device in accordance with the

embodiments of the present disclosure; and

DETAILED DESCRIPTION OF THE INVENTION

[0013] The following description is made for the purpose of illustrating the general principles of the invention and should not be taken in a limiting sense. The scope of the invention is best determined by reference to the appended claims.

[0014] Refer to FIG. **1**, FIG. **1** is a block diagram of a wireless communication device **100** in accordance with the embodiments of the present disclosure. The wireless communication device **100** comprises a first radio frequency circuit **110**, a second radio frequency circuit **120**, a third radio frequency circuit **130**, a first switch **140**, a second switch **150**, a first antenna **160**, a second antenna **170**, and a controller **180**. The wireless communication device **100** may be incorporated or implemented in a cell phone, a tablet computer, a notebook computer, a desktop computer, a wearable device, or an internet of thing device.

[0015] The first radio frequency circuit **110**, the second radio frequency circuit **120**, and the third radio frequency circuit **130** are configured to generate, process, transmit, or receive radio frequency signals. In some embodiments, the first radio frequency circuit **110**, the second radio frequency circuit **120**, and the third radio frequency circuit **130** may comprise a filter, a modulator, a demodulator, an oscillator, and an amplifier. In some embodiments, the first radio frequency circuit **110**, the second radio frequency circuit **120**, and the third radio frequency circuit **130** are radio frequency integrated circuits or chips. In some embodiments, the first radio frequency circuit **110**, the second radio frequency circuit **120**, and the third radio frequency circuit **130** may respectively apply different wireless communication technologies or protocols, such as Wi-Fi, Bluetooth, or thread.

[0016] The first switch **140** comprises a first end **141**, a second end **142**, a third end **143**, and a fourth end **144**. The first switch **140** is configured to connect the first end **141** to the third end **143** and to connect the second end **142** to the fourth end **144**, or to connect the first end **141** to the fourth end **144** and to connect the second end **142** to the third end **143**. In other words, the first switch **140** is able to switch between two connection modes. One is to connect the first end **141** to the third end **143** and to connect the second end **142** to the fourth end **144**. Another one is to connect the first end **141** to the fourth end **144** and to connect the second end **142** to the third end **143**. In some embodiments, the first switch **140** is a double pole double throw (DPDT) switch.

[0017] The second switch **150** comprises a fifth end **151**, a sixth end **152**, and a seventh end **153**. The second switch **150** is configured to connect either the fifth end **151** or the sixth end **152** to the seventh end **153** (i.e. to connect one of the fifth end **151** and the sixth end **152** to the seventh end **153**). In other words, the second switch **150** is able to switch between two connection modes. One is to connect the fifth end **151** to the seventh end **153**. Another one is to connect the sixth end **152** to the seventh end **153**. In some embodiments, the second switch **150** is a single pole double throw (SPDT) switch.

[0018] The first antenna **160** and the second antenna **170** are configured to transmit or receive signals wirelessly. The controller **180** is configured to control the first switch **140** and the second switch **150**. For example, the controller **180** may control the first switch **140** and the second switch **150** to switch to one of the connection modes. In some embodiments, the first radio frequency circuit **110**, the second radio frequency circuit **120**, or the third radio frequency circuit **130** is configured to control the controller **180**. In other words, one of the first radio frequency circuit **110**, the second radio frequency circuit **120**, and the third radio frequency circuit **130** may be configured to control the controller **180**. As a non-limiting example, the second radio frequency circuit **120** may be configured to control the controller **180**. The second radio frequency circuit **120** may receive information from the first radio frequency circuit **110** and the third radio frequency circuit **130** and determine the connection modes of the first switch **140** and the second switch **150** based on the information. In some embodiments, the information comprises the state (e.g. active, idle, on, or, off) of the radio frequency circuit, or the signal strength (e.g. received signal strength indication

(RSSI), reference signal received power (RSRP), or other indicator) measured at the radio frequency circuit. In some embodiments, the radio frequency circuit which is configured to control the controller **180** may determine the connection mode based on the RSSI of the first antenna **160** and the second antenna **170**, so as to connect the radio frequency circuit which requires high data rate (e.g. Wi-Fi) to the antenna with high RSSI. In this way, higher performance can be achieved.

[0019] Refer to FIG. **2**, FIG. **2** is a schematic diagram illustrating one of the embodiments of the present disclosure. The embodiment shown in FIG. **2** may be applied or used in a scenario that the first radio frequency circuit **110** is turned off or idle. In the embodiment shown in FIG. **2**, the first switch **140** is configured to connect the first end **141** to the fourth end **144** and to connect the second end **142** to the third end **143**. The second switch **150** is configured to connect the sixth end **152** to the seventh end **153**. As a result, the second radio frequency circuit **120** is connected to the first antenna **160** through the first switch **140**, and the third radio frequency circuit **130** is connected to the second antenna **170** through the second switch **150**. The second radio frequency circuit **120** is configured to transmit or receive signals (such as a first signal) through the first antenna **160**. The third radio frequency circuit **130** is configured to transmit or receive signals (such as a second signal) through the second antenna **170**. In some embodiments, the second radio frequency circuit **120** and the third radio frequency circuit **130** are configured to transmit or receive signals using a frequency-division duplexing (FDD) way. In some embodiments, the second radio frequency circuit **120** and the third radio frequency circuit **130** are configured to transmit or receive signals using a 2×2 multiple-input multiple-output (MIMO).

[0020] Alternatively, the embodiment shown in FIG. **2** may be applied or used in a scenario that the received signal strength indication (RSSI) measured at the first radio frequency circuit **110** is higher than a threshold. In this scenario, the first radio frequency circuit **110** is configured to receive signals (such as a first signal) through the first antenna **160** or the second antenna **170**. The second radio frequency circuit **120** is configured to transmit or receive signals (such as a second signal) through the first antenna **160**. The third radio frequency circuit **130** is configured to transmit or receive signals (such as a third signal) through the second antenna **170**.

[0021] Specifically, comparing to the situation that the first end **141** connects to the third end **143**, the signal may experience a larger loss (or decline) when transmitted from the third end **143** to the first end **141** in the situation that the first end **141** doesn't connect to the third end **143**. However, although the signal may experience a large loss, the signal can still be transmitted from the third end **143** to the first end **141** if only the power of the signal is large enough. Similarly, the signal can still be transmitted from the seventh end **153** to the fifth end **151** if only the power of the signal is large enough. Thus, when the RSSI measured at the first radio frequency circuit **110** is large, the first radio frequency circuit **110** can receive signals (such as leakage signals) through the first antenna **160** or the second antenna **170**, even the first end **141** doesn't connect to the third end **143** and even the seventh end **153** doesn't connect to the fifth end **151**.

[0022] Refer to FIG. **3**, FIG. **3** is a schematic diagram illustrating one of the embodiments of the present disclosure. The embodiment shown in FIG. **3** may be applied or used in a scenario that the second radio frequency circuit **120** is turned off or idle. In the embodiment shown in FIG. **3**, the first switch is configured to connect the first end **141** to the third end **143** and to connect the second end **142** to the fourth end **144**. The second switch **150** is configured to connect the sixth end **152** to the seventh end **153**. As a result, the first radio frequency circuit **110** is connected to the first antenna **160** through the first switch **140**, and the third radio frequency circuit **130** is connected to the second antenna **170** through the second switch **150**. The first radio frequency circuit **110** is configured to transmit or receive signals (such as a first signal) through the first antenna **160**. The third radio frequency circuit **130** is configured to transmit or receive signals (such as a second signal) through the second antenna **170**. In some embodiments, the first radio frequency circuit **110** and the third radio frequency circuit **130** are configured to transmit or receive signals using a FDD way. In some embodiments, the first radio frequency circuit **110** and the third radio frequency circuit **130** are configured to transmit or receive signals using a 2×2 MIMO.

[0023] Alternatively, the embodiment shown in FIG. **3** may be applied or used in a scenario that the RSSI measured at the second radio frequency circuit **120** is higher than a threshold. In this scenario, the first radio frequency circuit **110** is configured to transmit or receive signals (such as a first signal) through the first antenna **160**. The second radio frequency circuit **120** is configured to receive signals (such as a second signal) through the first antenna **160** or the second antenna **170** (the leakage signal). The third radio frequency circuit **130** is configured to transmit or receive signals (such as a third signal) through the second antenna **170**.

[0024] Refer to FIG. **4**, FIG. **4** is a schematic diagram illustrating one of the embodiments of the present disclosure. The embodiment shown in FIG. **4** may be applied or used in a scenario that the third radio frequency circuit **130** is turned off or idle. In the embodiment shown in FIG. **4**, the first switch **140** is configured to connect the first end **141** to the third end **143** and to connect the second end **142** to the fourth end **144**. The second switch **150** is configured to connect the fifth end **151** to the seventh end **153**. As a result, the first radio frequency circuit **110** is connected to the first antenna **160** through the first switch **140**, and the second radio frequency circuit **120** is connected to the second antenna **170** through the first switch **140** and the second switch **150**. The first radio frequency circuit **110** is configured to transmit or receive signals (such as a first signal) through the first antenna **160**. The second radio frequency circuit **120** is configured to transmit or receive signals (such as a second signal) through the second antenna **170**. In some embodiments, the first radio frequency circuit **110** and the second radio frequency circuit **120** are configured to transmit or receive signals using a FDD way. In some embodiments, the first radio frequency circuit **110** and the second radio frequency circuit **120** are configured to transmit or receive signals using a 2×2 MIMO.

[0025] Alternatively, the embodiment shown in FIG. **4** may be applied or used in a scenario that the RSSI measured at the third radio frequency circuit **130** is higher than a threshold. In this scenario, the first radio frequency circuit **110** is configured to transmit or receive signals (such as a first signal) through the first antenna **160**. The second radio frequency circuit **120** is configured to transmit or receive signals (such as a second signal) through the second antenna **170**. The third radio frequency circuit **130** is configured to receive signals (such as a third signal) through the second antenna **170** (the leakage signal).

[0026] Refer to FIG. **5**, FIG. **5** is a schematic diagram illustrating one of the embodiments of the present disclosure. The embodiment shown in FIG. **5** may be applied or used in a scenario that the third radio frequency circuit **130** is turned off or idle. In the embodiment shown in FIG. **5**, the first switch **140** is configured to connect the first end **141** to the fourth end **144** and to connect the second end **142** to the third end **143**. The second switch **150** is configured to connect the fifth end **151** to the seventh end **153**. As a result, the first radio frequency circuit **110** is connected to the second antenna **170** through the first switch **140** and the second switch **150**, and the second radio frequency circuit **120** is connected to the first antenna **160** through the first switch **140**. The first radio frequency circuit **110** is configured to transmit or receive signals (such as a first signal) through the second antenna **170**. The second radio frequency circuit **120** is configured to transmit or receive signals (such as a second signal) through the first antenna **160**. In some embodiments, the first radio frequency circuit **110** and the second radio frequency circuit **120** are configured to transmit or receive signals using a FDD way. In some embodiments, the first radio frequency circuit **110** and the second radio frequency circuit **120** are configured to transmit or receive signals using a 2×2 MIMO.

[0027] Alternatively, the embodiment shown in FIG. **5** may be applied or used in a scenario that the RSSI measured at the third radio frequency circuit **130** is higher than a threshold. In this scenario, the first radio frequency circuit **110** is configured to transmit or receive signals (such as a first signal) through the second antenna **170**. The second radio frequency circuit **120** is configured to transmit or receive signals (such as a second signal) through the first antenna **160**. The third radio frequency circuit **130** is configured to receive signals (such as a third signal) through the second antenna **170** (the leakage signal).

[0028] Refer to FIG. **6**, FIG. **6** is a block diagram of the wireless communication device **100** in accordance with the embodiments of the present disclosure. In the embodiment shown in FIG. **6**, the first radio frequency circuit **110** comprises a first communication module **111**, a second communication module **112**, and a diplexer **113**. The diplexer **113** comprises a first diplexer input end **1131**, a second diplexer input end **1132**, and a diplexer output end **1133**. The first diplexer input end **1131** and the second diplexer input end **1132** connect to the diplexer output end **1133**. The first communication module **111** connects to the first diplexer input end **1131**. The second communication module **112** connects to the second diplexer input end **1132**. The diplexer output end **1133** connects to the first end **141** of the first switch **140**.

[0029] The first communication module **111** and the second communication module **112** are configured to generate, process, transmit, or receive radio frequency signals. In some embodiments, the first communication module **111** and the second communication module **112** correspond to different bands. For example, the first communication module **111** and the second communication module **112** correspond to different Wi-Fi bands (such as 2.4 GHZ, and 5 GHz). In other words, the frequencies of the signals transmitted or received through the first communication module **111** and the second communication module **112** may be different. In some embodiments, the first communication module **111** and the second communication module **112** are hardware circuits or modules incorporated in the first radio frequency circuit **110**.

[0030] The diplexer **113** is configured to combine the signals from the first diplexer input end **1131** and the second diplexer input end **1132** to generate a combined signal and output the combined signal on the diplexer output end **1133**. The diplexer **113** is further configured to separate the signal from the diplexer output end **1133** to generate two signals and respectively output the two signal on the first diplexer input end **1131** and the second diplexer input end **1132**.

[0031] Refer to FIG. **7**, FIG. **7** is a block diagram of the wireless communication device **100** in accordance with the embodiments of the present disclosure. In the embodiment shown in FIG. **7**, the wireless communication device **100** further comprises a diplexer **190**. The diplexer **190** comprises a first diplexer input end **191**, a second diplexer input end **192**, and a diplexer output end **193**. The first diplexer input end **191** and the second diplexer input end **192** connect to the diplexer output end **193**. Moreover, the first radio frequency circuit **110** comprises a first communication module **111** and a second communication module **112**. The first communication module **111** connects to the first diplexer input end **191**. The second communication module **112** connects to the first end **141** of the first switch **140**. The third end **143** of the first switch **140** connects to the second diplexer input end **192**, and the diplexer output end **193** connects to the first antenna **160**. Thus, the first radio frequency circuit **110** and the first switch **140** connects to the first antenna **160** through the diplexer **190**. The first communication module **111** and the second communication module **112** have been described refer to FIG. **6**. Furthermore, the diplexer **190** is similar to the diplexer **113** in FIG. **6**.

[0032] The wireless communication device in accordance to embodiments of the present disclosure can fully use every antenna even when some of the radio frequency circuits are idle or turned off. When some of the radio frequency circuits are idle or turned off, the antenna can connect to other active radio frequency circuits through the switches. It should be noted that the present invention is not limited to the case that three radio frequency circuits share two antennas but is able to applied to the case that N radio frequency circuits share M antennas (N>M).

[0033] While the invention has been described by way of example and in terms of the preferred embodiments, it should be understood that the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

## Claims

**1**. A wireless communication device, comprising: a first radio frequency circuit; a second radio frequency circuit; a third radio frequency circuit; a first antenna; a second antenna; a first switch, comprising a first end, a second end, a third end, and a fourth end; and a second switch, comprising a fifth end, a sixth end, and a seventh end; wherein: the first end connects to the first radio frequency circuit; the second end connects to the second radio frequency circuit; the third end connects to the first antenna; the fourth end connects to the fifth end; the sixth end connects to the third radio frequency circuit; the seventh end connects to the second antenna; the first switch is configured to connect the first end to the third end and to connect the second end to the fourth end, or to connect the first end to the fourth end and to connect the second end to the third end; and the second switch is configured to connect the fifth end or the sixth end to the seventh end.
**2**. The wireless communication device as claimed in claim 1, wherein when the first radio frequency circuit is turned off or idle: the first switch is configured to connect the first end to the fourth end and to connect the second end to the third end; the second switch is configured to connect the sixth end to the seventh end; the second radio frequency circuit is configured to transmit or receive a first signal through the first antenna; and the third radio frequency circuit is configured to transmit or receive a second signal through the second antenna.
**3**. The wireless communication device as claimed in claim 1, wherein when the received signal strength indication (RSSI) measured at the first radio frequency circuit is higher than a threshold: the first switch is configured to connect the first end to the fourth end and to connect the second end to the third end; the second switch is configured to connect the sixth end to the seventh end; the first radio frequency circuit is configured to receive a first signal through the first antenna or the second antenna; the second radio frequency circuit is configured to transmit or receive a second signal through the first antenna; and the third radio frequency circuit is configured to transmit or receive a third signal through the second antenna.
**4**. The wireless communication device as claimed in claim 1, wherein when the second radio frequency circuit is turned off or idle: the first switch is configured to connect the first end to the third end and to connect the second end to the fourth end; the second switch is configured to connect the sixth end to the seventh end; the first radio frequency circuit is configured to transmit or receive a first signal through the first antenna; and the third radio frequency circuit is configured to transmit or receive a second signal through the second antenna.
**5**. The wireless communication device as claimed in claim 1, wherein when the received signal strength indication (RSSI) measured at the second radio frequency circuit is higher than a threshold: the first switch is configured to connect the first end to the third end and to connect the second end to the fourth end; the second switch is configured to connect the sixth end to the seventh end; the first radio frequency circuit is configured to transmit or receive a first signal through the first antenna; the second radio frequency circuit is configured to receive a second signal through the first antenna or the second antenna; and the third radio frequency circuit is configured to transmit or receive a third signal through the second antenna.
**6**. The wireless communication device as claimed in claim 1, wherein when the third radio frequency circuit is turned off or idle: the first switch is configured to connect the first end to the third end and to connect the second end to the fourth end; the second switch is configured to connect the fifth end to the seventh end; the first radio frequency circuit is configured to transmit or receive a first signal through the first antenna; and the second radio frequency circuit is configured to transmit or receive a second signal through the second antenna.
**7**. The wireless communication device as claimed in claim 1, wherein when the received signal

strength indication (RSSI) measured at the third radio frequency circuit is higher than a threshold: the first switch is configured to connect the first end to the third end and to connect the second end to the fourth end; the second switch is configured to connect the fifth end to the seventh end; the first radio frequency circuit is configured to transmit or receive a first signal through the first antenna; the second radio frequency circuit is configured to receive a second signal through the second antenna; and the third radio frequency circuit is configured to receive a third signal through the second antenna.

**8**. The wireless communication device as claimed in claim 1, wherein when the third radio frequency circuit is turned off or idle: the first switch is configured to connect the first end to the fourth end and to connect the second end to the third end; the second switch is configured to connect the fifth end to the seventh end; the first radio frequency circuit is configured to transmit or receive a first signal through the second antenna; and the second radio frequency circuit is configured to transmit or receive a second signal through the first antenna.

**9**. The wireless communication device as claimed in claim 1, wherein when the received signal strength indication (RSSI) measured at the third radio frequency circuit is higher than a threshold: the first switch is configured to connect the first end to the fourth end and to connect the second end to the third end; the second switch is configured to connect the fifth end to the seventh end; the first radio frequency circuit is configured to transmit or receive a first signal through the second antenna; the second radio frequency circuit is configured to transmit or receive a second signal through the first antenna; and the third radio frequency circuit is configured to receive a third signal through the second antenna.

**10**. The wireless communication device as claimed in claim 1, wherein the first radio frequency circuit comprises: a diplexer, comprising a first diplexer input end, a second diplexer input end, and a diplexer output end, wherein the first diplexer input end and the second diplexer input end connect to the diplexer output end; a first communication module, connected to the first diplexer input end; and a second communication module, connected to the second diplexer input end; wherein the diplexer output end connects to the first end of the first switch.

**11**. The wireless communication device as claimed in claim 1, further comprising: a diplexer, comprising a first diplexer input end, a second diplexer input end, and a diplexer output end, wherein the first diplexer input end and the second diplexer input end connect to the diplexer output end; wherein the first radio frequency circuit comprises: a first communication module, connected to the first diplexer input end; and a second communication module, connected to the first end of the first switch; wherein the third end of the first switch connects to the second diplexer input end, and the diplexer output end connects to the first antenna.

**12**. The wireless communication device as claimed in claim 1, further comprising: a controller, configured to control the first switch and the second switch.

**13**. The wireless communication device as claimed in claim 12, wherein the first radio frequency circuit, second radio frequency circuit, or third radio frequency circuit is configured to control the controller.

**14**. The wireless communication device as claimed in claim 1, wherein the first switch is a double pole double throw (DPDT) switch, and the second switch is a single pole double throw (SPDT) switch.