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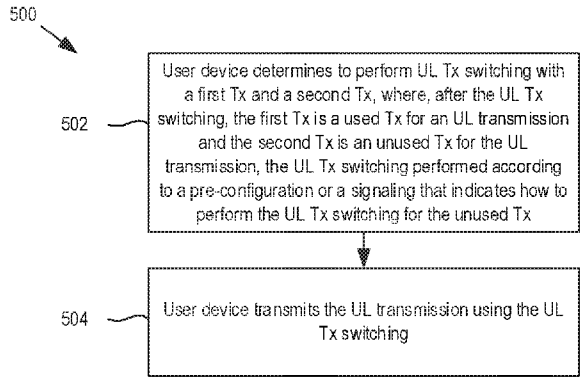

FIG. 5

(57) Abstract: This document generally relates to wireless communication involving a user device that determines to perform an uplink (UL) transmitter (Tx) switching with a first Tx and a second Tx, where, after the UL Tx switching, the first Tx is a used Tx and the second Tx is an unused Tx. The UL Tx switching is performed according to a pre-configuration or a signaling that indicates how to perform the UL Tx switching for the unused Tx. Also, a network device determines a band pair pattern or a band pair for a user device to perform UL Tx switching. The network device transmits a MAC-CE, DCI, RRC signaling to indicate or configure the band pair pattern or band pair. A user device receives the band pair pattern or band pair, and transmits an UL transmission using the UL Tx switching according to the band pair pattern or the band pair.

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TRANSMITTER SWITCHING AND BAND PAIR PATTERNS FOR WIRELESS COMMUNICATIONS

TECHNICAL FIELD

This document is directed generally to transmitter switching and band pair patterns in wireless communication.

BACKGROUND

In wireless communication, a user device may perform uplink (UL) transmitter (Tx) switching within up to two bands. In addition, for multi-carrier operation, a user device that transmits with two transmitters (also called a 2Tx user device), may transmit in at most two UL bands. Which two bands that are used may only be changed by radio resource control (RRC) reconfiguration. In addition, a 2Tx user device may only perform UL Tx switching between two UL bands. However, current UL Tx switching schemes may not allow a user device to perform UL Tx switching with three or four bands and simultaneous transmission with two transmitters, to enable more configured UL bands than its simultaneous transmission capability, and/or to support dynamic Tx carrier switching across configured bands. UL Tx switching schemes that overcome these deficiencies may be desirable.

SUMMARY

This document relates to methods, systems, apparatuses and devices for wireless communication. In some implementations, a method for wireless communication includes: determining, by the user device, to perform uplink (UL) transmitter (Tx) switching with a first Tx and a second Tx, where, after the UL Tx switching, the first Tx is a used Tx for an UL transmission and the second Tx is an unused Tx for the UL transmission, wherein the UL Tx switching is performed according to a pre-configuration or a signaling that indicates how to perform the UL Tx switching for the unused Tx; and transmitting, by the user device, the UL transmission after the UL Tx switching.

In some other implementations, a method for wireless communication includes: determining, by a network device, a band pair pattern or a band pair for one or more user devices to perform an uplink (UL) transmitter (Tx) switching; and transmitting, by the network device, a medium access control control element (MAC-CE), a downlink control information (DCI), or radio resource control (RRC) signaling to indicate or configure the band pair pattern or the band pair.

In some other implementations, a method for wireless communication includes: receiving, by a user device, a medium access control control element (MAC-CE), a downlink control information (DCI), or radio resource control (RRC) signaling indicating or configuring a band pair pattern or a band pair for an uplink (UL) transmitter (Tx) switching; and transmitting, by the user device, an UL transmission using the UL Tx switching according to the band pair pattern or the band pair.

In some other implementations, a device, such as a network device, is disclosed. The device may include one or more processors and one or more memories, wherein the one or more processors are configured to read computer code from the one or more memories to implement any of the methods above.

In yet some other implementations, a computer program product is disclosed. The computer program product may include a non-transitory computer-readable program medium with computer code stored thereupon, the computer code, when executed by one or more processors, causing the one or more processors to implement any of the methods above.

The above and other aspects and their implementations are described in greater detail in the drawings, the descriptions, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a block diagram of an example of a wireless communication system.

FIG. 2 shows a block diagram of an example configuration of transceiver and antenna components of a user device of FIG. 1.

FIG. 3 shows a block diagram illustrating relationships between carriers, bands, and cells.

FIG. 4 shows a diagram of transmitter (Tx) switching between cells on bands.

FIG. 5 shows a flow chart of an example method of wireless communication related to uplink (UL) Tx switching.

FIG. 6 shows a diagram of an example slot frame structure for three bands.

FIG. 7 shows a diagram of an example slot frame structure for four bands.

FIG. 8 shows a flow chart of an example method of wireless communication related to band pairs and/or band pair patterns.

FIG. 9 shows a flow chart of another example method of wireless communication related to band pairs and/or band pair patterns.

FIG. 10 shows a diagram of another example slot frame structure for four bands.

DETAILED DESCRIPTION

The present description describes various embodiments of systems, apparatuses, devices, and methods for wireless communications related to uplink (UL) transmitter (Tx) switching and band pair patterns.

Fig. 1 shows a diagram of an example wireless communication system 100 including a plurality of communication nodes (or just nodes) that are configured to wirelessly communicate with each other. In general, the communication nodes include at least one user device 102 and at least one network device 104. The example wireless communication system 100 in Fig. 1 is shown as including two user devices 102, including a first user device 102(1) and a second user device 102(2), and one device 104. However, various other examples of the wireless communication system 100 that include any of various combinations of one or more user devices 102 and/or one or more network devices 104 may be possible.

In general, a user device as described herein, such as the user device 102, may include a single electronic device or apparatus, or multiple (e.g., a network of) electronic devices or apparatuses, capable of communicating wirelessly over a network. A user device may comprise or otherwise be referred to as a user terminal, a user terminal device, or a user equipment (UE). Additionally, a user device may be or include, but not limited to, a mobile device (such as a mobile phone, a smart phone, a smart watch, a tablet, a laptop computer, vehicle or other vessel (human, motor, or engine-powered, such as an automobile, a plane, a train, a ship, or a bicycle as non-limiting examples) or a fixed or stationary device, (such as a desktop computer or other computing device that is not ordinarily moved for long periods of time, such as appliances, other relatively heavy devices including Internet of things (IoT), or computing devices used in commercial or industrial environments, as non-limiting examples). In various embodiments, a user device 102 may include transceiver circuitry 106 coupled to an antenna 108 to effect wireless communication with the network device 104. The transceiver circuitry 106 may also be coupled to a processor 110, which may also be coupled to a memory 112 or other storage device. The memory 112 may store therein instructions or code that, when read and executed by the processor 110, cause the processor 110 to implement various ones of the methods described herein.

Additionally, in general, a network device as described herein, such as the network device 104, may include a single electronic device or apparatus, or multiple (e.g., a network of) electronic devices or apparatuses, and may comprise one or more wireless access nodes, base stations, or other wireless network access points capable of communicating wirelessly over a network with one or more user devices and/or with one or more other network devices 104. For example, the network device 104 may comprise a 4G LTE base station, a 5G NR base station, a 5G central-unit base station, a 5G distributed-unit base station, a next generation Node B (gNB), an enhanced Node B (eNB), or other similar or next-generation (e.g., 6G) base stations, in various embodiments. A network device 104 may include transceiver circuitry 114 coupled to an antenna 116, which may include an antenna tower 118 in various approaches, to effect wireless communication with the user device 102 or another network device 104. The transceiver circuitry 114 may also be coupled to one or more processors 120, which may also be coupled to a memory 122 or other storage device. The memory 122 may store therein instructions or code that, when read and executed by the processor 120, cause the processor 120 to implement one or more of the methods described herein.

In various embodiments, two communication nodes in the wireless system 100—such as a user device 102 and a network device 104, two user devices 102 without a network device 104, or two network devices 104 without a user device 102—may be configured to wirelessly communicate with each other in or over a mobile network and/or a wireless access network according to one or more standards and/or specifications. In general, the standards and/or specifications may define the rules or procedures under which the communication nodes can wirelessly communicate, which, in various embodiments, may include those for communicating in millimeter (mm)-Wave bands, and/or with multi-antenna schemes and beamforming functions. In addition or alternatively, the standards and/or specifications are those that define a radio access technology and/or a cellular technology, such as Fourth Generation (4G) Long Term Evolution (LTE), Fifth Generation (5G) New Radio (NR), or New Radio Unlicensed (NR-U), as non-limiting examples.

Additionally, in the wireless system 100, the communication nodes are configured to wirelessly communicate signals between each other. In general, a communication in the wireless system 100 between two communication nodes can be or include a transmission or a reception, and is generally both simultaneously, depending on the perspective of a particular node in the communication. For example, for a given communication between a first node and a second node where the first node is transmitting a signal to the second node and the second node is receiving the signal from the first node, the first node may be referred to as a source or transmitting node or device, the second node may be referred to as a destination or receiving node or device, and the communication may be considered a transmission for the first node and a reception for the second node. Of course, since communication nodes in a wireless system 100 can both send and receive signals, a single communication node may be both a transmitting/source node and a receiving/destination node simultaneously or switch between being a source/transmitting node and a destination/receiving node.

Also, particular signals can be characterized or defined as either an uplink (UL) signal, a downlink (DL) signal, or a sidelink (SL) signal. An uplink signal is a signal transmitted from a user device 102 to a network device 104. A downlink signal is a signal transmitted from a network device 104 to a user device 102. A sidelink signal is a signal transmitted from a one user device 102 to another user device 102, or a signal transmitted from one network device 104 to a another

network device 104. Also, for sidelink transmissions, a first/source user device 102 directly transmits a sidelink signal to a second/destination user device 102 without any forwarding of the sidelink signal to a network device 104.

Additionally, signals communicated between communication nodes in the system 100 may be characterized or defined as a data signal or a control signal. In general, a data signal is a signal that includes or carries data, such multimedia data (e.g., voice and/or image data), and a control signal is a signal that carries control information that configures the communication nodes in certain ways in order to communicate with each other, or otherwise controls how the communication nodes communicate data signals with each other. Also, certain signals may be defined or characterized by combinations of data/control and uplink/downlink/sidelink, including uplink control signals, uplink data signals, downlink control signals, downlink data signals, sidelink control signals, and sidelink data signals.

For at least some specifications, such as 5G NR, data and control signals are transmitted and/or carried on physical channels. Generally, a physical channel corresponds to a set of time-frequency resources used for transmission of a signal. Different types of physical channels may be used to transmit different types of signals. For example, physical data channels (or just data channels), also herein called traffic channels, are used to transmit data signals, and physical control channels (or just control channels) are used to transmit control signals. Example types of traffic channels (or physical data channels) include, but are not limited to, a physical downlink shared channel (PDSCH) used to communicate downlink data signals, a physical uplink shared channel (PUSCH) used to communicate uplink data signals, and a physical sidelink shared channel (PSSCH) used to communicate sidelink data signals. In addition, example types of physical control channels include, but are not limited to, a physical downlink control channel (PDCCH) used to communicate downlink control signals, a physical uplink control channel (PUCCH) used to communicate uplink control signals, and a physical sidelink control channel (PSCCH) used to communicate sidelink control signals. As used herein for simplicity, unless specified otherwise, a particular type of physical channel is also used to refer to a signal that is transmitted on that particular type of physical channel, and/or a transmission on that particular type of transmission. As an example illustration, a PDSCH refers to the physical downlink shared channel itself, a downlink data signal transmitted

on the PDSCH, or a downlink data transmission. Accordingly, a communication node transmitting or receiving a PDSCH means that the communication node is transmitting or receiving a signal on a PDSCH.

Additionally, for at least some specifications, such as 5G NR, and/or for at least some types of control signals, a control signal that a communication node transmits may include control information comprising the information necessary to enable transmission of one or more data signals between communication nodes, and/or to schedule one or more data channels (or one or more transmissions on data channels). For example, such control information may include the information necessary for proper reception, decoding, and demodulation of a data signals received on physical data channels during a data transmission, and/or for uplink scheduling grants that inform the user device about the resources and transport format to use for uplink data transmissions. In some embodiments, the control information includes downlink control information (DCI) that is transmitted in the downlink direction from a network device 104 to a user device 102. In other embodiments, the control information includes uplink control information (UCI) that is transmitted in the uplink direction from a user device 102 to a network device 104, or sidelink control information (SCI) that is transmitted in the sidelink direction from one user device 102(1) to another user device 102(2).

In addition, in some embodiments, a user device 102 may be configured to support at least one simultaneous UL transmission mode across a band pair for UL transmissions. In a first simultaneous UL transmission mode (also called a switchedUL mode), the user device 102 does not support simultaneous UL transmission across a band pair. Accordingly, when the user device 102 transmits an UL transmission in the first simultaneous UL transmission mode, the user device 102 transmits the UL transmission without simultaneously transmitting across a band pair. In addition, in a second simultaneous UL transmission mode (also called a dualUL mode), the user device 102 supports simultaneous UL transmission across a band pair. Accordingly, when the user device 102 transmits an UL transmission in the second simultaneous UL transmission mode, the user device 102 may transmit the UL transmission by simultaneously transmitting across a band pair.

Also, for at least some embodiments, as used herein, the first and second UL simultaneous transmission modes may be referred to as, or otherwise correspond to, carrier aggregation (CA)

options. For example, the first simultaneous UL transmission (or switchedUL) mode may also be referred to, or correspond to, a first CA option or a switchedUL CA option. The second simultaneous UL transmission (or dualUL) mode may also be referred to, or correspond to, a second CA option or a dualUL CA option. Correspondingly, when a user device 102 operates with the switchedUL CA option, the user device 102 does not support and/or perform simultaneous UL transmission across a band pair. When a user device 102 operates with the dualUL CA option, the user device 102 supports and/or performs simultaneous UL transmission across a band pair.

Also, in some embodiments, the user device 102 may report the simultaneous UL transmission mode(s) to the network device 104. That is, the user device 102 may report, to the network device 104, that it supports simultaneous UL transmission across a band pair, that it does not support simultaneous UL transmission across a band pair, or that it both supports and does not support simultaneous UL transmission across a band pair. In particular of these embodiments, the user device 102 may report whether or not it supports simultaneous UL transmission across a band pair per Band Combination (BC). Also, the network device 104 may configured the simultaneous UL transmission mode (e.g., switchedUL or dualUL) per cell group, which may be considered as per BC or per band pair in embodiments where a 2Tx user device supports only two bands. That is, one available band pair in a Band Combination may support one simultaneous UL transmission mode.

Additionally, in general as used herein, a Band Combination may include a plurality of bands (e.g., five bands). In addition, as used herein, a band group may include up to three or four bands. A given band group may be included in or part of a Band Combination. Also, a Band Combination and/or a band group may include at least one band pair, where a band pair includes two bands.

Fig. 2 shows a block diagram of an example configuration of the transceiver 106 and the antenna 108. In particular, the transceiver 106 includes a first transmitter circuit 202(1) and a second transmitter circuit 202(2). In addition, the antenna 108 may include a first antenna component 204(1) and a second antenna component 204(2). In general, the first transmitter circuit 202(1) and the first antenna component 204(1) may form a first transmitter channel or chain, and the second transmitter circuit 202(2) and the second antenna component 204(2) may form a second transmitter channel or chain. A user device 102, with the configuration in Fig. 2, may be configured

to transmit a first UL transmission (or a first part of an UL transmission) using the first transmitter channel, and may be configured to transmit a second UL transmission (or a second part of a UL transmission) using the first transmitter channel. Also, as used herein, and unless specified otherwise, the term "transmitter" is used to refer to a transmitter circuit alone, an antenna component alone, or a combination of a transmitter circuit and an antenna component (i.e., a transmitter channel or chain).

Additionally, in various embodiments, the user device 102 may use the two transmitter channels to transmit on one or two bands or carriers. The user device 102 may do so in any of various ways. For example, the user device 102 may transmit on a single carrier using both the first transmit channel and the second transmit channel. As another example, the user device 102 may transmit on a first carrier using the first transmit channel and on a second carrier using the second transmit channel. As used herein, the terms "1 Tx" and "1T" refer to use of one channel to transmit on one carrier, and the terms "2 Tx" and "2T" refer to the use of two transmit channels to transmit on one carrier.

In addition, as used herein, the phrase "UL transmit case" refers to a particular configuration of the transmit channels used for an UL transmission on one or more carriers. Also, as described in further detail below, the user device 102 may switch between UL transmit cases during an UL Tx switching operation. Table 1 below lists two example UL transmit cases, Case 1 and Case 2.

Case 1	1 Tx on carrier 1 and 1 Tx on carrier 2
Case 2	0 Tx on carrier 1 and 2 Tx on carrier 2

Table 1: Example of UL Transmit Cases

Table 1 shows that for a first UL transmit case (Case 1), the user device 102 transmits an UL transmission on two carriers, using one transmit channel (1 Tx) for each carrier, such as by using a first transmitter to transmit on a first carrier (carrier 1) and a second transmitter to transmit on a second carrier (carrier 2). In addition, Table 1 shows that for a second UL transmit case (Case 2), the user device 102 transmits an UL transmission on only one carrier, using two

transmitters (2 Tx) to transmit on the second carrier. For this second case, the user device 102 does not use any transmit channels to transmit on the first carrier.

In addition, in various embodiments, the user device 102 may perform UL transmitter (Tx) switching to perform UL transmissions. In general, the user device 102 may perform UL Tx switching by switching from one UL transmit case to another UL transmit case. In operation, the user device 102 may transmit an UL transmission according to a first UL transmit case, and then may switch from the first UL transmit case to a second UL transmit case, and transmit an UL transmission according to the second UL transmit case. To illustrate, using Table 1 for example, the user device may transmit an UL transmission according to Case 1, such as by transmitting on the first carrier using the first transmitter and transmitting on the second carrier using the second transmitter. Then, the user device 102 may switch from Case 1 to Case 2, and then transmit an UL transmission according to Case 2, such as by transmitting on the second carrier using both the first and second transmitters.

In various embodiments, such as with reference to Table 1, the type of UL Tx switching that the user device 102 performs may be referred to as 1Tx-2Tx switching. For 1Tx-2Tx switching, the user device 102 may switch from using one transmitter to transmit on a carrier to using two transmitters to transmit on a carrier, or may switch from using two transmitters to one transmitter to transmit on a channel.

In addition, in various embodiments, UL transmit cases may also identify numbers of antenna ports corresponding to the carriers. The identification may be in the form of a mapping between carriers and respective numbers of antenna ports. For at least some of these embodiments, the numbers of antennas may depend on whether or not the user device 102 supports simultaneous transmission across a band pair. Table 2 shows example UL transmit cases when simultaneous transmission across a band pair is not supported, and further when the user device 102 applies carrier aggregation including a supplementary UL (SUL) band.

	Number of **Tx chains** in WID (carrier 1 + carrier 2)	Number of **antenna ports** for UL transmission (carrier 1 + carrier 2)
Case 1	1T+1T	1P+0P
Case 2	0T+2T	0P+2P, 0P+1P

Table 2: Example of UL Transmit Cases with Antenna Port Number Mapping where UE does not support simultaneous transmission across a band pair

In the example illustrated in Table 2, for a first UL transmit case (Case 1), the user device 102 transmits on the first carrier using the first transmitter, and transmits on the second carrier using the second transmitter. Also, based on that the user device 102 does not support simultaneous transmission across a band pair, the number of antenna ports for the UL transmission on the first carrier is one, and the number of antenna ports for the UL transmission on the second carrier is zero (1P+0P). Additionally, in the example illustrated in Table 2, for a second UL transmit case (Case 2), the user device 102 transmits on the second carrier using both the first and second transmitters. Also, based on that the user device 102 does not support simultaneous transmission across a band pair, the numbers of antenna ports for the two carriers can be one of two options. In a first option, the number of antenna ports for the first carrier is zero, and the number of antenna ports for the second carrier is two. In a second option, the number of antenna ports for the first carrier is zero, and the number of antenna ports for the second carrier is one.

Table 3 shows example UL transmit cases when simultaneous transmission across a band pair is supported.

	Number of **Tx chains** in WID (carrier 1 + carrier 2)	Number of **antenna ports** for UL transmission (carrier 1 + carrier 2)
Case 1	1T+1T	1P+0P, 1P+1P, 0P+1P
Case 2	0T+2T	0P+2P, 0P+1P

Table 3: Example of UL Transmit Cases with Antenna Port Number Mapping where UE supports simultaneous transmission across a band pair

In the example illustrated in Table 3, for a first UL transmit case (Case 1), the user device 102 transmits on the first carrier using the first transmitter, and transmits on the second carrier using the second transmitter. Also, based on that the user device 102 does support simultaneous transmission across a band pair, the number of antenna ports for the UL transmission can be one of three options. In a first option, the number of antenna ports for the first carrier is one, and the number of antenna ports for the second carrier is zero. In a second option, the numbers of antenna ports for the first and second carriers are each one. In a third option, the number of antenna ports

for the first carrier is zero, and the number of antenna ports for the second carrier is one. In a second UL transmit case, the user device 102 does not transmit on the first carrier with any transmitters, and transmits on the second carrier with two transmitters. Also, based on that the user device 102 does support simultaneous transmission across a band pair, the number of antenna ports for the UL transmission can be one of two options. In a first option, the number of antenna ports for the first carrier is zero, and the number of antenna ports for the second carrier is two. In a second option, the number of antenna ports for the first carrier is zero, and the number of antenna ports for the second carrier is one.

As mentioned above, the user device 102 may perform 1Tx-2Tx UL Tx switching, where the user device 102 switches between one and two transmitters for transmitting on a channel. Another type of UL Tx switching may include 2Tx-2Tx switching, where the user device 102 switches from using two transmitters to transmit on a carrier to using two transmitters to transmit on another carrier. Tables 4 and 5 below illustrate examples of 2Tx-2Tx UL Tx switching.

	Number of Tx chains in WID (carrier 1 + carrier 2)
Case 1	0T+2T
Case 2	2T+0T

Table 4: First Example of UL Transmit Cases for 2Tx-2Tx Switching

	Number of Tx chains in WID (carrier 1 + carrier 2)
Case 1	1T+1T
Case 2	0T+2T
Case 3	2T+0T

Table 5: Example of UL Transmit Cases combining 1Tx-2Tx and 2Tx-2Tx Switching

With reference to Table 4, in the first example of 2Tx-2Tx UL Tx switching, in a first transmit case (Case 1), the user device 102 transmits on a second carrier using two transmitters, and does not transmit on a first carrier with any transmitters. In a second transmit case (Case 2), the user device 102 transmits on the first carrier using two transmitters, and does not transmit on the second carrier with any transmitters. For the 2Tx-2Tx UL Tx switching, the user device 102

may switch from the first transmit case to the second transmit case, or may switch from the second transmit case to the first transmit case.

With reference to Table 5, the user device 102 may use a combination of 1Tx-2Tx switching and 2Tx-2Tx switching. For example, in Table 5, Case 1 corresponds to Case 1 in Table 2, and Cases 2 and 3 correspond to Cases 1 and 2 in Table 4, respectively. The user device 102 may perform 1Tx-2Tx switching by switching between Cases 1 and 2 and/or Cases 1 and 3, and may perform 2Tx-2Tx switching by switching between Cases 2 and 3.

Also, in various embodiments, UL transmit cases may also identify numbers of antenna ports corresponding to the carriers for 2Tx-2Tx switching, such as in the form of mapping between carriers and respective numbers of antenna ports, similar to Tables 2 and 3 above, which shows mapping between carriers and numbers of antenna ports for 1Tx-2Tx switching. The mappings may depend on whether the user device 102 supports or does not support simultaneous switching across a band pair. Table 6, below, shows example UL transmit cases with numbers of antenna ports mapping for 2Tx-2Tx switching where the user device 102 does not support simultaneous transmission across a band pair. Table 7, below, shows example UL transmit cases with numbers of antenna port mapping for 2Tx-2Tx switching where the user device 102 supports simultaneous transmission across a band pair.

	Number of **Tx chains** in WID (carrier 1 + carrier 2)	Number of **antenna ports** for UL transmission (carrier 1 + carrier 2)
Case 2	0T+2T	0P+2P, 0P+1P
Case 3	2T+0T	2P+0P, 1P+0P

Table 6: Example of UL Transmit Cases with Antenna Port Number Mapping for 2Tx-2Tx switching, where UE does not support simultaneous transmission across a band pair

	Number of **Tx chains** in WID (carrier 1 + carrier 2)	Number of **antenna ports** for UL transmission (carrier 1 + carrier 2)
Case 1	1T+1T	1P+0P, 1P+1P, 0P+1P
Case 2	0T+2T	0P+2P, 0P+1P

Case 3	2T+0T	2P+0P, 1P+0P

Table 7: Example of UL Transmit Cases with Antenna Port Number Mapping for combination of 1Tx-2Tx and 2Tx-2Tx switching, where UE supports simultaneous transmission across a band pair

Additionally, in various embodiments, the user device 102 may perform 1Tx-2Tx and/or 2Tx-2Tx UL Tx switching with respect to bands. For example, one carrier may be on one band (e.g., a Band A), and two carriers, such as two contiguous carriers, may be on another band (e.g., a Band B). For at least some of these embodiments, the band with the one carrier may be a supplementary UL (SUL) band, and the band with the two contiguous carriers may be a non-SUL or a normal UL (NUL) band. For at least some of these examples, the user device 102 may perform UL Tx switching between any two or three of the following cases for a first Band And a second band (i.e., Band A + Band B): Case 1: 1T + 1T; Case 2: 0T + 2T; Case 3: 2T + 0T.

Additionally, for embodiments where the user device 102 performs UL Tx switching with respect to bands, the UL transmit cases may identify numbers of antenna ports for the carriers of the bands, similar to Tables 2, 3, 6 and 7 above. Tables 8-11 show various UL transmit cases with of antenna port number mapping for two bands including three carriers, where a first band (Band A) includes one carrier and a second band (Band B) includes two contiguous carriers. Table 8 shows example UL transmit cases for 1Tx-2Tx UL Tx switching where the user device 102 does not support simultaneous transmission across a band pair. Table 9 shows example UL transmit cases for 1Tx-2Tx UL Tx switching where the user device 102 supports simultaneous transmission across a band pair. Table 10 shows example UL transmit cases for 2Tx-2Tx UL Tx switching where the user device 102 does not support simultaneous transmission across a band pair. Table 11 shows example UL transmit cases for 2Tx-2Tx UL Tx switching where the user device 102 supports simultaneous transmission across a band pair.

	Number of **Tx chains** in WID (Band A + Band B)	Number of **antenna ports** for UL transmission (Band A (carrier 1) + Band B (carrier 2 + carrier 3))
Case 1	1T+1T	1P+(0P+0P)

Case 2	0T+2T	0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P)

Table 8: Example UL transmit cases with Antenna Port Number Mapping for 1Tx-2Tx switching where UE does not support simultaneous transmission across a band pair

	Number of **Tx chains** in WID (Band A + Band B)	Number of **antenna ports** for UL transmission (Band A (carrier 1) + Band B (carrier 2 + carrier 3))
Case 1	1T+1T	1P+(0P+0P), 1P+(1P+0P), 1P+(0P+1P), 1P+(1P+1P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P)
Case 2	0T+2T	0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P)

Table 9: Example UL transmit cases with Antenna Port Number Mapping for 1Tx-2Tx switching where UE supports simultaneous transmission across a band pair

	Number of **Tx chains** in WID (Band A + Band B)	Number of **antenna ports** for UL transmission (Band A (carrier 1) + Band B (carrier 2 + carrier 3))
Case 2	0T+2T	0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P)
Case 3	2T+0T	2P+(0P+0P), 1P+(0P+0P)

Table 10: Example UL transmit cases with Antenna Port Number Mapping for 2Tx-2Tx switching where UE does not support simultaneous transmission across a band pair

	Number of **Tx chains** in WID (Band A + Band B)	Number of **antenna ports** for UL transmission (Band A (carrier 1) + Band B (carrier 2 + carrier 3))
Case 1	1T+1T	1P+(0P+0P), 1P+(1P+0P), 1P+(0P+1P), 1P+(1P+1P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P)
Case 2	0T+2T	0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P)
Case 3	2T+0T	2P+(0P+0P), 1P+(0P+0P)

Table 11: Example UL transmit cases with Antenna Port Number Mapping for 2Tx-2Tx switching where UE supports simultaneous transmission across a band pair

Also, in various embodiments, the user device 102 may be configured with three bands for which to perform UL Tx switching and within which to transmit UL transmissions. The three bands may include a first band (Band A), a second band (Band B), and a third band (Band C). For at least some of these embodiments, the user device 102 may dynamically select any two of these three bands to perform UL Tx switching. In various of these embodiments, the three bands may include various combination of SUL bands and normal or non-SUL (NUL) bands, examples of two scenarios are as follows.

In a first scenario (Scenario 1): Band A is a SUL band or a non-SUL band, Band B is a non-SUL band, and Band C is a SUL band or a non-SUL band. That is, Band C is similar as Band A. In one example of Scenario 1, Band A includes a first carrier (carrier 1), Band B includes a second carrier (carrier 2), and Band C includes a third carrier (carrier 3). In a second example of Scenario 1, Band A includes carrier 1, Band B includes carriers 2 and 3, and Band C includes a fourth carrier (carrier 4).

In a second scenario (Scenario 2), Band A is a SUL Band or a non-SUL Band, Band B is a non-SUL Band, and Band C is a non-SUL Band. That is, Band C is similar as Band B. In one example of Scenario 2, Band A includes carrier 1, Band B includes carrier 2, and Band C includes carriers 3 and 4. In a second example of Scenario 2, Band A includes carrier 1, Band B includes carriers 2 and 3, and Band C includes carrier 4 and a fifth carrier (carrier 5).

Additionally, in various other embodiments, the user device 102 may be configured with four bands, including a first band (Band A), a second band (Band B), a third band (Band C), and a fourth band (Band D), for which to perform UL Tx switching and within which to transmit UL transmissions. Similar to the three-Band Configurations, the user device 102 may dynamically select any two of the four bands to perform UL Tx switching. In various of these embodiments, the four bands may include various combinations of SUL and NUL bands, examples of two scenarios are as follows.

In a first scenario (Scenario 1), Band A is a SUL band or a non-SUL band, Band B is a non-SUL band, and Band C is a SUL band or a non-SUL band. That is, Band C is similar as Band A. In a first example of Scenario 1, band includes a first carrier (carrier 1), Band B includes a second carrier (carrier 2), Band C includes a third carrier (carrier 3), and Band D includes a fourth

carrier (carrier 4). In a second example of Scenario 1, Band A includes carrier 1, Band B includes carrier 2, Band C includes carrier 3, and Band D includes carrier 4 and a fifth carrier (carrier 5). In a third example of Scenario 1, Band A includes carrier 1, Band B includes carriers 2 and 3, Band C includes carrier 4, and Band D includes carrier 5. In a fourth example of Scenario 1, Band A includes carrier 1, Band B includes carriers 2 and 3, Band C includes carrier 4, and Band D includes carrier 5 and a sixth carrier (carrier 6).

In a second scenario (Scenario 2), Band A is a SUL band or a non-SUL band, Band B is a non-SUL band, and Band C is a non-SUL band. That is Band C is similar as Band B. In a first example of Scenario 2, Band A includes carrier 1, Band B includes carrier 2, Band C includes carriers 3 and 4, and band D includes carrier 5. In a second example of Scenario 2, Band A includes carrier 1, Band B includes carrier 2, Band C includes carriers 3 and 4, and band D includes carriers 5 and 6. In a third example of Scenario 2, Band A includes carrier 1, Band B includes carriers 2 and 3, Band C includes carriers 4 and 5, and band D includes carrier 6. In a fourth example of Scenario 2, Band A includes carrier 1, Band B includes carriers 2 and 3, Band C includes carriers 4 and 5, and band D includes carriers 6 and 7.

Also, for embodiments where the user device 102 performs dynamic Tx carrier switching across the configured bands, at least one of the following options. In a first option, the user device 102 may perform dynamic Tx carrier switching across all the supported UL transmission cases supported by the UE and based on UL scheduling, i.e., via UL grant and/or RRC configuration for UL transmission. In a second option, the network device 104 may indicate two bands out of the configured bands (3 or 4 bands) via DCI or medium access control (MAC) control element (CE). In a third option, the user device 102 may select one anchor Band Among the configured bands (3 or 4 bands), and may perform dynamic Tx carrier switching only from the anchor band to a non-anchor Band And/or from a non-anchor band to the anchor band.

Table 12 shows an example set of ten UL transmit cases for four bands with antenna port number mapping. The second column in Table 12 indicates the antenna port numbers for when the user device 102 does not support simultaneous transmission across multiple carriers, and the third column indicates the antenna port numbers for when the user device 102 supports simultaneous transmission across up to two carriers.

	Number of Tx chains in Band A, B, C and D	Number of antenna ports in Band A, B, C and D (no simultaneous transmission across multiple carriers)	Number of antenna ports in Band A, B, C and D (simultaneous transmission across up to 2 carriers)
Case 1	1T+1T+0T+0T	n/a	1P+0P+0P+0P, 1P+1P+0P+0P, 0P+1P+0P+0P
Case 2	0T+2T+0T+0T	0P+2P+0P+0P, 0P+1P+0P+0P	0P+2P+0P+0P, 0P+1P+0P+0P
Case 3	2T+0T+0T+0T	2P+0P+0P+0P, 1P+0P+0P+0P	2P+0P+0P+0P, 1P+0P+0P+0P
Case 4	1T+0T+1T+0T	n/a	1P+0P+0P+0P, 1P+0P+1P+0P, 0P+0P+1P+0P
Case 5	1T+0T+0T+1T	n/a	1P+0P+0P+0P, 1P+0P+0P+1P, 0P+0P+0P+1P
Case 6	0T+1T+1T+0T	n/a	0P+1P+0P+0P, 0P+1P+1P+0P, 0P+0P+1P+0P
Case 7	0T+1T+0T+1T	n/a	0P+1P+0P+0P, 0P+1P+0P+1P, 0P+0P+0P+1P
Case 8	0T+0T+1T+1T	n/a	0P+0P+1P+0P, 0P+0P+1P+1P, 0P+0P+0P+1P
Case 9	0T+0T+2T+0T	0P+0P+2P+0P, 0P+0P+1P+0P	0P+0P+2P+0P, 0P+0P+1P+0P
Case 10	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P	0P+0P+0P+2P, 0P+0P+0P+1P

Table 12: Example UL Transmit Cases for 4 bands with antenna port number mapping, where the UE does not support simultaneous transmission across multiple carriers and does support simultaneous transmission across up to two carriers

For embodiments where the user device 102 supports all UL transmit cases (e.g., all ten UL transmit cases in Table 12) in accordance with the first option above, the user device 102 may switch between any two UL transmit cases without any additional restrictions. For example, suppose a current transmit state of the user device 102 is to transmit on two carriers on two bands using one transmitter to transmit on each band, and the user device 102 is to switch two different carriers on two different bands but still using one transmitter to transmit on each band. For example, the user device 102 may switch from Case 1 to Case 8. Corresponding to Cases 1 and 8 in Table 12, the user device 102 may transmit a first transmission on carrier 1 in cell 1 and on carrier 2 in cell 2 (Case 1), and then switch and transmit a second transmission on carrier 3 in cell 3 and carrier 4 in cell 4 (Case 8). Correspondingly, Fig. 3 shows a one-to-one relationship between four bands, four carriers, and four cells.

Also, for at least some embodiments incorporating the second option above, where the network device 104 indicates a band pair out of the configured bands (3 or 4 bands), there may be no additional restrictions as to which band pairs are selected. For example, suppose there are six band pairs corresponding to a Band Combination having four bands. After the network device 104

selects a band pair and indicates them to the user device 102, the user device 102 may perform UL Tx switching to switch to the a band pair indicated by the network device 102. Any subsequent UL Tx switching may be within the indicated a band pair until a next indication from the network device 104. Fig. 4 illustrates an example. With reference to Fig. 4, a currently available band pair may include bands 1 and 2. Any UL Tx switching is performed within bands 1 and 2, e.g., between cell 1 on band 1 and cell 2 on band 2. At the network side, the network device 104 may select a band pair out of the four bands. For example, the network device 104 may select bands 3 and 4, and indicate the selected bands 3 and 4 to the user device 102, such as by way of a DCI or MAC CE. In response to the indication, the user device 102 may switch from bands 1 and 2 to bands 3 and 4. Thereafter, any switching by the user device 102 is within bands 3 and 4, e.g., between cell 3 on band 3 and cell 4 on band 4, until a next indication is received from the network device 104.

The following describes various embodiments related to performing UL Tx switching with an unused transmitter, and/or ways to reduce an amount of times band pair switching is indicated when there are one or more time division duplex (TDD) bands within a configured number (e.g., three or four) bands.

Fig. 5 is a flow chart of an example method 500 for wireless communication related to UL Tx switching. At block 502, a user device 102 may determine to perform uplink (UL) transmitter (Tx) switching with a first Tx and a second Tx, where, after the UL Tx switching, the first Tx is a used Tx for an UL transmission and a second Tx is an unused Tx for the UL transmission. The UL Tx switching is performed according to a pre-configuration or a signaling that indicates how to perform the UL Tx switching for the unused Tx. At block 504, the user device transmits the UL transmission using the UL Tx switching.

Embodiment 1

In further detail, in some embodiments for the method 500, a user device 102 may perform a previous UL transmission in a first transmit case. Then, the user device 102 may perform an UL Tx switching instance to switch from the first transmit case to a second transmit case. After the UL Tx switching instance is performed, the user device 102 may perform an UL transmission in the second transmit case. In a transmit case, each of the two transmitters of the user device 102 may be a used transmitter or an unused transmitter. A transmitter is a used transmitter when it transmits

on an antenna port during a transmission instance. Also, a transmitter is an unused transmitter when it does not transmit on an antenna port during a transmission instance. Accordingly, after the user device 102 performs the UL Tx switching instance and is in the second transmit case, one of the transmitters of the user device 102 may be an unused transmitter, either in switchedUL or dualUL. For at least some embodiments, including those where the user device 102 is able to perform dynamic UL Tx switching across all supported UL transmit cases and based on UL scheduled, such as via UL grant and/or radio resource control (RRC) configuration for UL transmission, the user device 102 may determine how to configure, move, switch, or operate an unused transmitter during UL Tx switching according to a pre-configuration (or predefined rule) or a signaling that indicates how to perform the UL Tx switching for the unused transmitter.

In addition, in various embodiments, a user device 102 performs UL Tx switching according to a UL Tx switching scheme across up to three or four bands, and/or with a restriction that it can perform up to 2 Tx simultaneous transmission. Suppose for example, that the user device 102 performs UL Tx switching across three bands, including a Band A, a Band B, and a Band C. Correspondingly, the user device 102 may perform UL Tx switching between six possible UL transmit cases, as indicated below in Table 13.

UL Transmit Cases	Number of Tx Chains (Band A + Band B + Band C)
Case 1-1	1T+1T+0T
Case 1-2	0T+1T+1T
Case 1-3	1T+0T+1T
Case 2-1	2T+0T+0T
Case 2-2	0T+2T+0T
Case 2-3	0T+0T+2T

Table 13: UL Transmit Cases within the scenario of up to 2 Tx on each band

As shown in Table 13, for UL Transmit Case 1-1, the user device 102 uses a first transmitter to transmit on Band A, a second transmitter to transmit on Band B, and no transmitters to transmit on Band C, for UL Transmit Case 1-2, the user device 102 uses a first transmitter to transmit on Band B, a second transmitter to transmit on Band C, and no transmitters to transmit on Band A, and so on. Correspondingly, for each UL transmit case, the two transmitters of the user device 102 are assigned to transmit on only one band (i.e., two transmitters on one band, such as in

transmit cases 2-1, 2-2, 2-3) or on two bands (i.e., one transmitter on each of two bands, such as in transmit cases 1-1, 1-2, 1-3).

Embodiment 1-1

Additionally, in various embodiment, the number of transmitters up to on which a given band may used may be specified and/or limited. For example, a given band may be limited to having only one or up to two transmitters transmit on it.

In one example, suppose three bands have a transmitter limit configuration of: 1T-1T-2T, that is a maximum number of supported Tx on three bands, Bands A, B, and C, are 1Tx, 1Tx and 2Tx, respectively, with one carrier on each band. In other embodiments, one or more bands may be also supported with two or more carriers. That is, both Band A and Band B are limited to have at most one transmitter, and Band C is limited to have at most two transmitters. The transmission switching option parameter, i.e. uplinkTxSwitchingOption, may be set to 'switchedUL', can be also named as CA option 1 as previously described, which means that the user device 102 does not support simultaneous transmission between or across two bands. Under the 'switchedUL' operation, the user device 102 may perform an UL transmission on one band of bands A, B, or C. Under this condition, the possible combinations of numbers of antenna ports for UL transmission for at least some of the entries in Table 13 are listed below in Tables 14-17. Also, in various embodiments, the switched UL can be regarded as not including the normal CA mode or including the normal CA mode. The normal CA mode means the maximum number of supported Tx on two bands A+B are 1Tx and 1Tx, then at least one of one port (1P) on Band A, 1P on Band B, and 1P+1P on band pair A+B can be supported.

Transmit cases	Number of Tx Chains (Band A + Band B + Band C)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-3	1T+0T+1T	1P+0P+0P,
Case 1-2	0T+1T+1T	0P+1P+0P
Case 2-3	0T+0T+2T	0P+0P+2P, 0P+0P+1P

Table 14: Example mapping for three bands with 1T-1T-2T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-1	1T+1T+0T	1P+0P+0P, 0P+1P+0P
Case 1-2	0T+1T+1T	0P+1P+0P
Case 1-3	1T+0T+1T	1P+0P+0P
Case 2-3	0T+0T+2T	0P+0P+2P, 0P+0P+1P

Table 15: Example mapping for three bands with 1T-1T-2T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-1	1T+1T+0T	1P+0P+0P, 0P+1P+0P
Case 1-2	0T+1T+1T	0P+1P+0P, 0P+0P+1P
Case 1-3	1T+0T+1T	1P+0P+0P, 0P+0P+1P
Case 2-3	0T+0T+2T	0P+0P+2P, 0P+0P+1P

Table 16: Example mapping for three bands with 1T-1T-2T in the SwitchedUL mode

Switching cases	Number of Tx Chains (Band A + Band B + Band C)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-1	1T+1T+0T	1P+0P+0P, 0P+1P+0P, 1P+1P+0P
Case 1-2	0T+1T+1T	0P+1P+0P
Case 1-3	1T+0T+1T	1P+0P+0P
Case 2-3	0T+0T+2T	0P+0P+2P, 0P+0P+1P

Table 17: Example mapping for three bands with 1T-1T-2T in the switchedUL mode

For example, for at least some of the entries in Tables 14-17, Band A is a frequency division duplex (FDD) band, while Band B and Band C are each time division duplex (TDD) bands. To further illustrate, Fig. 6 shows a slot frame structure diagram illustrating ten slots for the three bands A, B, and C. Each slot is designed as "D" for downlink, "U" for uplink, or "S" for special. Each "D" represents a downlink slot designated or configured for one or more DL transmissions, and each "U" represents an uplink slot designated or configured for one or more UL transmissions. Also, each "S" represents a "special" slot that partially includes D symbols and partially includes U

symbols. In addition, an S slot is designated or configured for one or more DL transmissions on the D symbols, and is designated or configured for one or more UL transmissions on the U symbols.

Referring particularly to the example Fig 6, the frame structure for bands C and B are: 'SUDDSUUDDD' and 'DDDDDDDSUU', respectively. Also, for at least some embodiments, the frame structures uses a radio frame with a subcarrier spacing (SCS) of 15 kHz. In addition, for at least some embodiments, the switching period is reported for each band pair A+B, band pair B+C, and band pair A+C respectively. The switching periods for the three band pairs may be the same value as, or different values from, each other. For example, two switching periods may be the same and a third may be different from the other two, all three may be the same as each other, or all three may be different from each other.

Referring particularly to Table 14, the transmit cases provide a unique operation state for 1-port transmission on each band. Correspondingly, no ambiguity issues occur when switching between the transmit cases in Table 14. However, when switching between the transmit cases in Table 14, a user device 102 may use additional, or an undesirably high amount of, switching periods. To illustrate, with reference to Fig. 6, the user device 102 may perform a 1-port UL transmission on Slot 6 on Band C, and then on Slot 7 on Band A, and then on Slot 8 on Band B. Following Table 14, the user device 102 may switch 1Tx on Band C to Band A to support the 1-port transmission on Band A (i.e., from Case 2-3 to Case 1-3). Then, the user device 102 may switch 1Tx on Band A to Band B to support the 1-port transmission on Band B (i.e., from Case 1-3 to Case 1-2).

In contrast to the transmit cases in Table 14, the transmit cases in Tables 15-17 provide more than one operation state for the 1-port transmission on some specific bands or all of the bands. In these cases, ambiguity issues may occur. To illustrate using the slot frame structure in Fig. 6, the user device 102 may perform a 1-port UL transmission on Slot 6 on Band C, and then on Slot 7 on Band A, and then on Slot 8 on Band B. Using the transmit cases in Table 15 with the frame structure in Fig. 6 as an example, an ambiguity issue may occur when the user device 102 performs a preceding UL transmission on Slot 6 on Band C in transmit Case 2-3, and then is to perform a 1-port transmission on Band A. The ambiguity issue may arise since the user device 102, configured with switchedUL, with or without supporting normal CA mode, may not know if it should switch from transmit Case 2-3 to transmit Case 1-3 or to transmit Case 1-1 in order to transmit on Band A on Slot

7, based on Table 14 alone, as both transmit Case 1-3 and transmit Case 1-1 provide 1Tx on Band A. In transmit Case 2-3, before switching, the user device 102 has both of its first and second transmitters (2Tx) on Band C, corresponding to the 0T+0T+2T configuration of transmit Case 2-3. In a first example, suppose that the user device 102 switches to transmit Case 1-3. In doing so, the user device 102 may ultimately perform two switching steps since it has to transmit on Band B on Slot 8. In further detail, according to a first switching step from transmit Case 2-3 to transmit Case 1-3, the first transmitter (1Tx) on Band C may switch to Band A and the second transmitter (1Tx) may still be on Band C after the switching. Also, in transmit Case 1-3, the user device 102 may have the port configuration of 1P+0P+0P. Correspondingly, when transmitting on Band A on Slot 7, the first transmitter is a used transmitter since it is transmitting on a port on Band A, and the second transmitter is an unused transmitter since it is not transmitting on any port on Band C, corresponding to the 1P+0P+0P port configuration associated with transmit Case 1-3. Then, in order for the user device 102 to transmit on Band B on Slot 8, the user device 102 may perform a second switching step to switch from transmit Case 1-3 to transmit Case 1-1. In doing so, the second transmitter on Band C may switch to Band B, such that the two transmitters of the user device 102, having the transmitter configuration 1Tx+1Tx, are located on Band A and Band B. For this switching situation with two steps, the user device 102 performs two UL Tx switching instances over two switching periods, including a first switching period for band pair A+C (i.e., for the user device 102 to switch the first transmitter from Band C to Band A), and a second switching period for band pair B+C (i.e., for the user device 102 to switch one transmitter from Band C to Band B).

Still referring to Table 15 and Fig. 6, in a second example, the user device 102 may switch from transmit Case 2-3 directly to transmit Case 1-1 (i.e., without first switching to transmit Case 1-3). When the user device 102 switches from transmit Case 2-3 to transmit Case 1-1, the user device 102 may use only one switching instance with one switching period in order to be configured to have the first transmitter transmit on Band A on Slot 7 and to have the second transmitter transmit on Band B on Slot 8. In particular, when switching from transmit Case 2-3 to transmit Case 1-1, the two transmitters (2Tx) of the user device 102 on Band C may switch to 1Tx on Band A and 1Tx on Band B. As a result, the user device 102 may complete the switching for UL transmissions on Slots 7 and 8 by performing only one UL Tx switching instance in one switching period. For at least some embodiments, the switching period for the one switching instance may be the maximum value of a

first switching period of band pair A+C (e.g., for a first transmitter to switch from Band C to Band A) and second switching period of band pair B+C (e.g., for a second transmitter to switch from Band C to Band B). Also, in transmit Case 1-1 on Slot 7, the user device 102 may have the port configuration 1P+0P+0P, such that the first transmitter is a used transmitter on Band A and the second transmitter is an unused transmitter on Band B. Then, on Slot 8, the user device 102, still in transmit Case 1-1, may have the port configuration 0P+1P+0P, such that the first transmitter is an unused transmitter on Band A and the second transmitter is a used transmitter on Band B.

Similar switching may also be performed for embodiments where the wireless access node 104 indicates two bands (or a band pair) out of a certain configured number of bands (e.g., three or four), and the user device 102 may perform dynamic Tx switching between the indicated bands. For such embodiments, the user device 102 may switch both transmitters (2Tx) on Band C to a 1Tx+1Tx configuration on Band A and Band B using one Tx switching instance having one switching period, that is from band pair A+C or B+C to band pair A+B. For such embodiments, the switching period to perform one switching period involving multiple band pairs, such as to switch from a preceding band pair A+C or B+C to a target band pair A+B as illustrated, may be, or may be determined by or based on, one of the following:

(1) the switching period for the preceding band pair;

(2) the switching period for the target band pair;

(3) the larger of the switching period for the preceding band pair and the switching period for the target band pair;

(4) a single value, or multiple values for different band pairs for different switching instances, reported by the user device 102;

(5) a maximum value of a switching period of one preceding band pair (e.g., band pair A+C in the above example) and switching period of a second preceding band pair (e.g., band pair B+C in the above example), such as in a switching case from 2Tx on one band (e.g., Band C) to 1Tx+1Tx on two other bands (e.g., Band A and Band B).

In order to resolve the above ambiguity issue (i.e., so that the user device 102 operates without the ambiguity), the user device 102 may operate according to one of the following methods.

In a first method (Method 1), the user device 102 performs UL Tx switching according to a pre-configured or predefined rule (or default behavior). In a first example of Method 1, the default behavior is to keep the unused Tx in the previous band during an initial or first switching period. The user device 102 may then switch the unused Tx to a different band during another or a second switching period. To illustrate, using the example above also with reference to Fig. 6, over Slots 6-8, the user device 102 is to transmit on Slot 6 on Band C, then on Slot 7 on Band A, and then on Slot 8 on Band B, as previously described. To do so, after transmitting on slot 6, the user device 102 may move one transmitter on Band C to Band A in order to transmit on Slot 7. According to the first option, during a first switching period, the user device 102 moves a used transmitter from Band C to Band A so that the used transmitter can transmit on Slot 7 on Band A. During the first switching period, the user device 102 keeps the unused transmitter on Band C, according to the first example of the predefined rule or default behavior (Method 1). According to the above Tables 14-17, during the first switching period, the user device 102 switches from transmit Case 2-3 to transmit Case 1-3. Then, during a second switching period, the user device 102 moves the unused transmitter from Band C to Band B for the UL transmission on Slot 8 on Band B. According to the above Tables 14-17, during the second switching period, the user device 102 moves from transmit Case 1-3 to transmit Case 1-1.

In a second example of Method 1, the default behavior is to move the unused Tx from the previous band to a third or different band during the same switching period that the used Tx is moved from the previous band to a second band, or to the band on which the preceding transmission is located. In particular embodiments of the second method, the user device 102 moves the unused Tx from the previous band to the third band if one or more downlink slots or symbols on the previous band follow after the slot on which the user device 102 performed an UL transmission on the previous band. In other embodiments, the user device 102 moves the unused Tx from the previous band to the third band if only the third band and the second band (or up to two bands within three or more bands) which is not the previous band have the one or more uplink slots or symbols after the slot on which the user device 102 performed an UL transmission on the previous band. For example, with reference to Fig. 6, the user device 102 performs an UL transmission on Slot 6 on Band C. Further, as indicated in Fig. 6, the slots or symbols following Slot 6 (i.e., Slots 7, 8 and 9) are downlink slots. On Slot 7, the transmitter transmitting on Band A is a used transmitter, and the transmitter not

transmitting on Band A is an unused transmitter. According to the second example of Method 1, the user device 102 moves the unused transmitter from Band C to Band B during the same switching period that the user device 102 moves the used transmitter from Band C to Band A. In this way, according to the second example, the user device 102 uses only one switching period to switch a first transmitter from Band C to Band A and a second transmitter from Band C to Band B. According to Tables 14-17, the user device 102 may switching direction from transmit Case 2-3 to transmit Case 1-1 using only one switching period.

In a second method (Method 2), the user device 102 may use additional signaling indication to indicate how to perform UL Tx switching for the unused transmitter. The signaling may indicate one of two possible ways to do the switching.

In a first example of Method 2, the user device 102 may use radio resource control (RRC) signaling to configure one of two possible ways to perform the switching. In particular embodiments, the user device 102 may perform the switching according to the way indicated by the signaling for each dynamic UL Tx switching involving an unused Tx. In various embodiments, the RRC signaling could be configured for different switching cases involving a certain number of (e.g., three or four) bands and for certain maximum numbers of supported Tx chains for the different bands. To illustrate as an example, with reference to Tables 14-17, candidate values of the RRC signaling may comprise: {1Tx+1Tx on Band A+C, 1Tx+1Tx on Band A+B}. In other embodiments, the RRC signaling may be configured for all scenarios of a certain number (e.g., 3 or 4) bands with different supported maximum Tx chains. That is, the candidate values of the RRC signaling may comprise: {unused Tx on previous band, unused Tx switched to the third band}. In various embodiments, the RRC parameter can be set to indicate that it is configured or not configured to represent the two ways.

In a second example of Method 2, the user device 102 may use a downlink control information (DCI) or a medium access control control element (MAC-CE) to indicate one of two possible ways to do the switching. That is, for each dynamic UL Tx switching involving an unused Tx, the DCI or MAC-CE may indicate a way to do the switching, and the ways to do the switching may be different depending on use of dynamic indication by the DCI or MAC-CE. This second example of Method 2 is similar to using a DCI to indicate a band pair to which the 2Tx may be switched, such as when switching from one band pair to another band pair. An advantage may be

that allowing different switching ways may allow the network to reduce the number of switching periods depending on the sequence of UL transmissions allocated to the user device.

Accordingly, through use of a pre-configuration, predefined rules, default behavior, or an additional signaling indication, a total number of switching periods may be reduced if the unused Tx can be switched to a third band, including situations where downlink slots/symbols on the previous band follow the slot on which an UL transmission was performed on the previous band.

In addition or alternatively, for UL Tx switching involving the transmit cases in Table 15, a similar ambiguity issue may arise for the case when a 1-port transmission is to be transmitted on Band B, and the user device 102 performed the preceding transmission using transmit Case 2-3. When the user device 102 does not support simultaneous transmission on two bands, the user device 102 may not know if it should switch from transmit Case 2-3 to transmit Case 1-2 or transmit Case 1-1. The ambiguity may be even more complex when switching between the transmit cases in Table 16, since the ambiguity may arise for 1-port transmission in all bands A, B, C. To avoid the ambiguity issue, the user device 102 may use a predefined rule or default behavior, or additional signaling indication, as described above.

In addition or alternatively, in view of the transmit cases in Table 17, suppose transmit Case 1-1 is considered or regarded as comprising all possible antenna ports for UL transmission of a normal carrier aggregation (CA) case. When the user device 102 performs UL Tx switching from another transmit case to transmit Case 1-1, the user device 102 may switch 1Tx or 2Tx to one band of band pair A+B or two bands of band pair A+B. For example, the user device 102 may switch 1Tx on Band C to Band A when switching from Case 1-2 to Case 1-1, 1Tx on Band C to Band B when switching from Case 1-3 to Case 1-1, and 2Tx on Band C to 1Tx on Band A and 1Tx on Band B when switching from Case 2-3 to Case 1-1. Such switching operations to transmit Case 1-1 may be regarded as a fallback to the normal CA case, or to transmit Case 1-1.

For at least some of these embodiments involving switching between the transmit cases in at least of Tables 15, 16, and 17, there may not be a switching period within the band pair A+B (that is switching period = 0us for the band pair). Also, in various of these embodiments, the user device 102 may support simultaneous transmission on the band pair A+B.

Embodiment 1-2

In other embodiments, the user device 102 may transmit on three bands, with maximum number of transmitters per band being: 1T-1T-1T, with one carrier on each band. That is, all bands are limited to have at most one transmission chain. When a user device 102 operates in the switchUL mode (i.e., the user device 102 does not support simultaneous transmission on two bands), the user device 102 may perform an UL transmission one band of the three bands, Bands A, B, or C. Under these conditions, some example possible combinations of numbers of antenna ports for UL transmissions for provided below in Tables 18-21.

Transmit cases	Number of Tx Chains (Band A + Band B + Band C)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-1	1T+1T+0T	1P+0P+0P
Case 1-2	0T+1T+1T	0P+1P+0P
Case 1-3	1T+0T+1T	0P+0P+1P

Table 18: Example mapping for three bands with 1T-1T-1T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-1	1T+1T+0T	1P+0P+0P, **0P+1P+0P**
Case 1-2	0T+1T+1T	**0P+1P+0P**
Case 1-3	1T+0T+1T	0P+0P+1P

Table 19: Example mapping for three bands with 1T-1T-1T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-1	1T+1T+0T	1P+0P+0P, 0P+1P+0P
Case 1-2	0T+1T+1T	0P+1P+0P,0P+0P+1P
Case 1-3	1T+0T+1T	1P+0P+0P, 0P+0P+1P

Table 20: Example mapping for three bands with 1T-1T-1T in the SwitchedUL mode

Transmit	Number of Tx Chains	Number of antenna ports for UL transmission

cases	(Band A + Band B + Band C)	Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3)
Case 1-1	1T+1T+0T	1P+0P+0P, **0P+1P+0P, 1P+1P+0P**
Case 1-2	0T+1T+1T	**0P+1P+0P**
Case 1-3	1T+0T+1T	0P+0P+1P

Table 21: Example mapping for three bands with 1T-1T-1T in the SwitchedUL mode with normal CA

For some embodiments involving UL Tx switching using the transmit cases in Tables 18-21, Band A is a FDD band, and Band B and Band C are TDD bands. Example UL Tx switching between the transmit cases in Tables 18-21 are described with reference to the slot frame structure of Fig. 6. As previously described, in the example slot frame structure, Bands C and B may have the following slot designations, respectively: 'SUDDSUUDDD' and 'DDDDDDDSUU'. For at least some of these embodiments, a radio frame may have a subcarrier spacing (SCS) of 15 kHz. In addition or alternatively, the switching period is reported for each of band pair A+B, band pair B+C, and band pair A+C. Any two switching periods for these band pairs may be the same as or different from each other.

Additionally, similar to UL Tx switching according to the transmit cases in Tables 14-17, UL Tx switching according to the transmit cases in Table 18 may not create any ambiguity issues for unused transmitters. However, ambiguity issues may arise when performing UL Tx switching between transmit cases in Tables 19-21.

Referring to Table 19, as an example, an ambiguity issue may occur when, for example, the user device 102 is to perform a 1-port transmission on band B, and the user device 102 performed a preceding transmission using transmit Case 1-3 to transmit on Band C. The ambiguity issue may arise since the user device 102 may not know whether to switch to transmit Case 1-1 or to transmit Case 1-2, since both transmit cases provide for transmission on Band B. In a first way, the user device 102 may decide to switch from transmit Case 1-3 to transmit Case 1-2. However, transmit Case 1-2 does not provide for transmission on Band A. As such, if the user device 102 switches to transmit Case 1-2, and in event the user device 102 has to transmit on both Band B and Band A in one or more next slots or symbols, the user device 102 may perform two switching instances in two switching periods. In further detail, when transmitting on Band C in transmit Case 1-3, a first transmitter on

Band A is unused and a second transmitter on Band C is used. Then, in a first switching instance to transmit Case 1-2, the user device 102 may switch the first, unused Tx on Band A to Band B, while the second transmitter stays on Band C. In transmit Case 1-2, the first transmitter is a used transmitter on Band B and the second transmitter is an unused transmitter on Band C. Then, the user device 102 may perform second switching from transmit Case 1-2 to transmit Case 1-1 by switching the second, unused transmitter on Band C will to Band A. After the second switching instance, the user device 102 may have the transmitter configuration 1Tx+1Tx located on band A and band B. In this way, the user device 102 performs two UL Tx switching instances in two switching periods, i.e., a first switching period of band pair A+B, and a second switching period of band pair A+C.

In a second way, the user device 102 may decide to switch from transmit Case 1-3 directly to transmit Case 1-1, without first switching to transmit Case 1-2. In doing so, the user device 102 may perform only one switching step in one switching period, which includes switching 1Tx on Band C to 1Tx on Band B while leaving the other 1Tx on Band A. After the switching, the user device 102 has a transmitter configuration of 1Tx+1Tx located on band pair A+B.

For such situations, the user device 102 may use a pre-configuration, predefined rules, default behavior, and/or additional signaling indication that indicates to the user device 102 how to perform switching for the unused transmitter.

Embodiment 1-3

In other embodiments, a user device 102 may perform UL transmissions on four bands, including Bands A, B, C and D. Table 22, below, provides ten example cases transmit, with the condition that the number of Tx per band can be up to two.

Transmit Cases	Number of Tx Chains (Band A + Band B + Band C)
Case 1-1	1T+1T+0T+0T
Case 1-2	0T+1T+1T+0T
Case 1-3	0T+0T+1T+1T
Case 1-4	1T+0T+0T+1T
Case 1-5	1T+0T+1T+0T
Case 1-6	0T+1T+0T+1T
Case 2-1	2T+0T+0T+0T

Case 2-2	0T+2T+0T+0T
Case 2-3	0T+0T+2T+0T
Case 2-4	0T+0T+0T+2T

Table 22: Example Transmit Cases for Four Bands

In one embodiment, the number of Tx per band, for four bands, are 1T-1T-1T-1T, with one carrier on each band. That is, all bands are limited to have at most one transmission chain. The transmission switching option parameter, i.e. uplinkTxSwitchingOption, may is set to 'switchUL'. When operating in the switchUL mode, the user device 102 may perform an uplink transmission on one band of Bands A, B, C or D. Under this condition, example possible combinations of numbers of antenna ports for uplink transmission for some of the entries in Table 22 are listed in Tables 23-26, below.

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P
Case 1-3	0T+0T+1T+1T	0P+0P+1P+0P
Case 1-4	1T+0T+0T+1T	0P+0P+0P+1P

Table 23: Example mapping for four bands with 1T-1T-1T-1T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, **0P+0P+1P+0P**
Case 1-3	0T+0T+1T+1T	**0P+0P+1P+0P**
Case 1-4	1T+0T+0T+1T	0P+0P+0P+1P

Table 24: Example mapping for four bands with 1T-1T-1T-1T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P, 0P+1P+0P+0P

Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, 0P+0P+1P+0P
Case 1-3	0T+0T+1T+1T	0P+0P+1P+0P, 0P+0P+0P+1P
Case 1-4	1T+0T+0T+1T	1P+0P+0P+0P, 0P+0P+0P+1P
Case 1-5	1T+0T+1T+0T	1P+0P+0P+0P,0P+0P+1P+0P
Case 1-6	0T+1T+0T+1T	0P+1P+0P+0P, 0P+0P+0P+1P

Table 25: Example mapping for four bands with 1T-1T-1T-1T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, 0P+0P+1P+0P, 0P+0P+1P+1P
Case 1-3	0T+0T+1T+1T	0P+0P+1P+0P
Case 1-4	1T+0T+0T+1T	0P+0P+0P+1P

Table 26: Example mapping for four bands with 1T-1T-1T-1T in the SwitchedUL mode

Example UL Tx switching across four bands using the transmit cases in Tables 23-26 are now described. In some examples, Bands A and C are FDD bands, and Bands B and D are TDD bands. To supplement the UL Tx switching, examples are described with reference to Fig. 7, which shows an example slot frame structure including ten slots on the four Bands A, B, C, and D. The slot designations for the slots on Bands D and B, respectively, are: 'SUDDSUUDDD' and 'DDDDDDDSUU'. For at least some embodiments, a radio frame may have a subcarrier spacing (SCS) of 15 kHz. In addition or alternatively, the switching periods may be reported for each of band pair A+B, band pair B+C, band pair C+D and band pair A+D. Any two of the switching periods may be the same or different from each other, in any of various embodiments. respectively with same or different value. Also, when switching according to the transmit cases in Table 25, an additional switching periods may be reported for band pairs A+C and B+D.

Referring to Table 23, no ambiguity issues may arise for the transmit cases in Table 23 due to their unique operation states for 1-port transmission on each band. However, switching between these transmit cases may create additional, or undesirably high amounts of, switching periods. To illustrate with reference to Fig. 7, the user deice 102 may perform a 1-port transmission on Slot 6 on Band D, and then on Slot 7 on Band C, and then on Slot 8 on band B. Following Table 23, the user device 102 may switch 1Tx on Band A to band C to support the 1-port transmission on

band C on Slot 7 (corresponding to switching from transmit Case 1-4 to transmit Case 1-3). Then, the user device 102 may switch 1Tx on Band D to Band B to support the 1-port transmission on Band B on Slot 8 (corresponding to switching from transmit Case 1-3 to transmit Case 1-2).

However, for Tables 24-26, more than one transmit case for one-port transmission may be used on a specific band or all bands. In these cases, ambiguity issues may occur. To illustrate with reference to Fig. 7, the user device 102 may perform a one-port transmission on Slot 6 on Band D, and then on Slot 7 on Band C, and then on Slot 8 on Band B. Referring particularly to Table 24, one ambiguity issue may occur when the user device 102 is to perform a 1-port transmission on Band C on Slot 7, and performs a preceding transmission on Band D on Slot 6 using transmit Case 1-4. If the user device 102 is in switchedUL, with or without normal CA mode, the user device 102 may not know, from the transmit cases in Table 24 alone, if it should switch from transmit Case 1-4 to transmit Case 1-3 or transmit Case 1-2, as both transmit cases allow the user device 102 to transmit on Band C . There could be two possible ways to do the switching.

In a first way, the user device 102 may switch from transmit Case 1-4 to transmit Case 1-3. However, transmit Case 1-3 does not allow for transmitting on Band B. As such, if the user device 102 is to also transmit on Band B, such as on Slot 8, the user device 102 may perform two switching instances, from transmit Case 1-4 to transmit Case 1-3, and then from transmit Case 1-3 to transmit Case 1-2. In further detail, in transmit Case 1-4, the user device 102 has first transmitter as a used transmitter on Band D and a second transmitter as an unused transmitter on Band A. Then, when the user device 102 first switches from transmit Case 1-4 to transmit Case 1-3, the user device 102 may switch the first transmitter on Band A to Band C, while keeping the second transmitter on band D. In transmit Case 1-3, the first transmitter, transmitting on Band C, is a used transmitter, and the second transmitter, not transmitting on Band D, is an unused transmitter. The user device 102 may then perform a second UL Tx switching from transmit Case 1-3 to transmit Case 1-2, which switches the second, unused 1Tx from Band D to Band B. At the end of the second switching, the user device 102, in transmit Case 1-2, may have a transmitter configuration of 1Tx+1Tx located on Band B and Band C. The user device 102, in transmit Case 1-2, can then use the second transmitter to transmit on Band B. In this first way, the user device 102 performs two UL Tx switching instances involving two switching periods, including a first switching period for band pair A+C (i.e., a switching period during which the user device 102 switches 1Tx from Band A to Band C), and a second switching period for band pair D+B (i.e., a switching period during which the user device 102 switches 1Tx from Band D to Band B).

A second way to perform switching is for the user device 102 to perform a single

switching instance from transmit Case 1-4 to transmit Case 1-2 (without first switching to transmit Case 1-3). That is, the user device 102 may switch 1Tx from Band A and 1Tx on band D to 1Tx on Band B and 1Tx on Band C during one switching period. As such, the user device performs one UL Tx switching instance. The switching period for the one switching instance may be the maximum value of the switching period of band pair A+C and the switching period of band pair B+D. This single-instance switching and corresponding switching period may also be used where the network indicates two bands (or a band pair) out of a certain number of configured bands (e.g., three or four bands) via a DCI or MAC-CE, and the user device 102 performs dynamic Tx switching between indicated bands. The user device 102 may switch from a transmitter configuration of 1T+1T on Band A and Band D to a 1T+1T transmitter configuration on Band B and Band C in one switching instance using a single switching period, that is, from band pair A+D to band pair B+C.

Another example, referring to Table 25, the user device 102 may be in transmit Case 1-4, where it has one antenna port on band D. Accordingly, on transmit Case 1-4, the user device 102 has a first transmitter as a used transmitter on band D, and a second transmitter as an unused transmitter on band A. To have a transmitter on band C, the user device 102 may switch to transmit Case 1-5 or to transmit Case 1-2. To switch from transmit Case 1-4 to transmit Case 1-5, the first, used Tx is switched from band D to band C while the second, unused Tx stays on band A. To switch from transmit Case 1-4 to transmit Case 1-2, the first, used Tx switches from band D to band C, and the second, unused Tx on band A is switched to a fourth band, i.e., band B. In this scenario, the fourth band (i.e., band B), is not the band for the UL transmission after switching, it is not the band for the preceding UL transmission before switching, and it is not the band with the unused Tx before the switching.

For such embodiments involving UL Tx switching with four bands, such as illustrated with respect to Figs. 22-26, the user device 102 may perform the UL Tx switching according to a pre-configuration, predefined rules, default behavior, or additional signaling indicating that indicates how to switch an unused transmitter, such as previously described.

Embodiment 1-4

In another embodiment where the user device 102 performs UL transmissions on four bands, including Bands A, B, C, and D, a transmitter configuration for the four bands indicating the number Tx per band may be: 1T-1T-1T-2T, with one carrier on each band. According to this transmitter configuration, only of the bands (e.g., Band D) can support more than one transmitter chain. In some embodiments, the transmission switching option parameter, i.e.

uplinkTxSwitchingOption, is set to 'switchUL', such that the user device 102 transmits without supporting simultaneous transmission on two bands. Accordingly, when operating in the switchUL mode, the user device 102 performs an UL uplink transmission on one band of Bands A, B, C or D. Under these conditions, possible combinations of numbers of antenna ports for uplink transmit cases in Table 22 above are listed below in the Tables 27-.30

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-4	1T+1T+0T+1T	1P+0P+0P+0P
Case 1-6	0T+1T+0T+1T	0P+1P+0P+0P
Case 1-3	0T+0T+1T+1T	0P+0P+1P+0P
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 27: Example mapping for four bands with 1T-1T-1T-2T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, **0P+0P+1P+0P**
Case 1-3	0T+0T+1T+1T	**0P+0P+1P+0P**
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 28: Example mapping for four bands with 1T-1T-1T-2T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P, 0P+1P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, 0P+0P+1P+0P
Case 1-3	0T+0T+1T+1T	0P+0P+1P+0P, 0P+0P+0P+1P
Case 1-4	1T+0T+0T+1T	1P+0P+0P+0P, 0P+0P+0P+1P
Case 1-5	1T+0T+1T+0T	1P+0P+0P+0P,0P+0P+1P+0P
Case 1-6	0T+1T+0T+1T	0P+1P+0P+0P, 0P+0P+0P+1P
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 29: Example mapping for four bands with 1T-1T-1T-2T in the SwitchedUL mode

Table 6-4 another mapping for Band A+B+C+D with 1T-1T-1T-2T in 'switchedUL' including normal CA case

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, **0P+0P+1P+0P, 0P+1P+1P+0P**
Case 1-3	0T+0T+1T+1T	**0P+0P+1P+0P**
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 30: Example mapping for four bands with 1T-1T-1T-2T in the SwitchedUL mode including normal CA

In some UL Tx switching using the transmit cases in Tables 27-30, Bands A and C are FDD bands, and Bands B and D are TDD bands. Further examples of UL Tx switching using the transmit cases in Tables 27-30 are described with reference to the slot frame structure of Fig. 7.

Referring particularly to Table 27, the transmit cases are each unique to each other for 1-port transmission, and therefore do not create any ambiguity issues for UL Tx switching. However, switching between transmit cases in Table 27 may use additional, or an undesirably high amount of, switching periods. To illustrate using Fig. 7, the user device 102 may perform a 1-port transmission on Slot 6 on Band D, and then on Slot 7 on Band C, and then on Slot 8 on Band B. Following Table 27, the user device 102 may switch 1Tx from Band D to Band C to support the 1-port transmission on Band C on Slot 7 (e.g., switch from transmit Case 2-4 to transmit Case 1-3). Then, the user device 102 may switch 1Tx from Band C to Band B to support the 1-port transmission on Band B on Slot 8 (e.g., switch from transmit Case 1-3 to transmit Case 1-6).

However, for Tables 28-30, more than one transmit case for one-port transmission may be used on a specific band or all bands. In these cases, ambiguity issues may occur. Using the example in Fig. 7 to illustrate, the user device 102 may perform a 1-port transmission on Slot 6 on Band D, and then on Slot 7 on Band C, and then on Slot 8 on Band B. Following Table 28, one ambiguity issue may happen when the user device 102 is to perform a 1-port transmission on Band C on Slot 7, and the user device 102 performed a preceding transmission on Band D on Slot 6 using transmit Case 2-4. In such a situation, the user device 102, if in switchedUL mode, may not know,

based on Table 28 alone, whether to switch from transmit Case 2-4 to transmit Case 1-3 or to transmit Case 1-2, as both transmit cases support transmitting on Band C. There could be two possible ways to do the switching.

In a first way, the user device 102 may first switch from transmit Case 2-4 to transmit Case 1-3. When transmitting on Band D using transmit Case 2-4, the first device 102 may have a first transmitter as a used transmitter on Band D and a second transmitter as an unused transmitter also on Band D. To switch from transmit Case 2-4 to transmit Case 1-3, the user device 102 may switch the first transmitter on Band D to Band C, while keeping the second, unused transmitter still on band D. In transmit Case 1-3, the first transmitter is still a used transmitter and the second transmitter is still an unused transmitter. Then, in order to be able to transmit on Band B, such as on Slot 8, the user device 102 may perform a second switching from transmit Case 1-3 to transmit Case 1-2, where the user device 102 switches the second, unused transmitter on Band D to Band B, while keeping the first transmitter on Band C. At the end of the second switching instance, the user device 102 may have a transmitter configuration of 1Tx+1Tx located on Band B and Band C. In this first, way, the user device 102 performs two UL Tx switching instances using two switching periods, including a first switching period for band pair D+C (e.g., a first switching period to switch 1Tx from Band D to Band C), and a second switching period for band pair D+B (e.g., a second switching period to switch 1Tx from Band D to Band B).

In a second way, the user device 102, in transmit Case 2-4, may switch using only one switching instance with only one switching period and still being able to transmit on Band C Slot on Slot 7 and on Band B on Slot 8. In particular, the user device 102 may perform a single switching instance that switches from transmit Case 2-4 to transmit Case 1-2. During the single switching instance, the user device 102 has 2Tx on Band D, and switches 1Tx from Band D to Band B and 1Tx from Band C to Band B. In this way, the user device 102 performs one UL Tx switching instance. For this single UL Tx switching instance, the switching period may be a maximum value of a switching period of band pair D+C (e.g., a switching period to switch between Bands D and C), and a switching period of band pair D+B (e.g., a switching period to switch between Bands D and B). This single-instance switching and corresponding switching period may also used where the network indicates two bands (or a band pair) out of a certain number of configured bands (e.g., three or four bands) via a DCI or MAC-CE, and the user device 102 performs dynamic Tx switching between

indicated bands. The user device 102 may switch from both Tx on Band D to a transmitter configuration of 1T+1T on Band B and Band C in one switching instance during a single switching period.

For such embodiments involving UL Tx switching with four bands, such as illustrated with respect to Figs. 27-30, the user device 102 may perform the UL Tx switching according to a pre-configuration, predefined rules, default behavior, or additional signaling indicating that indicates how to switch an unused transmitter, such as previously described.

Embodiment 1-5

In another embodiment where the user device 102 performs UL transmissions on four bands, including Bands A, B, C, and D, a transmitter configuration for the four bands indicating the number of Tx per band may be: 1T-1T-2T-2T, with one carrier on each band. According to this transmitter configuration, only one transmission chain can be configured for Band A and Band B, while up to 2 transmission chains can be configured for Band C and Band D. In some of these embodiments, the transmission switching option parameter, i.e. uplinkTxSwitchingOption, is set to 'switchUL', such that the user device 102 transmits without supporting simultaneous transmission on two bands. Accordingly, when operating in the switchUL mode, the user device 102 performs an UL transmission on one band of Bands A, B, C or D. Under these conditions, possible combinations of numbers of antenna ports for uplink transmit cases in Table 22 above are listed below in Tables 31-34.

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case A	1T+0T+0T/1T+1T/0T	1P+0P+0P+0P
Case B	0T+1T+1T/0T+0T/1T	0P+1P+0P+0P
Case 2-3	0T+0T+2T+0T	0P+0P+2P+0P,0P+0P+1P+0P
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 31: Example mapping for four bands with 1T-1T-2T-2T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, 0P+0P+1P+0P
Case 2-3	0T+0T+2T+0T	0P+0P+2P+0P,0P+0P+1P+0P
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 32: Example mapping for four bands with 1T-1T-2T-2T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P, 0P+1P+0P+0P
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, 0P+0P+1P+0P
Case 1-3	0T+0T+1T+1T	0P+0P+1P+0P, 0P+0P+0P+1P
Case 1-4	1T+0T+0T+1T	1P+0P+0P+0P, 0P+0P+0P+1P
Case 1-5	1T+0T+1T+0T	1P+0P+0P+0P,0P+0P+1P+0P
Case 1-6	0T+1T+0T+1T	0P+1P+0P+0P, 0P+0P+0P+1P
Case 2-3	1T+0T+0T+1T	0P+0P+2P+0P, 0P+0P+1P+0P
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 33: Example mapping for four bands with 1T-1T-2T-2T in the SwitchedUL mode

Transmit cases	Number of Tx Chains (Band A + Band B + Band C +Band D)	Number of antenna ports for UL transmission Band A(Carrier 1)+Band B(Carrier 2)+ Band C(Carrier 3) + Band D(Carrier 4)
Case 1-1	1T+1T+0T+0T	1P+0P+0P+0P,
Case 1-2	0T+1T+1T+0T	0P+1P+0P+0P, 0P+0P+1P+0P, 0P+1P+1P+0P
Case 2-3	0T+0T+2T+0T	0P+0P+2P+0P, **0P+0P+1P+0P**
Case 2-4	0T+0T+0T+2T	0P+0P+0P+2P, 0P+0P+0P+1P

Table 34: Example mapping for four bands with 1T-1T-2T-2T in the SwitchedUL mode including normal CA

In some UL Tx switching using the transmits cases in Tables 31-34, Bands A and B are FDD bands, and Bands C and D are TDD bands. Further examples of UL Tx switching using the transmit cases in Tables 31-34 are described with reference to the slot frame structure of Fig. 7.

Referring particularly to Table 31, the transmit cases are each unique to each other for 1-port transmission, and therefore do not create any ambiguity issues for UL Tx switching. However, switching between transmit cases in Table 31 may use additional, or an undesirably high amount of, switching periods. To illustrate using Fig. 7, the user device 102 may perform a 1-port transmission on Slot 6 on Band D, and then on Slot 7 on Band C, and then on Slot 8 on Band B. Following Table 31, the user device 102 may switch 2Tx on Band D to Band C to support the 1-port transmission on Band C (e.g., switch from transmit Case 2-4 to transmit Case 2-3). Then, the user device 102 may switch 1Tx on Band C to Band B to support the 1-port transmission on Band B (e.g., switch from transmit Case 2-3 to transmit Case B), in which Case B here should be Case 1-2 (i.e., 0T+1T+1T+0T). In another example, if the user device 102 is to transmit a 1-port transmission on Band B, and the user device 102 performed a preceding transmission using transmit Case 2-4, the user device 102 may switch 1Tx on Band D to Band C. That is, the user device 102 may switch from transmit Case 2-4 to transmit Case B, in which Case B here is Case 1-6 (i.e., 0T+1T+0T+1T).

However, for Tables 31-34, more than one transmit case for 1-port transmission may be used a specific band or all bands. In these cases, ambiguity issues may occur. Same example in Fig. 7 to illustrate, the user device 102 may perform a 1-port transmission on Slot 6 on Band D, and then on Slot 7 on Band C, and then on Slot 8 on Band B. Following Table 32, one ambiguity issue may happen when the user device 102 is to perform a 1-port transmission on Band C on Slot 7, and the user device 102 performs a preceding transmission on Band D on Slot 6 using transmit Case 2-4. In such a situation, the user device, if in switchedUL, may not know whether to switch from transmit Case 2-4 to transmit Case 2-3 or to transmit Case 1-2, as both transmit cases allow the user device 102 to transmit on Band C. There could be two possible ways to do the switching.

In a first way, the user device 102 may first switch from transmit Case 2-4 to transmit Case 2-3, that is, may switch 2Tx on Band D to 2Tx Band C. Then, the user device 102 may perform a second switching from transmit Case 2-3 to transmit Case 1-2, where the user device 102 switches 1Tx on Band C to Band B, while keeping the other 1Tx on Band C. At the end of the second switching instance, the user device 102 may have a transmitter configuration of 1Tx+1Tx located on Band B and Band C. In this first way, the user device 102 performs two UL Tx switching instances using two switching periods, including a first switching period for band pair D+C (e.g., a first switching period to switch 2Tx from Band D to Band C), and a second switching period for

band pair C+B (e.g., a second switching period to switch 1Tx from Band C to Band B).

In a second way, the user device 102 may switch using only one switching instance with only one switching period. In particular, the user device 102 may perform a single switching instance that switches from transmit Case 2-4 to transmit Case 1-2. During the single switching instance, the user device 102 has 2Tx on Band D, and switches 1Tx on Band D to Band B and the second 1Tx on Band D to Band C. In this way, the user device 102 performs one UL Tx switching instance, and in doing so, is still able to transmit on Band C on Slot 7 and on Band B on Slot 8. For this single UL Tx switching instance, the switching period may be a maximum value of a switching period of band pair D+C (e.g. a switching period to switch from Band D to Band C), and a switching period of band pair D+B (e.g., a switching period to switch from Band D to Band B).

In another example with reference to Table 34, the user device 102 may be in transmit Case 1-1, such that it has a first transmitter as a used Tx on one port (1P) on band A and a second transmitter as an unused Tx on band B. In order to transmit on band C, the user device 102 may switch from transmit Case 1-1 to transmit Case 1-2 or to transmit Case 2-3. If the user device 102 switches to transmit Case 1-2, the user device 102 may switch the first, used Tx on 1P from band A to band C, while the second, unused Tx on band B stays on band B. Also, if the user device 102 switches from transmit Case 1-1 to transmit Case 2-3, the user device 102 may switch the first, used Tx on band A and the second, unused Tx on band B both to band C for the UL transmission after switching.

For such embodiments involving UL Tx switching with four bands, such as illustrated with respect to Figs. 31-34, the user device 102 may perform the UL Tx switching according to a pre-configuration, predefined rules, default behavior, or additional signaling indicating that indicates how to switch an unused transmitter, such as previously described.

Also, in the various embodiments described above, there is only one carrier per band. Similar UL Tx switching may be performed across bands as described above, where at least one of the bands includes at least two carriers (e.g., at least two continuous carriers).

Embodiment 2

Fig. 8 shows a flow chart of an example method 800 for wireless communication related to band pairs and/or band pair patterns. At block 802, a network device 104 determines a band pair

pattern or a band pair for one or more user devices to perform uplink (UL) transmitter (Tx) switching. At block 804, the network device 104 transmits a MAC-CE, a DCI, or RRC signaling to indicate or configure the band pair pattern or the band pair.

Fig. 9 shows a flow chart of another example method 900 for wireless communication related to band pairs and/or band pair patterns. At block 902, a user device 102 receives a MAC-CE, a DCI, or RRC signaling indicating or configuring a band pair pattern or a band pair for uplink (UL) transmitter (Tx) switching. At block 904, the user device 102 transmits an UL transmission using the UL Tx switching according to the band pair pattern or the band pair.

In further detail, in various embodiments of the method 800 and/or the method 900, the network device 104 indicates two bands out a certain configured number of bands (e.g., three or four bands), any two of the configured bands may be a band pair, and in case there are no additional restrictions for band pairs, there may be a total of six band pairs within 4 bands of a band combination (BC). After the network device 104 selects and/or indicates two bands, then the user device 102 may perform UL Tx switching according to the indicated two bands. For example, if currently available two bands are band 1 and band 2, after the network device 104 indicates the selected the two bands are band 3 and band 4, such as by a DCI or MAC CE, the user device 102 may perform UL Tx switching within band 3 and band 4. For example, referring back to Fig. 4, the user device 102 may currently perform UL Tx in cell 1 and cell 2 from band 1 and band 2. Then, if cell 3 and cell 4 from band 3 and band 4 are selected out from among four cells configured in four bands (e.g., by network indication, and/or by a cells or bands switching signaling), then the user device 102 may perform UL Tx switching within band 3 and band 4 for a subsequent UL transmission until a next indication by the network device 104.

In addition or alternatively, for embodiments where there are one or more TDD bands within the configured three or four bands, band pair switching may be frequent and band pair switching signaling may be sent frequently. Table 35 below shows four bands with different UL/DL configurations, carrier frequencies, and system bandwidths. One carrier on each band is assumed.

Band index	Band A	Band B	Band C	Band D
Carrier Frequency	4.9GHz	2.6GHz	700MHz	2GHz
System Bandwidth	100MHz	100MHz	20MHz	20MHz
Frame configuration	DDDSUDDSUU	DDDDDDDSUU	FDD	FDD

	(unaligned frame boundary: SUDDSUUDDD)			
S(DL:UL)	10D:2G:2U	6D:4G:4U	-	-
Sub-carrier Spacing	30KHz	30KHz	30KHz	30KHz

Table 35: Band configuration for four bands

If only one band pair is indicated by the MAC-CE or the DCI, band pair switching signaling based on the DCI may be sent frequently, while band pair switching signaling based on the MAC-CE may be unworkable due to, e.g., about 3 milliseconds of, MAC-CE processing time.

Fig. 10 shows a frame structure for four bands, with each slot designed as downlink (D), uplink (U), or special (S), similar to Figs. 6 and 7 above. As shown in Fig. 10, assume there are five possible band pairs: A+C, B+D, A+D, B+C and C+D. Band pair switching signaling may be sent up to 6 times in a radio frame. Correspondingly, band pair switching signaling may include: an indication of switching to band pair A+C in slot 1, an indication of switching to band pair C+D in slots 2 to 4, an indication of switching to band pair A+C in slots 5 to 6, an indication of switching to band pair C+D in slot 7, an indication of switching to band pair B+D in slots 8 to 9, and indication of switching to band pair C+D in slot 0.

In order to avoid indicating the band pair switching by MAC-CE or DCI frequently, the user device 102 and/or the network device 104 may employ or apply one or more of the following schemes.

In a first scheme (Scheme 1): the network device 104 and/or the user device 102 may use a MAC-CE or a DCI to indicate one band pair pattern. The band pair pattern that is indicated may be from among a plurality of band pair patterns. For at least some embodiments, all, or at least some, of the plurality of band pair patterns may be configured by RRC. In some embodiments, the band pair pattern is configured within a period, e.g. a radio frame, one or multiple TDD frame structure periodicities (e.g., TDD DL/UL configuration periodicity), or a configured period. Further, the period comprising a plurality of slots using the SCS of one cell or carrier of one band among the configured 3 or 4 bands, may include one of the following: (1) a minimum SCS of one cell or carrier of one band among the configured 3 or 4 bands; (2) a maximum SCS of one cell or carrier of one band among the configured 3 or 4 bands; or (3) a configured or anchor or predefined cell or carrier of one band among the configured 3 or 4 bands. In case the SCS of two or more bands are the same, the network device 104 may use the RRC signaling of a cell group to configure the band pair pattern,

or using one of the cells to configured the band pair pattern, such as the cell with the lowest cell index. For example, a SCS of the UL BWP of the carrier or cell on band A is 15kHz, and the other SCSs are 30KHz, 30Khz, 60Khz. The network device 104 may use the 15khz on band A to configure the band pair pattern. For example, the network device 104 may determine that band pair A+B is to occupy one slot with SCS=15Khz on band A, and is to occupy two slots with SCS=30khz on band B.

To further illustrate, suppose a period for the band pair pattern is ten slots, such as the ten slots shown in Fig. 10 for example. In addition, suppose a first band pair pattern is: {C+D, A+C, C+D, C+D, C+D, A+C, A+C, C+D, B+C, B+C} on each slot, and a second band pair pattern is: {C+D, A+D, C+D, C+D, C+D, A+D, A+D, C+D, B+D, B+D} on each slot. In some embodiments, the two band pair patterns may be configured by RRC. The band pair pattern may be used based on the indication of the MAC-CE or the DCI. Also, for at least some embodiments, the user device 102 may use a band pair pattern indicated by a DCI or a MAC-CE until a next band pair pattern is indicated by a MAC-CE or DCI. Also, in some embodiments, the band pair pattern may include band pairs for less than all of the slots in a period. In particular of these embodiments, U slots/symbols are located only on up to two bands. For example, using the example ten-slot period as above, in some embodiments, a band pair pattern may include band pairs for less than all ten slots. For example, a first band pair may be: {A+C, A+C, A+C, B+C, B+C} on slots 1/5/6/8/9, the a second band pair pattern may be: {A+D, A+D, A+D, B+D, B+D} on slots 1/5/6/8/9.

In a second scheme (Scheme 2), the user device 102 and/or the network device 104 may use a MAC-CE to indicate up to N band pairs with a duration for each of the N band pairs within a period. In any of various embodiments, N may be a fixed or preconfigured value or may be configured by RRC. To illustrate as an example, with reference to Fig. 10, N=10, corresponding to the ten slots of the period. Correspondingly, the MAC-CE may indicate: {(1) band pair C+D with a duration equal to 1 slot, (2) band pair A+C with a duration equal to 1 slot, (3) band pair C+D with a duration equal to 3 slots, (4) band pair A+C with a duration equal to 2 slots, (5) band pair C+D with a duration equal to 1 slot, (6) band pair B+C with a duration equal to 1 slot, (7) null, (8) null, (9) null, and (10) null}, within a period of 10 slots. The user device 102 may use the band pair pattern as indicated by the MAC-CE. Also, in some embodiments, the user device 102 may use the band pair pattern until a next band pair pattern is indicated by a MAC-CE.

In a third scheme (Scheme 3), the user device 102 and/or the network device 104 may use a MAC-CE to indicate a band pair pattern within a period. To illustrate, referring Fig. 10 again for example, suppose a period for a band pair pattern is ten slots. A MAC-CE may indicate a band pair pattern to be: {C+D, A+C, C+D, C+D, C+D, A+C, A+C, C+D, B+D, B+D}, with a band pair on each slot. Then, the user device 102 may use the band pair pattern indicated by the MAC-CE. Also, in some embodiments, the user device 102 may use the band pair pattern until a next band pair pattern is indicated by a MAC-CE.

In a fourth scheme (Scheme 4), a band pair pattern may be configured by RRC signaling. Use of such a scheme may avoid or prevent using dynamic signaling to indicate band pair switching or a band pair pattern. To illustrate, using Fig. 10 for example, suppose a period for a band pair pattern is ten slots, the band pair pattern is configured by RRC, and that the band pair pattern is: {C+D, A+C, C+D, C+D, C+D, A+C, A+C, C+D, B+D, B+D}, with a band pair on each slot.

Through use of any of the above four schemes for band pair and/or band pair pattern indication, UL Tx switching may be reduced. Also, in various embodiments, indicating the band pair or band pair pattern, such as in accordance with the above schemes, may avoid indicating band pair switching by MAC-CE or DCI too frequently, especially for embodiments where there are one or more TDD bands within a configured number of (e.g., three or four) bands. Also, in any of various embodiments, a network device 104 may indicate the same band pair pattern or different band pair patterns for different user devices 104, depending on network implementation.

Embodiment 2-1

In addition or alternatively, for at least some embodiments, the user device 102 and/or the network device 104 may use a band pair pattern where the user device 102 can perform dynamic UL Tx switching across all supported transmit cases based on UL scheduling (e.g., via UL grant and/or RRC configuration for UL transmission).

Also, as mentioned, for embodiments or situations where there are one or more TDD bands within a configured number of (e.g., three or four) bands, band pair switching may be frequent. For example, as shown in Table 35, four bands, with one carrier on each band, may have different UL/DL configurations, carrier frequencies and system bandwidths. Also, as illustrated in the example in Fig. 10, using four bands may provide five possible band pairs: A+C, B+D, A+D, B+C

and C+D, and RRC configuration may provide a band pair pattern that includes a band pair on each slot, such as: {C+D, A+C, C+D, C+D, C+D, A+C, A+C, C+D, B+D, B+D} for a ten-slot time period. The band pair or band pair pattern can be derived by other methods in other embodiments.

In some embodiments, a user device 102 may support less than all possible switching cases (i.e., less than all possible switching from one transmit case to another). Rather, the user device 102 may support only a limited number of switching cases when switching to a particular band pair. This, in turn, may reduce the complexity of UL Tx switching implementation. To illustrate, suppose for example that the user device 102 is configured to switch between the transmit cases listed in Table 12, and that the user device 102 is configured to communicate over ten slots, such as in Fig. 10. In order to switch to band pair A+C on Slot 1, the user device 102 may only support switching from transmit cases 10, 9, 8 to transmit cases 3, 4, 9, respectively; to switch to band pair C+D in slots 2 to 4, the user device 102 may only support switching from transmit cases 3, 4 9 to transmit cases 10, 9, 8, respectively; to switch to band pair A+C in slots 5 to 6, the user device 102 may only support switching from transmit cases 10, 9, 8 to transmit cases 3, 4, /9, respectively; to switch to band pair C+D in slot 7, the user device 102 may only support switching from transmit cases 3, 4, 9 to transmit cases 10, 9, 8, respectively; to switch to band pair B+D in slots 8 to 9, the user device 102 may only support switching from transmit cases 10, 9, 8 to transmit cases 2, 7, 10, respectively; and to switch to band pair C+D in slot , the user device 102 may only support switching from transmit cases 2, 7, 10 to transmit cases 10, 9, 8, respectively. As a result, with this band pair pattern, the user device 102 may not switch to or from transmit cases 1, 5, or 6, which may desirably reduce UE complexity. Also, in various embodiments, different user device 102 may be indicated with the same band pair or band pair patterns as each other, or different band pairs or band pair patterns from each other, which may depend on network implementation.

Also, in some embodiments, a switching period between two band pairs may be determined by one of the following:

(1) the switching period for the preceding band pair;

(2) the switching period for the target band pair;

(3) the larger of the switching period of the preceding band pair and the switching period of the target band pair;

(4) reported by user device 102 between the two band pairs, where the value may be a single value or multiple separate values for different band pair switching;

(5a) where there are three bands and the switching is from 2Tx on a first band (Band C) to 1Tx+1Tx on second and third bands (Band A and Band B) (that is, the band pair switching is from band pair A+C or B+C to band pair A+B), a maximum value of a switching period to switch from the first band to the second band, and a switching period to switch from the first band to the third band; or

(5b) where there are four bands and the switching is from 1Tx+1Tx on first and second bands (e.g., Band C and Band D) to 1Tx+1Tx on third and fourth bands (e.g., Band A and Band B) (that is, the band pair switching is from band pair C+D to band pair A+B), a maximum value of switching periods of band pairs of the four bands, e.g., the maximum value of switching periods of the band pairs: A+C, A+D, B+C and B+D.

In sum, band pair patterns may be used to reduce the number of transmit and/or switching cases that are used from a total number of potential transmit and/or switching cases, which may desirably reduce UE complexity. In embodiments, the reduction in complexity may be especially experienced where there are one or more TDD bands within the configured number of (e.g., 3 or 4) bands.

Embodiment 2-2

In addition or alternatively, MAC-CE indicate a band pair or a band pair pattern may be indicated, such as via a MAC-CE, in combination with a CA option (or simultaneous transmission mode). In further detail, in some embodiments, a user device 102 may report that it does not support simultaneous transmission across two bands (i.e., it supports operating in the switchedUL mode (CA option 1), that it does support simultaneous transmission across two bands (i.e., it supports operating in the dualUL mode (CA option 2), or that it can 'both' support and not support simultaneous transmission across two bands (i.e., that it supports operating in both the switchedUL mode and in the dualUL mode). In various embodiments, the user device 102 may report its support of simultaneous transmission (switchedUL, dualUL, or both) per band combination (BC), where a band combination may include a plurality of bands (e.g., five or more bands, although other numbers of bands are possible). Also, in some embodiments, the user device 102 may report a list of band pairs

that it supports (supportedBandPairListNR). In particular of these embodiments, the user device 102 may report the list per BC. Additionally, for embodiments where the user device 102 reports 'both', the simultaneous transmission mode (e.g., switchedUL or dualUL) may be indicated in combination with a band pair or a band pair pattern, such as in accordance with the band pair and/or band pair pattern indicating described above.

To further illustrate, using Scheme 4 described above, for example, a band pair pattern combined with a CA option with each band pair may be configured by RRC signaling. Doing so, may avoid or prevent the use of dynamic signaling to indicate band pair switching or a band pair pattern. For example, referring to Figure 10, suppose a period for a band pair pattern is ten slots, and a band pair pattern with a CA option (or simultaneous transmission mode) with each band pair is configured by RRC. An example band pair pattern combined with a CA option for each band pair may be: {C+D, A+C, C+D, C+D, C+D, A+C, A+C, C+D, B+D, B+D}, with a band pair on each slot, combined with switchedUL for band pair C+D, dualUL for band pair A+C, and dualUL for band B+D.

For another example including supplemental UL (SUL) bands and non-supplemental or normal UL (NUL) bands, suppose three or four bands includes: a SUL band, a corresponding NUL band, and one or two other NUL bands. For example, suppose Band A is a SUL band with corresponding NUL Band B, and Band C and Band D are each NUL bands. Assume the period for the band pair pattern is ten slots, a band pair pattern with a CA option (or simultaneous transmission mode) with each band pair is configured by RRC. For example, the band pair pattern is:{C+D, A+B, C+D, C+D, C+D, A+B, A+C, C+D, B+D, B+D}, with a band pair on each slot, combined with switchedUL for band pair A+B, switchedUL for band pair A+C, dualUL for band pair C+D, and dualUL for band B+D. In other embodiments, the CA option (or simultaneous transmission mode) may be implicitly determined for each band pair. As a non-limiting example, only switchedUL is used for a SUL band combined with any other band, and dualUL is used for one NUL band combined with any other NUL band.

In addition or alternatively, in one embodiment, the user device 102 may report 'switchedUL'(CA option 1) or dualUL'(CA option 2) per band pair. For some of these embodiments, the user device 102 may also report a list of supported band pairs (e.g., supportedBandPairListNR)

for a band combination (BC). Then, the user device 102 and/or the network device 104 may implicitly determine the CA option (or simultaneous transmission mode) may be implicitly determined, in combination with a band pair or a band pair pattern based, such as in accordance with the above-described embodiments.

In sum, the CA option (or simultaneous transmission mode) may be explicitly or implicitly determined, in combination with a band pair or a band pair pattern. This, in turn, may provide more flexibility to perform UL Tx switching within each band pair in case more than one band pair is available across three or four bands.

The description and accompanying drawings above provide specific example embodiments and implementations. The described subject matter may, however, be embodied in a variety of different forms and, therefore, covered or claimed subject matter is intended to be construed as not being limited to any example embodiments set forth herein. A reasonably broad scope for claimed or covered subject matter is intended. Among other things, for example, subject matter may be embodied as methods, devices, components, systems, or non-transitory computer-readable media for storing computer codes. Accordingly, embodiments may, for example, take the form of hardware, software, firmware, storage media or any combination thereof. For example, the method embodiments described above may be implemented by components, devices, or systems including memory and processors by executing computer codes stored in the memory.

Throughout the specification and claims, terms may have nuanced meanings suggested or implied in context beyond an explicitly stated meaning. Likewise, the phrase "in one embodiment/implementation" as used herein does not necessarily refer to the same embodiment and the phrase "in another embodiment/implementation" as used herein does not necessarily refer to a different embodiment. It is intended, for example, that claimed subject matter includes combinations of example embodiments in whole or in part.

In general, terminology may be understood at least in part from usage in context. For example, terms, such as "and", "or", or "and/or," as used herein may include a variety of meanings that may depend at least in part on the context in which such terms are used. Typically, "or" if used to associate a list, such as A, B or C, is intended to mean A, B, and C, here used in the inclusive sense, as well as A, B or C, here used in the exclusive sense. In addition, the term "one or more"

as used herein, depending at least in part upon context, may be used to describe any feature, structure, or characteristic in a singular sense or may be used to describe combinations of features, structures or characteristics in a plural sense. Similarly, terms, such as "a," "an," or "the," may be understood to convey a singular usage or to convey a plural usage, depending at least in part upon context. In addition, the term "based on" may be understood as not necessarily intended to convey an exclusive set of factors and may, instead, allow for existence of additional factors not necessarily expressly described, again, depending at least in part on context.

Reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the present solution should be or are included in any single implementation thereof. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment is included in at least one embodiment of the present solution. Thus, discussions of the features and advantages, and similar language, throughout the specification may, but do not necessarily, refer to the same embodiment.

Furthermore, the described features, advantages and characteristics of the present solution may be combined in any suitable manner in one or more embodiments. One of ordinary skill in the relevant art will recognize, in light of the description herein, that the present solution can be practiced without one or more of the specific features or advantages of a particular embodiment. In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments of the present solution.

The subject matter of the disclosure may also relate to or include, among others, the following aspects:

A first aspect includes a method for wireless communication that includes: determining, by the user device, to perform uplink (UL) transmitter (Tx) switching with a first Tx and a second Tx, where, after the UL Tx switching, the first Tx is a used Tx for an UL transmission and the second Tx is an unused Tx for the UL transmission, wherein the UL Tx switching is performed according to a pre-configuration or a signaling that indicates how to perform the UL Tx switching for the unused Tx; and transmitting, by the user device, the UL transmission after the UL Tx switching.

A second aspect includes the first aspect, and further includes wherein at least one of: the UL Tx switching is performed across three bands, including a first band, a second band, and a third band, with one or more carriers on each band, each of the second band and the third supports a maximum of one Tx and the first band supports a maximum of two Tx, wherein a preceding UL transmission before the UL Tx switching is on the first band, wherein the UL transmission after the UL Tx switching is on the second band, and neither the preceding UL transmission before the UL Tx switching nor the UL transmission after the UL Tx switching is on the third band; the UL Tx switching is performed across three bands, with one or more carriers on each band, each of the three bands supports a maximum of one Tx, wherein the preceding UL transmission before the UL Tx switching is on a first band of the three bands and the unused Tx is on a second band of the three bands before the UL Tx switching, wherein the band used for the UL transmission after UL Tx switching is not the first band and the second band; the UL Tx switching is performed across four bands, with one or more carriers on each band, each of the four bands supports a maximum of one Tx, wherein the preceding UL transmission before the UL Tx switching is on a first band of the four bands and the unused Tx is on a second band of the four bands before the UL Tx switching, wherein the band used for the UL transmission after UL Tx switching is not the first band and the second band; the UL Tx switching is performed across four bands, each of three of the four bands supports a maximum of one Tx and one of the four bands supports a maximum of two Tx, wherein the preceding UL transmission before the UL Tx switching is on the one of the four bands that supports the maximum of two Tx, and both the first Tx and the second Tx are on the one of the four bands that supports the maximum of two Tx before the UL Tx switching; or the UL Tx switching is performed across four bands, each of a first two of the four bands supports a maximum of one Tx and each of a second two of the four bands supports a maximum of two Tx, wherein the preceding UL transmission before the UL Tx switching is on one of the second two bands that supports the maximum of two Tx, and both the first Tx and the second Tx are on the one of the second two bands before the UL Tx switching.

A third aspect includes any of the first or second aspects, and further includes wherein the pre-configuration or the signaling indicates that the unused Tx is to stay on a previous band with one or more carriers when performing the UL Tx switching or after UL Tx switching.

A fourth aspect includes any of the first or second aspects, and further includes wherein the pre-configuration or the signaling indicates that the unused Tx is to switch to a different band with one or more carriers from a previous band when performing the UL Tx switching or after UL Tx switching.

A fifth aspect includes the fourth aspect, and further includes wherein one or more downlink (DL) slots or symbols on the previous band follow a preceding slot on which a preceding UL transmission was performed on the previous band with one or more carriers.

A sixth aspect includes the fourth aspect, and further includes wherein the different band comprises one of: a third band different from a second band on which the UL transmission is performed after the UL Tx switching, and different from a first band on which the preceding UL transmission is performed before the UL Tx switching; the second band on which the UL transmission is performed after the UL Tx switching; or a fourth band different from the second band on which the UL transmission is performed after the UL Tx switching, different from the first band on which the preceding UL transmission is performed before the UL Tx switching, and different from a third band that the unused Tx is on before the UL Tx switching.

A seventh aspect includes any of the second through sixth aspects, and further includes wherein one or two bands of the three or four bands is a supplemental uplink (SUL) band and remaining bands are NUL bands, or all the three or four bands are non-SUL or normal UL (NUL) bands.

An eighth aspect includes any of the first through seventh aspects, and further includes wherein the simultaneous transmission across two bands is not supported for the UL Tx switching.

A ninth aspect includes a method for wireless communication that includes: determining, by the network device, a band pair pattern or a band pair for one or more user devices to perform an uplink (UL) transmitter (Tx) switching; and transmitting, by the network device, a medium access control control element (MAC-CE), a downlink control information (DCI), or radio resource control (RRC) signaling to indicate or configure the band pair pattern or the band pair.

A tenth aspect includes a method for wireless communication that includes: receiving, by a user device, a medium access control control element (MAC-CE), a downlink control information (DCI), or radio resource control (RRC) signaling indicating or configuring a band pair pattern or a band pair for an uplink (UL) transmitter (Tx) switching; and transmitting, by the user

device, an UL transmission using the UL Tx switching according to the band pair pattern or the band pair.

An eleventh aspect includes any of the ninth or tenth aspects, and further includes wherein determining the band pair pattern comprises using MAC-CE or DCI to determine the band pair pattern from among a plurality of band pair patterns configured by radio resource control (RRC) signaling.

A twelfth aspect includes the eleventh aspect, and further includes wherein the band pair pattern corresponds to a time period comprising a plurality of slots.

A thirteenth aspect includes any of the ninth or tenth aspects, and further includes wherein the band pair pattern comprises N band pairs, wherein each band pair corresponds to a respective duration within a time period comprising a plurality of slots.

A fourteenth aspect includes the thirteenth aspect, and further includes wherein the band pair pattern comprising the N band pairs and the respective durations are indicated by the MAC-CE.

A fifteenth aspect includes any of the ninth or tenth aspects, and further includes wherein the MAC-CE indicates the band pair pattern within a period comprising a plurality of slots.

A sixteenth aspect includes any of the ninth or tenth aspects, and further includes wherein the band pair pattern within a period comprising a plurality of slots is configured by the RRC signaling.

A seventeenth aspect includes any of the twelfth, thirteenth, fifteenth, or sixteenth aspects, and further includes wherein the period comprising a plurality of slots comprises: at least one time division duplex (TDD) periodicity, a fixed value, or a configured value.

An eighteenth aspect includes any of the twelfth, thirteenth, fifteenth, or sixteenth aspects, and further includes wherein the period comprising a plurality of slots uses a subcarrier spacing (SCS) of one cell or carrier of one band among a configured three or more bands: a minimum or a maximum SCS of the one cell or carrier of the one band among the configured three or more bands, or a configured, anchor or predefined cell or carrier of the one band among the configured three or more bands.

A nineteenth aspect includes the seventeenth aspect, and further includes wherein the band pair pattern is configured or indicated by one of: each band pair per slot of all of the plurality of slots; or each band pair per slot of less than all of the plurality of slots.

A twentieth aspect includes the nineteenth aspect, and further includes wherein the less than all of the plurality of slots comprise UL slots or symbols located on at least three bands of three or more configured bands.

A twenty-first aspect includes any of the ninth through twentieth aspects, and further includes wherein the user device uses the band pair pattern for the UL Tx switching until a next band pair pattern indication by a next MAC-CE or a next DCI.

A twenty-second aspect includes any of the first through twenty-second aspects, and further includes wherein a switching period of the UL Tx switching to switch from two transmitters on a first band to one transmitter on a second band and one transmitter on a third band, or a switching period between two band pairs, is based on: a first switching period to switch between the first band to the second band or between the first band and the third band; a second switching period to switch between the second band and the third band; a larger of the first switching period and the second switching period; a single time period or a plurality of time periods reported by the user device; or a maximum switching period among a switching period to switch between the first band and the second band and a switching period to switch between the first band and the third band; a maximum value of switching periods of four band pairs of the first band and the third band, the first band and the fourth band, the second band and the third band, the second band and the fourth band, in case band pair of the first band and the second band is switched to band pair of the third band and the fourth band.

A twenty-third aspect includes a wireless communications apparatus comprising a processor and a memory, wherein the processor is configured to read code from the memory to implement any of the first through twenty-second aspects.

A twenty-fourth aspect includes a computer program product comprising a computer-readable program medium comprising code stored thereupon, the code, when executed by a processor, causing the processor to implement any of the first through twenty-second aspects.

In addition to the features mentioned in each of the independent aspects enumerated above, some examples may show, alone or in combination, the optional features mentioned in the dependent aspects and/or as disclosed in the description above and shown in the figures.

CLAIMS

1. A method for wireless communication, the method comprising:

determining, by the user device, to perform uplink (UL) transmitter (Tx) switching with a first Tx and a second Tx, where, after the UL Tx switching, the first Tx is a used Tx for an UL transmission and the second Tx is an unused Tx for the UL transmission, wherein the UL Tx switching is performed according to a pre-configuration or a signaling that indicates how to perform the UL Tx switching for the unused Tx; and

transmitting, by the user device, the UL transmission after the UL Tx switching.

2. The method of claim 1, wherein at least one of:

the UL Tx switching is performed across three bands, including a first band, a second band, and a third band, with one or more carriers on each band, each of the second band and the third supports a maximum of one Tx and the first band supports a maximum of two Tx, wherein a preceding UL transmission before the UL Tx switching is on the first band, wherein the UL transmission after the UL Tx switching is on the second band, and neither the preceding UL transmission before the UL Tx switching nor the UL transmission after the UL Tx switching is on the third band;

the UL Tx switching is performed across three bands, with one or more carriers on each band, each of the three bands supports a maximum of one Tx, wherein the preceding UL transmission before the UL Tx switching is on a first band of the three bands and the unused Tx is on a second band of the three bands before the UL Tx switching, wherein the band used for the UL transmission after UL Tx switching is not the first band and the second band;

the UL Tx switching is performed across four bands, with one or more carriers on each band, each of the four bands supports a maximum of one Tx, wherein the preceding UL transmission before the UL Tx switching is on a first band of the four bands and the unused Tx is on a second band of the four bands before the UL Tx switching, wherein the band used for the UL transmission after UL Tx switching is not the first band and the second band;

the UL Tx switching is performed across four bands, each of three of the four bands supports a maximum of one Tx and one of the four bands supports a maximum of two Tx, wherein the

preceding UL transmission before the UL Tx switching is on the one of the four bands that supports the maximum of two Tx, and both the first Tx and the second Tx are on the one of the four bands that supports the maximum of two Tx before the UL Tx switching; or

the UL Tx switching is performed across four bands, each of a first two of the four bands supports a maximum of one Tx and each of a second two of the four bands supports a maximum of two Tx, wherein the preceding UL transmission before the UL Tx switching is on one of the second two bands that supports the maximum of two Tx, and both the first Tx and the second Tx are on the one of the second two bands before the UL Tx switching.

3. The method of claim 1 or 2, wherein the pre-configuration or the signaling indicates that the unused Tx is to stay on a previous band with one or more carriers when performing the UL Tx switching or after UL Tx switching.

4. The method of claim 1 or 2, wherein the pre-configuration or the signaling indicates that the unused Tx is to switch to a different band with one or more carriers from a previous band when performing the UL Tx switching or after UL Tx switching.

5. The method of claim 4, wherein one or more downlink (DL) slots or symbols on the previous band follow a preceding slot on which a preceding UL transmission was performed on the previous band with one or more carriers.

6. The method of claim 4, wherein the different band comprises one of:

a third band different from a second band on which the UL transmission is performed after the UL Tx switching, and different from a first band on which the preceding UL transmission is performed before the UL Tx switching;

the second band on which the UL transmission is performed after the UL Tx switching; or

a fourth band different from the second band on which the UL transmission is performed after the UL Tx switching, different from the first band on which the preceding UL transmission is performed before the UL Tx switching, and different from a third band that the unused Tx is on before the UL Tx switching.

7. The method of claim 2, wherein one or two bands of the three or four bands is a supplemental uplink (SUL) band and remaining bands are NUL bands, or all the three or four bands are non-SUL or normal UL (NUL) bands.

8. The method of claim 1 or 2, wherein the simultaneous transmission across two bands is not supported for the UL Tx switching.

9. A method for wireless communication, the method comprising:

determining, by a network device, a band pair pattern or a band pair for one or more user devices to perform an uplink (UL) transmitter (Tx) switching; and

transmitting, by the network device, a medium access control control element (MAC-CE), a downlink control information (DCI), or radio resource control (RRC) signaling to indicate or configure the band pair pattern or the band pair.

10. A method for wireless communication, the method comprising:

receiving, by a user device, a medium access control control element (MAC-CE), a downlink control information (DCI), or radio resource control (RRC) signaling indicating or configuring a band pair pattern or a band pair for an uplink (UL) transmitter (Tx) switching; and

transmitting, by the user device, an UL transmission using the UL Tx switching according to the band pair pattern or the band pair.

11. The method of claims 9 or 10, wherein determining the band pair pattern comprises using the MAC-CE or the DCI to determine the band pair pattern from among a plurality of band pair patterns configured by the radio resource control (RRC) signaling.

12. The method of claims 11, wherein the band pair pattern corresponds to a time period comprising a plurality of slots.

13. The method of claims 9 or 10, wherein the band pair pattern comprises N band pairs, wherein each band pair corresponds to a respective duration within a time period comprising a plurality of slots.

14. The method of claim 13, wherein the band pair pattern comprising the N band pairs and the respective durations are indicated by the MAC-CE.

15. The method of claims 9 or 10, wherein the MAC-CE indicates the band pair pattern within a period comprising a plurality of slots.

16. The method of claims 9 or 10, wherein the band pair pattern within a period comprising a plurality of slots is configured by the RRC signaling.

17. The method of any of claims 12, 13, 15, or 16, wherein the period comprising a plurality of slots comprises: at least one time division duplex (TDD) periodicity, a fixed value, or a configured value.

18. The method of any of claims 12, 13, 15, or 16, wherein the period comprising a plurality of slots uses a subcarrier spacing (SCS) of one cell or carrier of one band among a configured three or more bands: a minimum or a maximum SCS of the one cell or carrier of the one band among the configured three or more bands, or a configured, anchor or predefined cell or carrier of the one band among the configured three or more bands.

19. The method of claim 17 or 18, wherein the band pair pattern is configured or indicated by one of:

each band pair per slot of all of the plurality of slots; or

each band pair per slot of less than all of the plurality of slots.

20. The method of claim 19, wherein the less than all of the plurality of slots comprise UL slots or symbols located on at least three bands of three or more configured bands.

21. The method of claims 9 or 10, wherein the user device uses the band pair pattern for the UL Tx switching until a next band pair pattern indication by a next MAC-CE or a next DCI.

22. The method of any of claims 1-21, wherein a switching period of the UL Tx switching to switch from two transmitters on a first band to one transmitter on a second band and one transmitter on a third band, or a switching period between two band pairs, is based on:

a first switching period to switch between the first band to the second band or between the first band and the third band;

a second switching period to switch between the second band and the third band;

a larger of the first switching period and the second switching period;

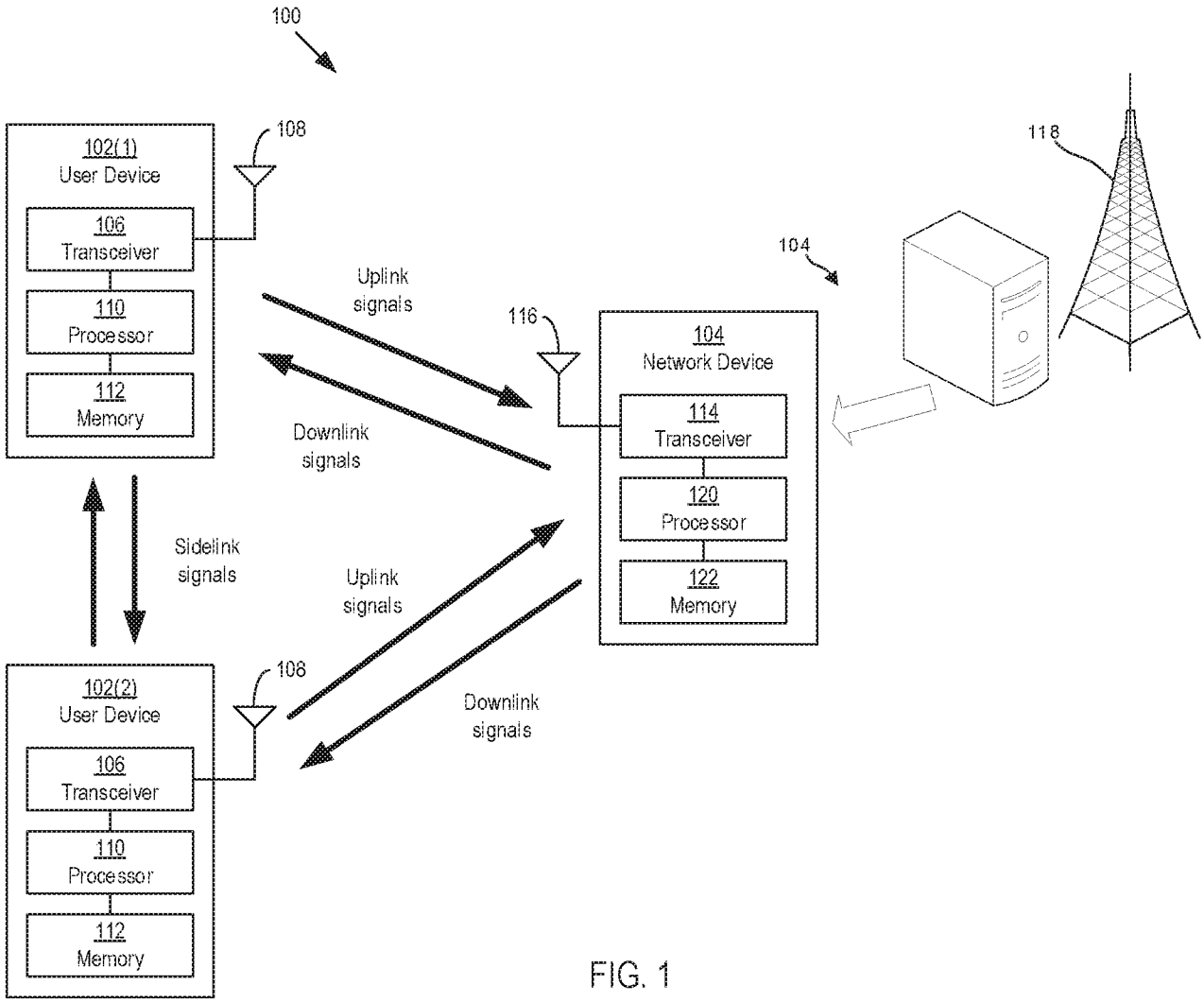
a single time period or a plurality of time periods reported by the user device; or

a maximum switching period among a switching period to switch between the first band and the second band and a switching period to switch between the first band and the third band;

a maximum value of switching periods of four band pairs of the first band and the third band, the first band and the fourth band, the second band and the third band, the second band and the fourth band, in case band pair of the first band and the second band is switched to band pair of the third band and the fourth band.

23. A wireless communications apparatus comprising a processor and a memory, wherein the processor is configured to read code from the memory to implement a method of any of claims 1 to 22.

24. A computer program product comprising a computer-readable program medium comprising code stored thereupon, the code, when executed by a processor, causing the processor to implement a method of any of claims 1 to 22.


100
102(1)
User Device
106
Transceiver
110
Processor
112
Memory
108
Uplink
signals
Downlink
signals
116
104
Network Device
114
Transceiver
120
Processor
122
Memory
104
118
Sidelink
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signals
Downlink
signals
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User Device
106
Transceiver
110
Processor
112
Memory
108

FIG. 1

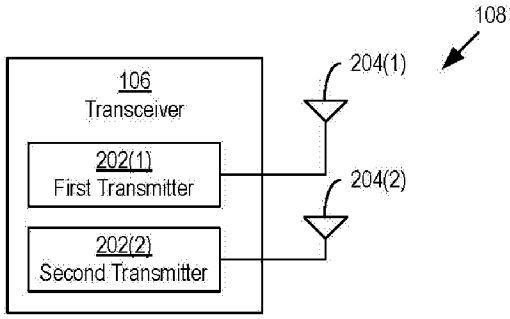

FIG. 2

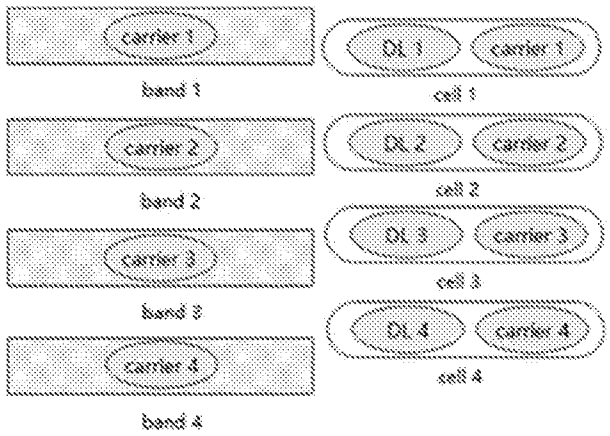

FIG. 3

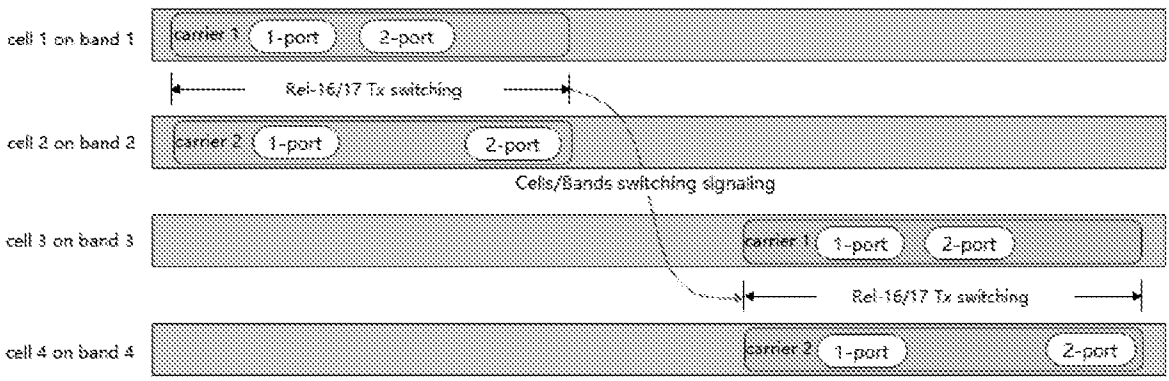

FIG. 4

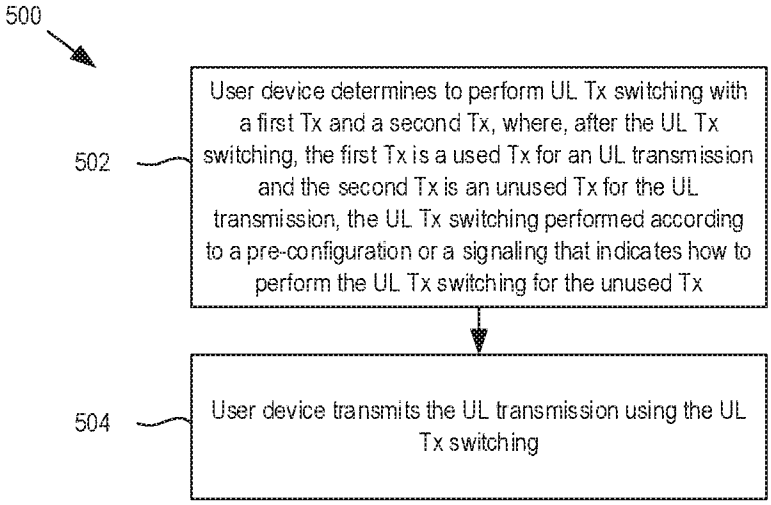

FIG. 5

Slot Index	0	1	2	3	4	5	6	7	8	9
Band C	S	U	D	D	S	U	U	D	D	D
Band B	D	D	D	D	D	D	D	S	U	U
Band A	U	U	U	U	U	U	U	U	U	U

FIG. 6

Slot Index	0	1	2	3	4	5	6	7	8	9
Band D	S	U	D	D	S	U	U	D	D	D
Band C	U	U	U	U	U	U	U	U	U	U
Band B	D	D	D	D	D	D	D	S	U	U
Band A	U	U	U	U	U	U	U	U	U	U

FIG. 7

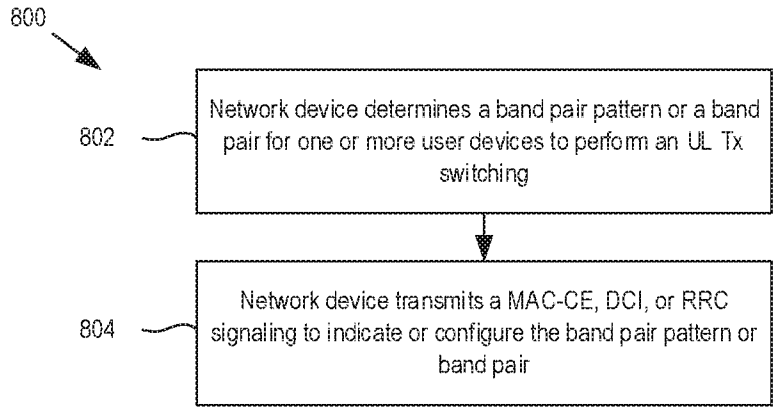

FIG. 8

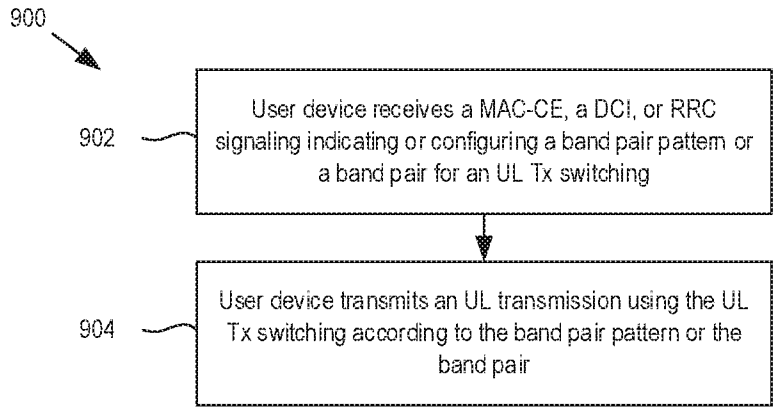

FIG. 9

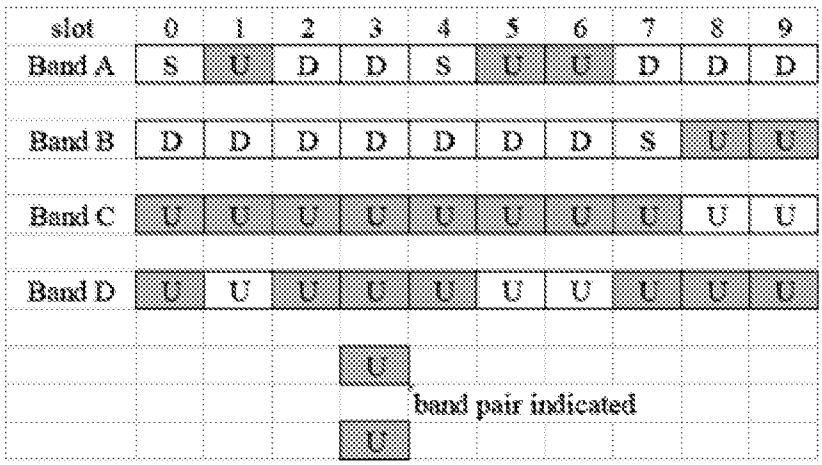

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/113711

A. CLASSIFICATION OF SUBJECT MATTER

H04L5/00(2006.01)i;H04W36/06(2009.01)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:H04W,H04L

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,ENTXT,WPABS,3GPP:frequency,band,carrier,combination,set,dci,mac,pair,rrc,switch,switching,transmitter,tx,ul, unused,uplink,configuration,indicate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 114245431 A (CHINA TELECOM CO., LTD.) 25 March 2022 (2022-03-25) description, paragraphs 0033-0092	1-24
X	US 2019334666 A1 (QUALCOMM INC.) 31 October 2019 (2019-10-31) description, paragraphs 0075-0132	9-24
X	CHINA TELECOM. "R2-2003264 Report of email discussion [Post109e#33][R16 Other] UL TX Switching-NR_FR1" *3GPP TSG-RAN2 Meeting#109bis-e,* 30 April 2020 (2020-04-30), sections 2-3	9-24
A	ZTE. "R1-2102484 Discussion on Rel-17 UL Tx Switching" *3GPP TSG RAN WG1#104b-e,* 20 April 2021 (2021-04-20), the whole document	1-24
A	CATT. "R1-2102583 Discussion on R17 enhancements for UL TX switching" *3GPP TSG RAN WG1 Meeting #104b-e,* 20 April 2021 (2021-04-20), the whole document	1-24

☑ 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	Date of mailing of the international search report
24 April 2023	**28 April 2023**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/113711

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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