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(54) **METHOD AND APPARATUS FOR ADAPTING A CHANNEL SENSING THRESHOLD**

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**Publication Classification**

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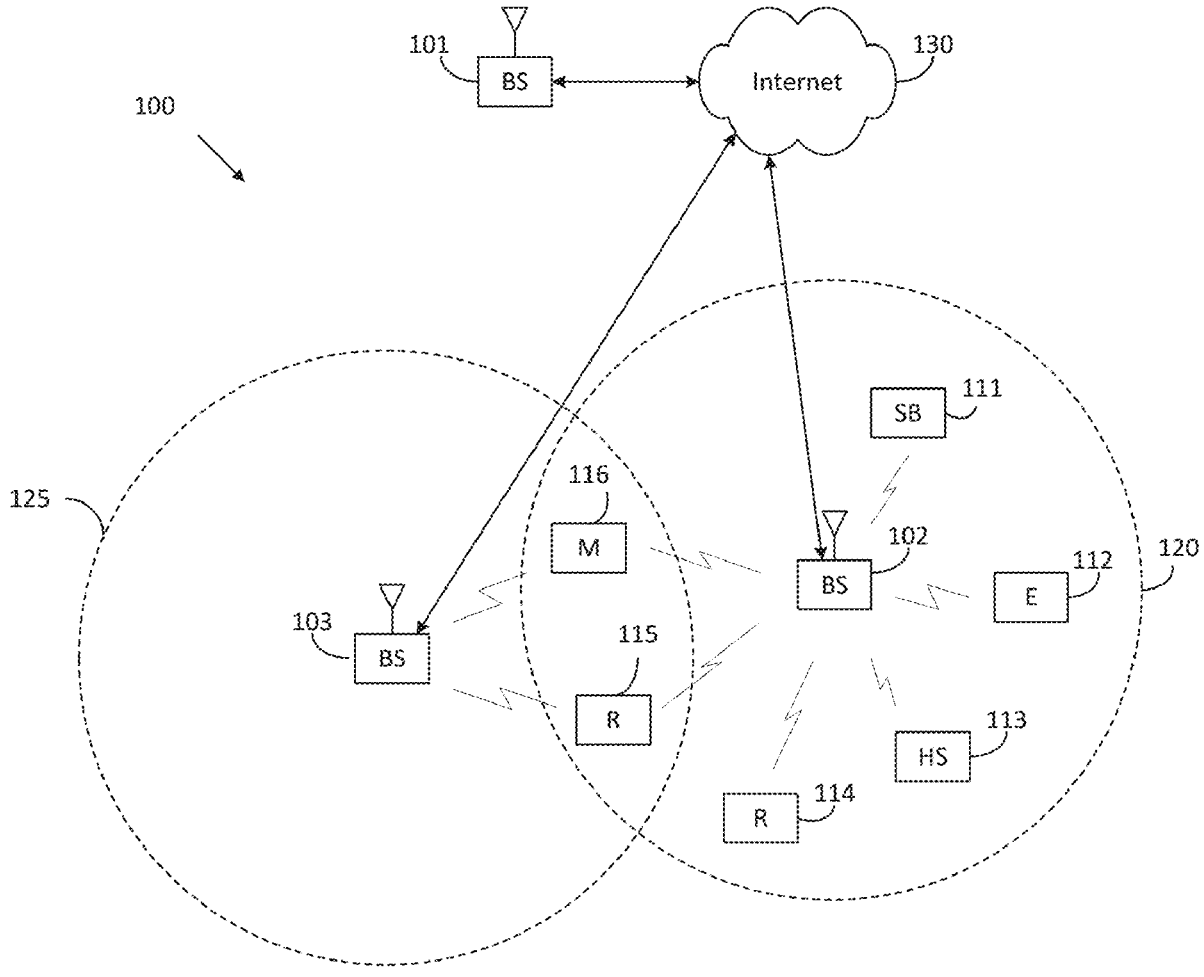
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| ***H04W 16/14*** | (2006.01) |
| ***H04W 16/28*** | (2006.01) |
| ***H04L 5/00*** | (2006.01) |

(52) **U.S. Cl.**

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(57) **ABSTRACT**

Methods and apparatuses for adapting a channel sensing threshold in a wireless communication system operating with shared spectrum channel access. A method for operating a base station (BS) includes determining whether an antenna configuration for channel sensing is omni-directional or directional and determining a channel sensing threshold. The channel sensing threshold includes two parts: a first part of the channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the channel sensing threshold depending on the antenna configuration. The method further includes performing a channel sensing procedure based on the antenna configuration and the channel sensing threshold and transmitting downlink (DL) data over a channel based on the channel being sensed as idle in the channel sensing procedure.



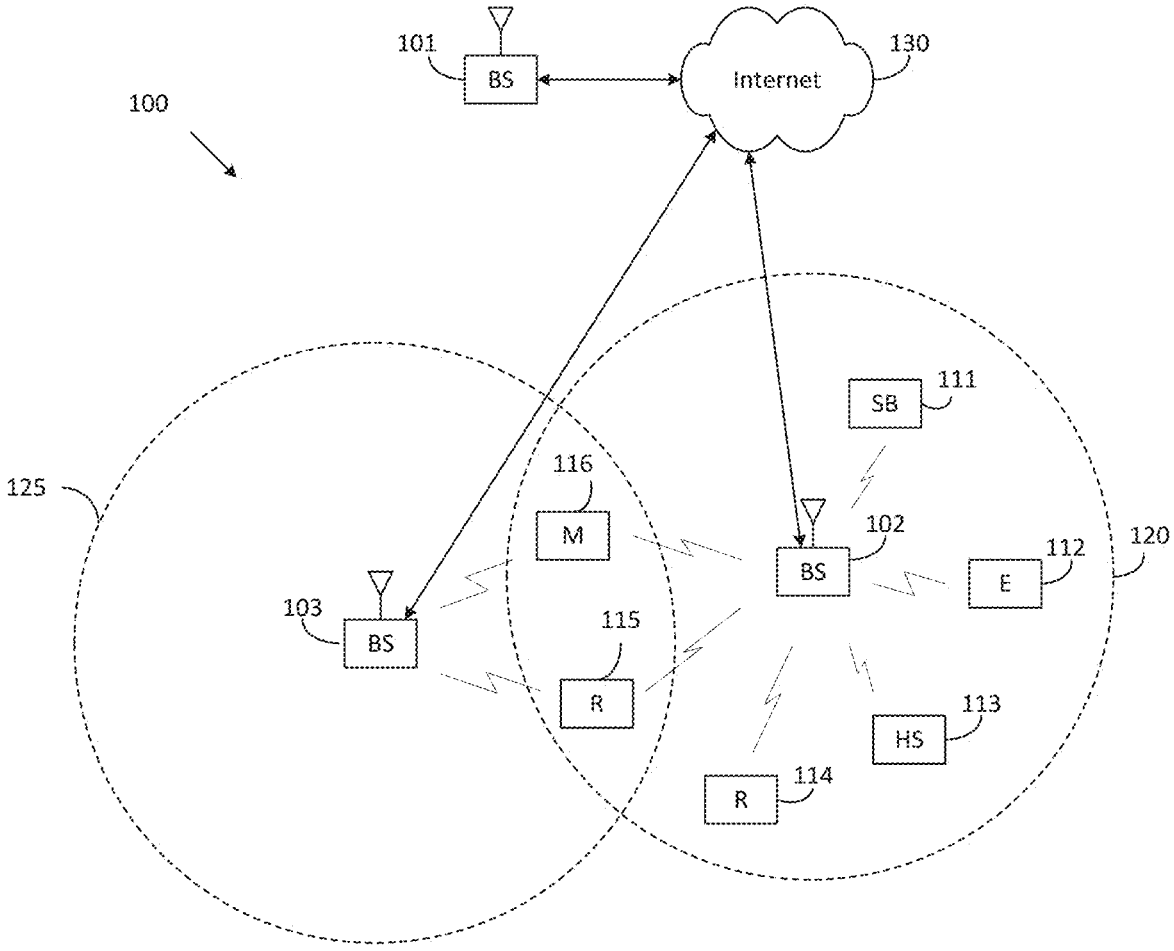

100
101
BS
Internet
130
125
SB
111
116
M
102
BS
112
E
120
103
BS
115
R
113
HS
R
114

FIG. 1

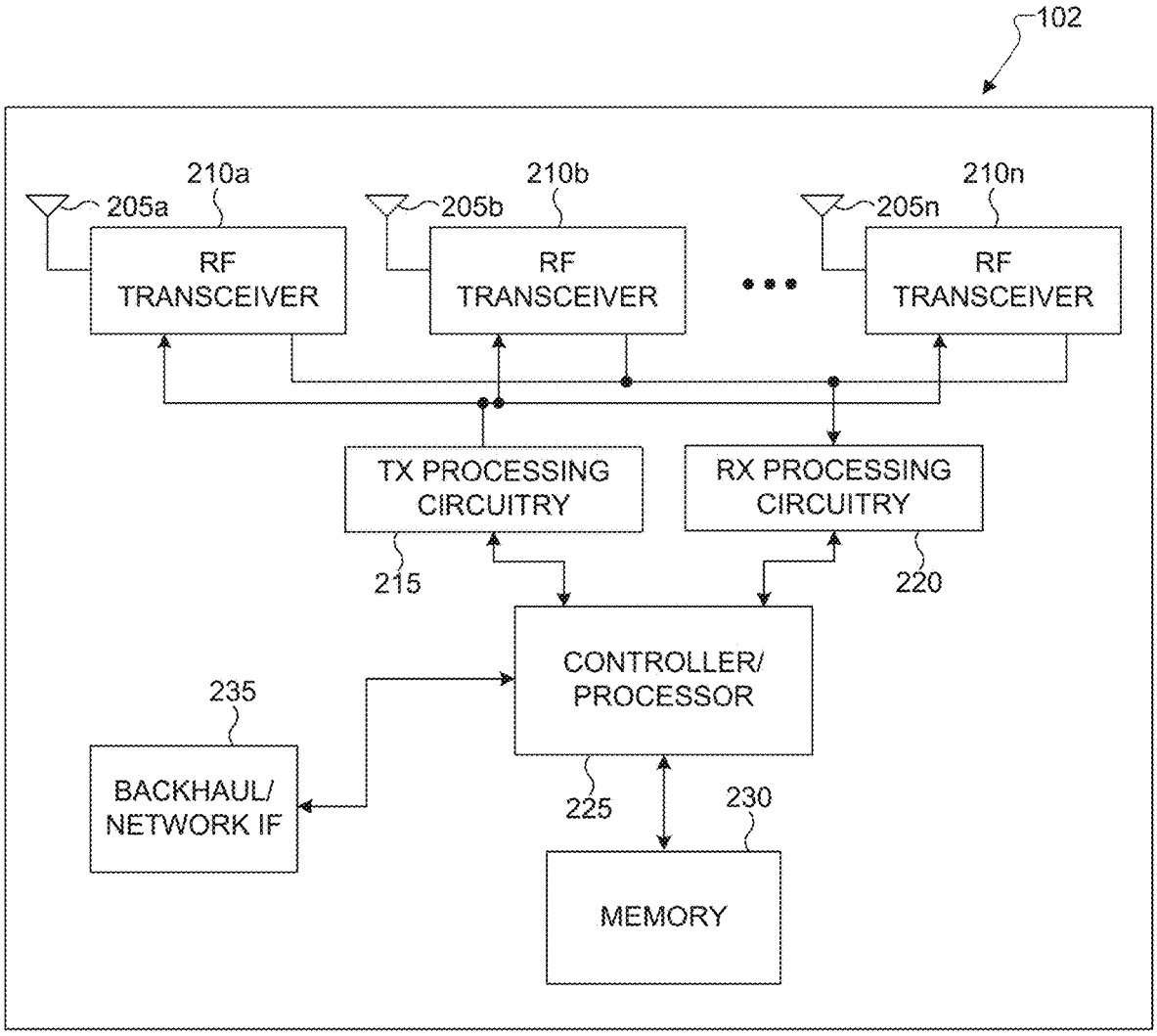

102
210a
205a
RF TRANSCEIVER
210b
205b
RF TRANSCEIVER
210n
205n
RF TRANSCEIVER
TX PROCESSING CIRCUITRY
215
RX PROCESSING CIRCUITRY
220
CONTROLLER/ PROCESSOR
235
BACKHAUL/ NETWORK IF
225
230
MEMORY

FIG. 2

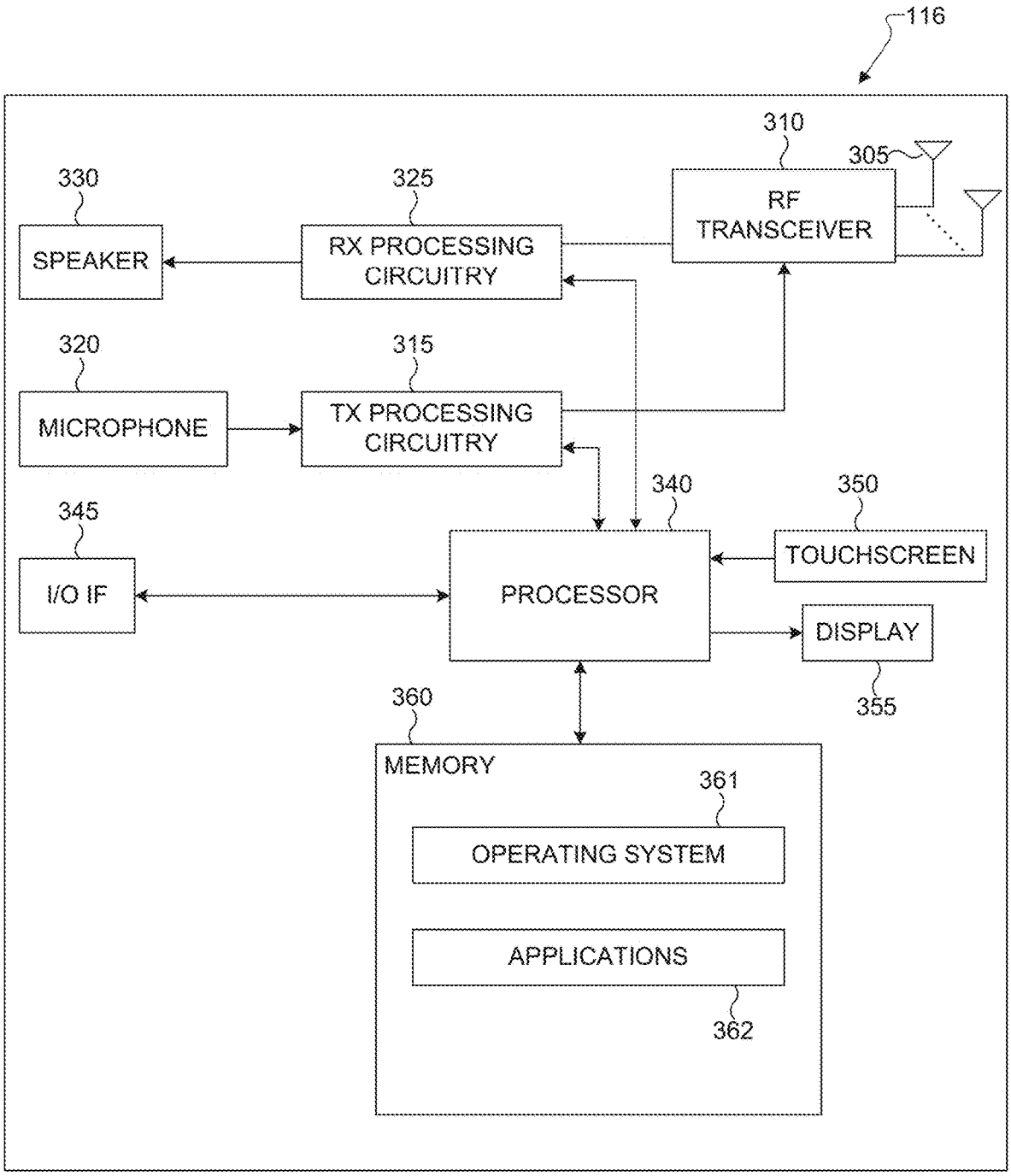

116
310
305
330
325
RF TRANSCEIVER
SPEAKER
RX PROCESSING CIRCUITRY
320
315
MICROPHONE
TX PROCESSING CIRCUITRY
340
350
345
TOUCHSCREEN
I/O IF
PROCESSOR
DISPLAY
355
360
MEMORY
361
OPERATING SYSTEM
APPLICATIONS
362

FIG. 3

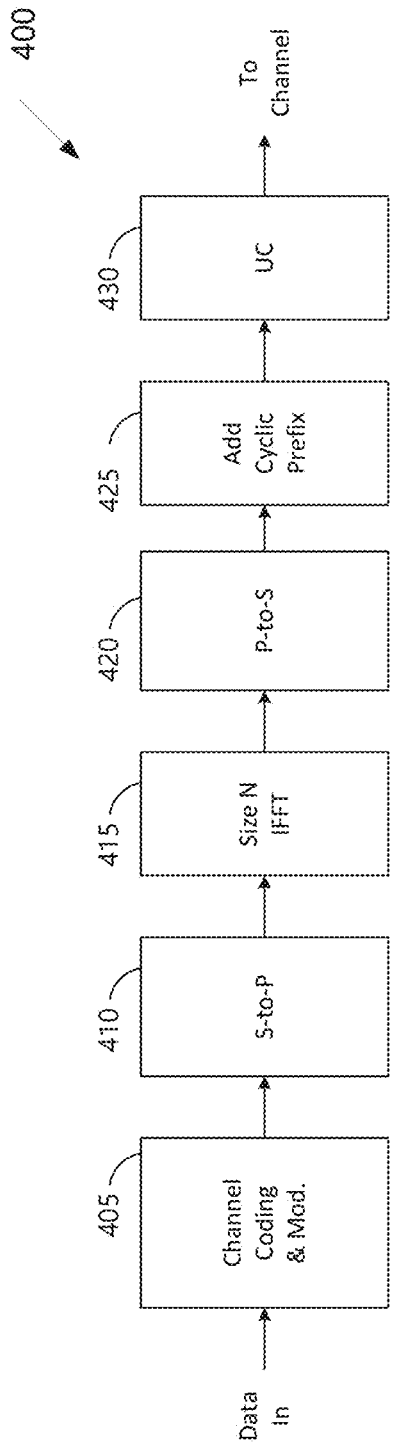

400
Data In
405
Channel Coding & Mod.
410
S-to-P
415
Size N IFFT
420
P-to-S
425
Add Cyclic Prefix
430
UC
To Channel

FIG. 4

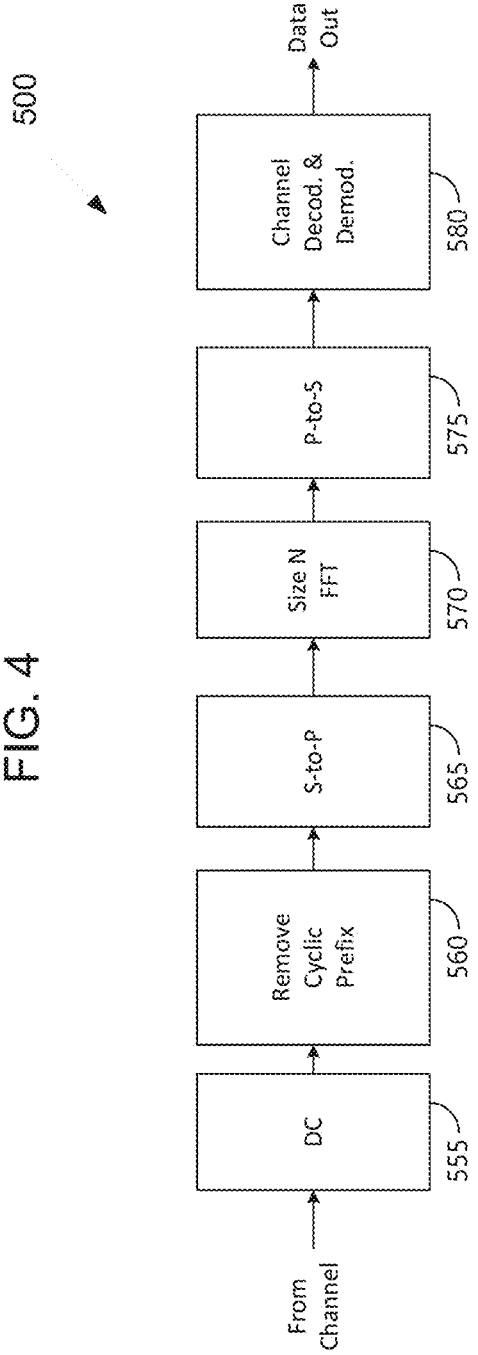

500
From Channel
555
DC
560
Remove Cyclic Prefix
565
S-to-P
570
Size N FFT
575
P-to-S
580
Channel Decod. & Demod.
Data Out

FIG. 5

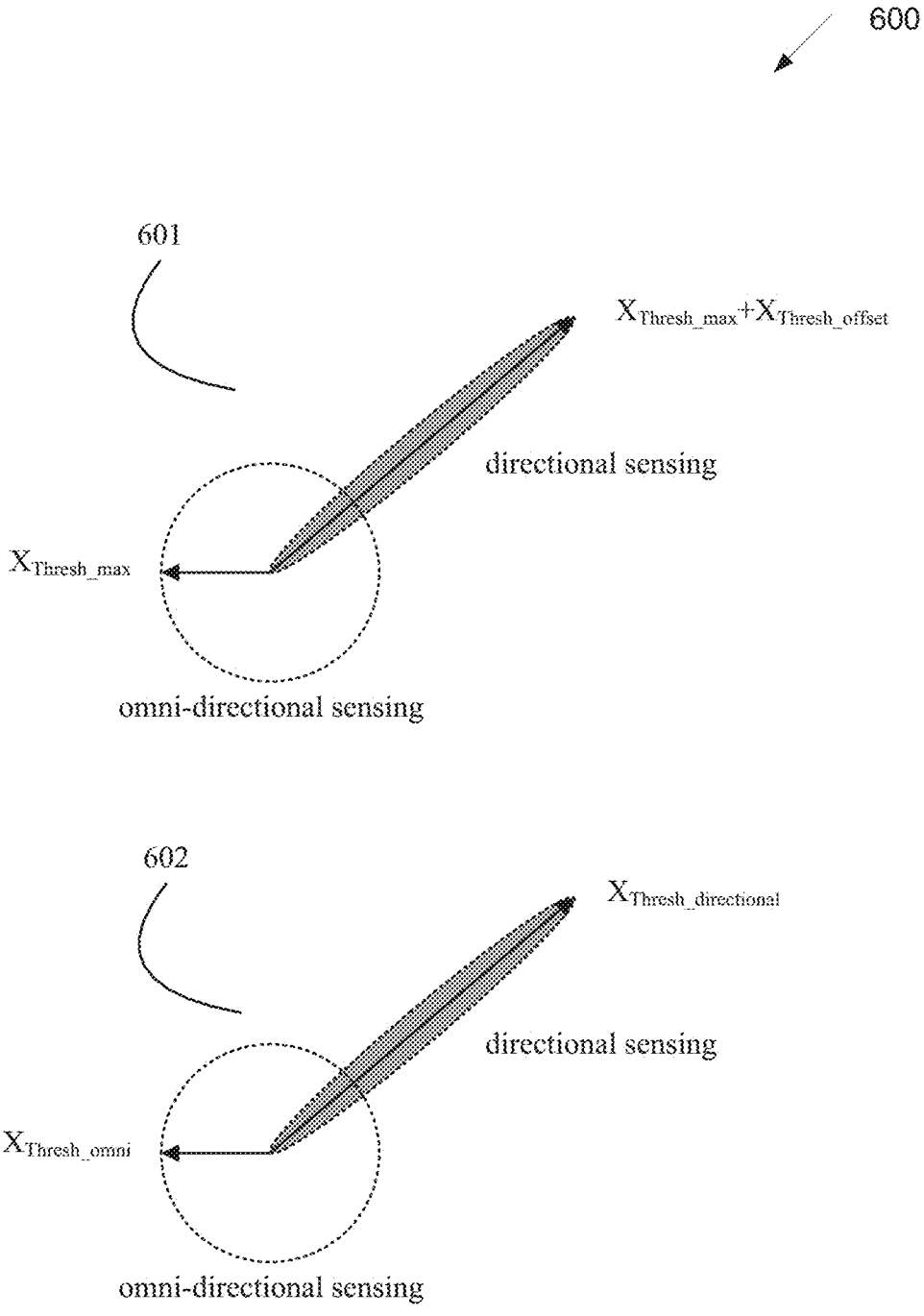

600
601
$X_{Thresh_max}+X_{Thresh_offset}$
directional sensing
$X_{Thresh_max}$
omni-directional sensing
602
$X_{Thresh_directional}$
directional sensing
$X_{Thresh_omni}$
omni-directional sensing

FIG. 6

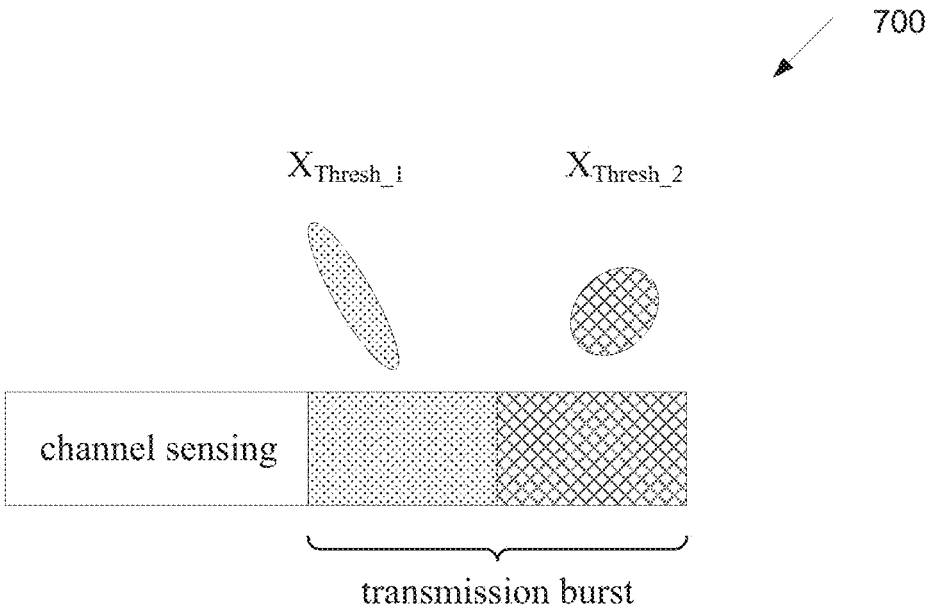

700
$X_{Thresh_1}$
$X_{Thresh_2}$
channel sensing
transmission burst

FIG. 7

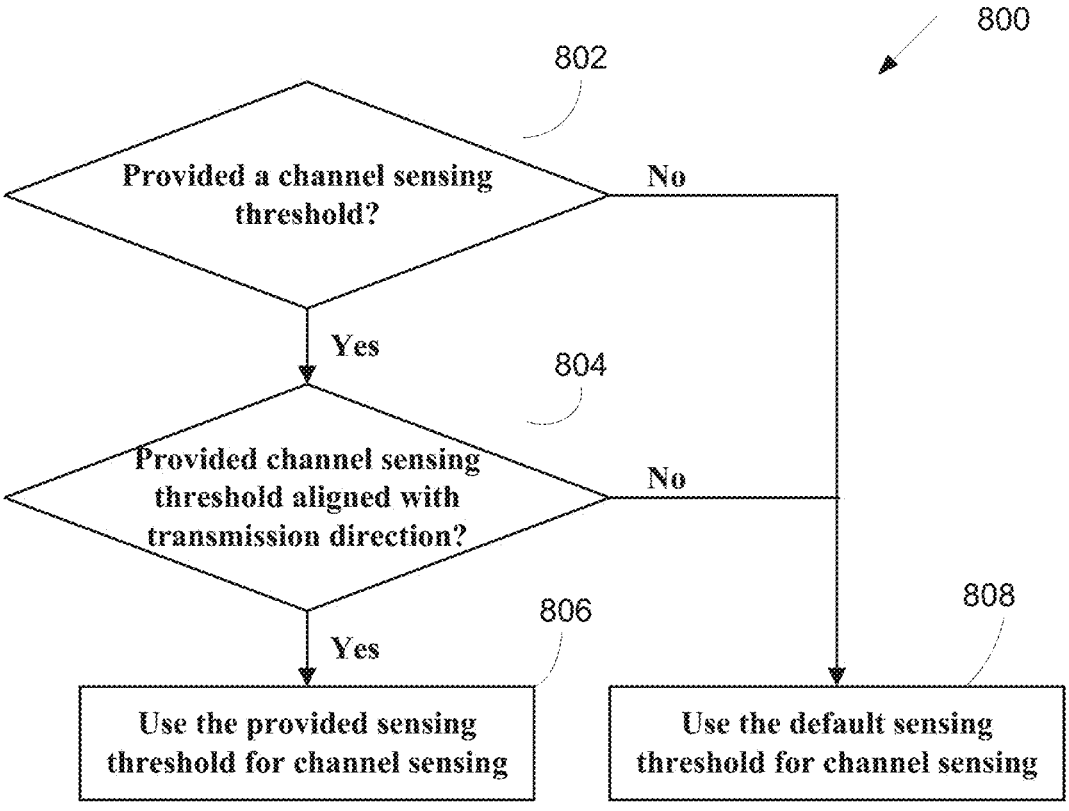

800
802
Provided a channel sensing threshold?
No
Yes
804
Provided channel sensing threshold aligned with transmission direction?
No
Yes
806
808
Use the provided sensing threshold for channel sensing
Use the default sensing threshold for channel sensing

FIG. 8A

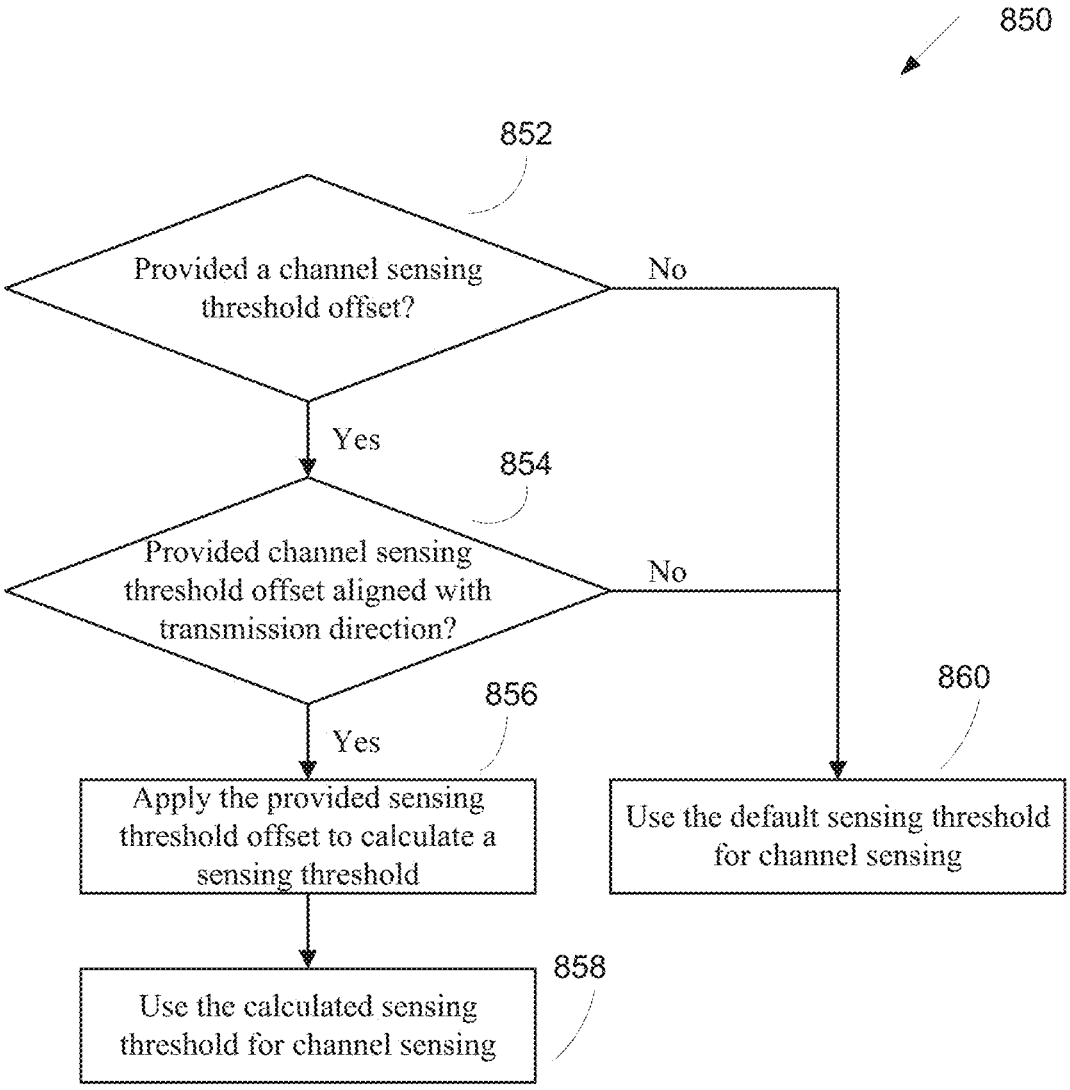

850
852
Provided a channel sensing threshold offset?
No
Yes
854
Provided channel sensing threshold offset aligned with transmission direction?
No
856
Yes
860
Apply the provided sensing threshold offset to calculate a sensing threshold
Use the default sensing threshold for channel sensing
858
Use the calculated sensing threshold for channel sensing

FIG. 8B

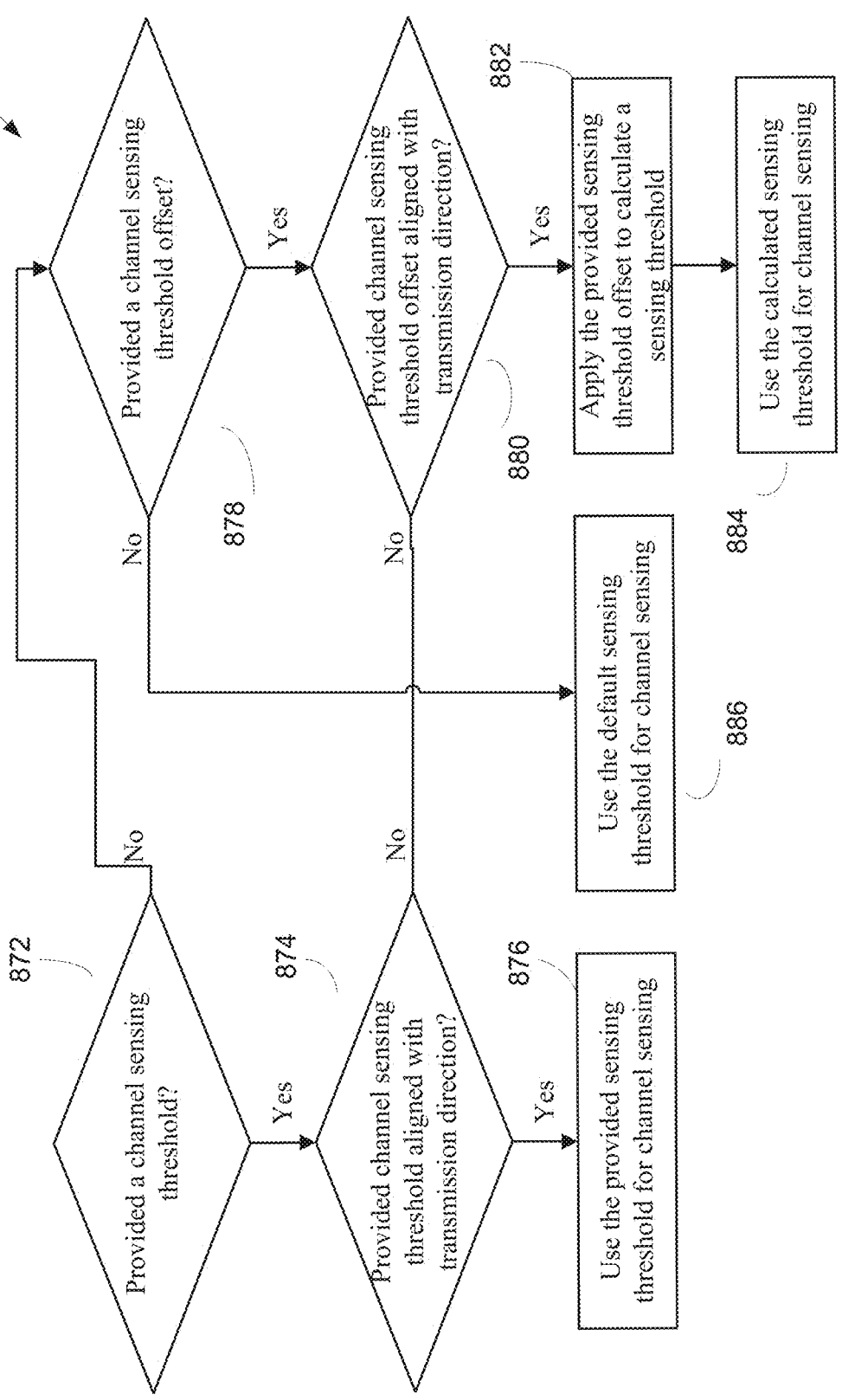

870
Provided a channel sensing threshold offset?
Yes
No
878
Provided channel sensing threshold offset aligned with transmission direction?
Yes
No
880
882
Apply the provided sensing threshold offset to calculate a sensing threshold
Use the calculated sensing threshold for channel sensing
884
Use the default sensing threshold for channel sensing
886
872
Provided a channel sensing threshold?
Yes
No
874
Provided channel sensing threshold aligned with transmission direction?
Yes
No
876
Use the provided sensing threshold for channel sensing

FIG. 8C

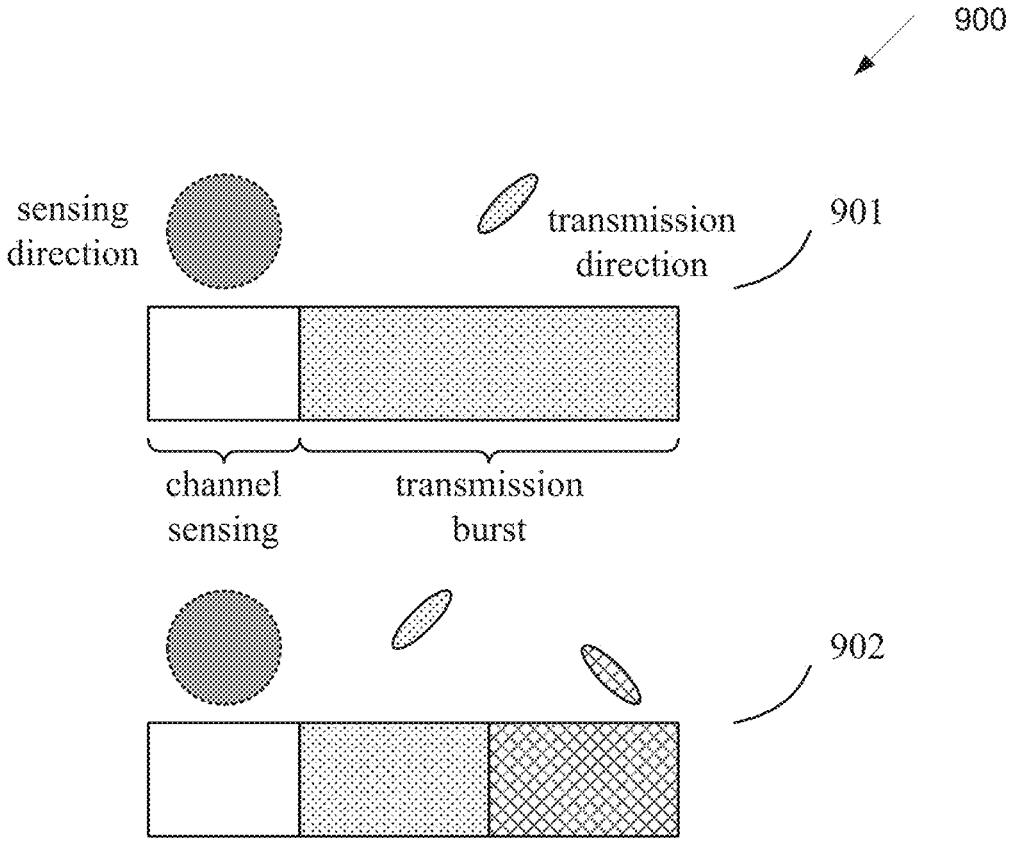

900
sensing direction
transmission direction
901
channel sensing
transmission burst
902

FIG. 9

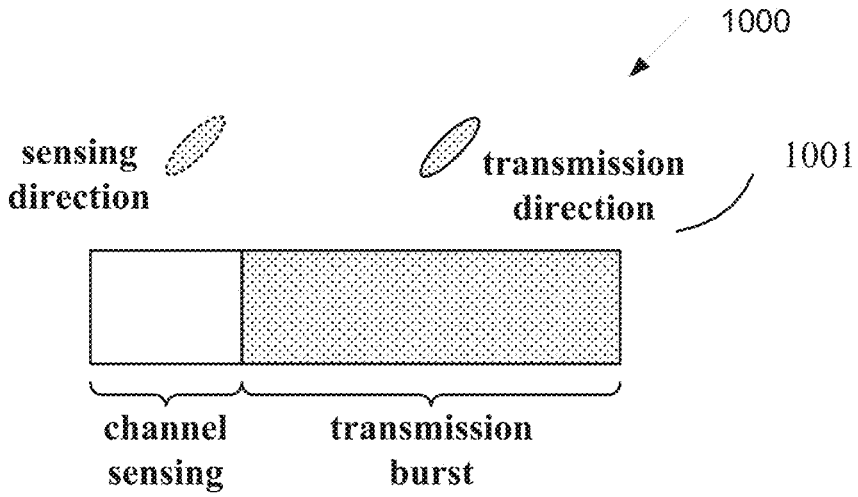

1000
sensing direction
transmission direction
1001
channel sensing
transmission burst

FIG. 10

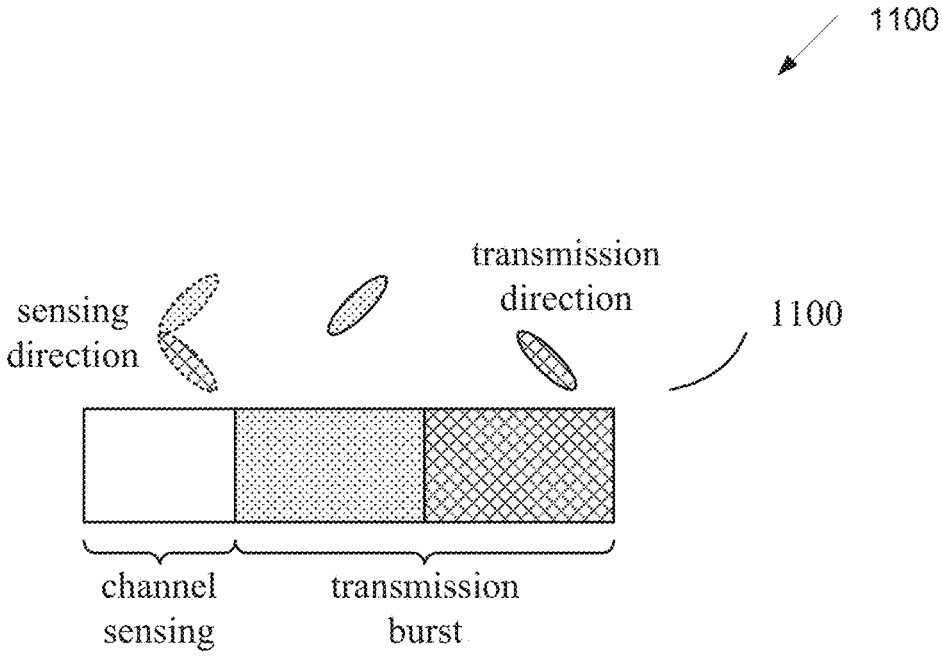

1100
transmission
direction
sensing
direction
1100
channel
sensing
transmission
burst

FIG. 11

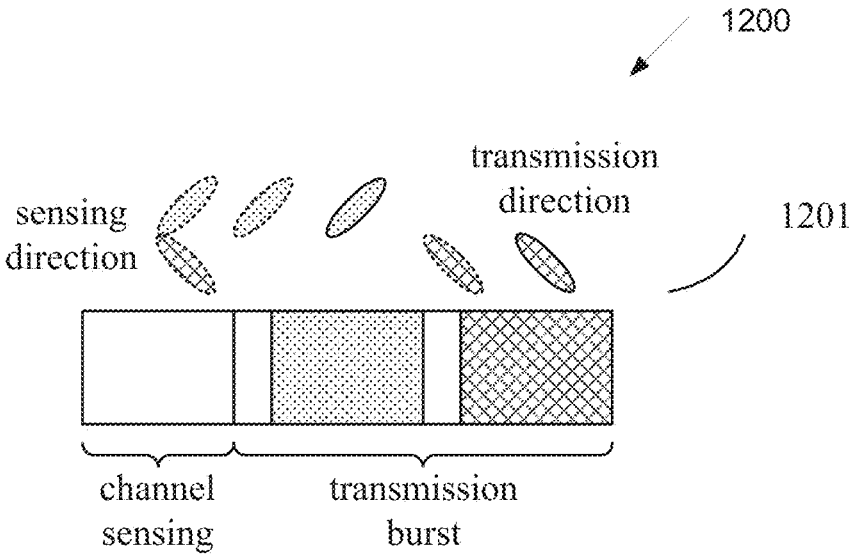

1200
transmission
direction
sensing
direction
1201
channel
sensing
transmission
burst

FIG. 12

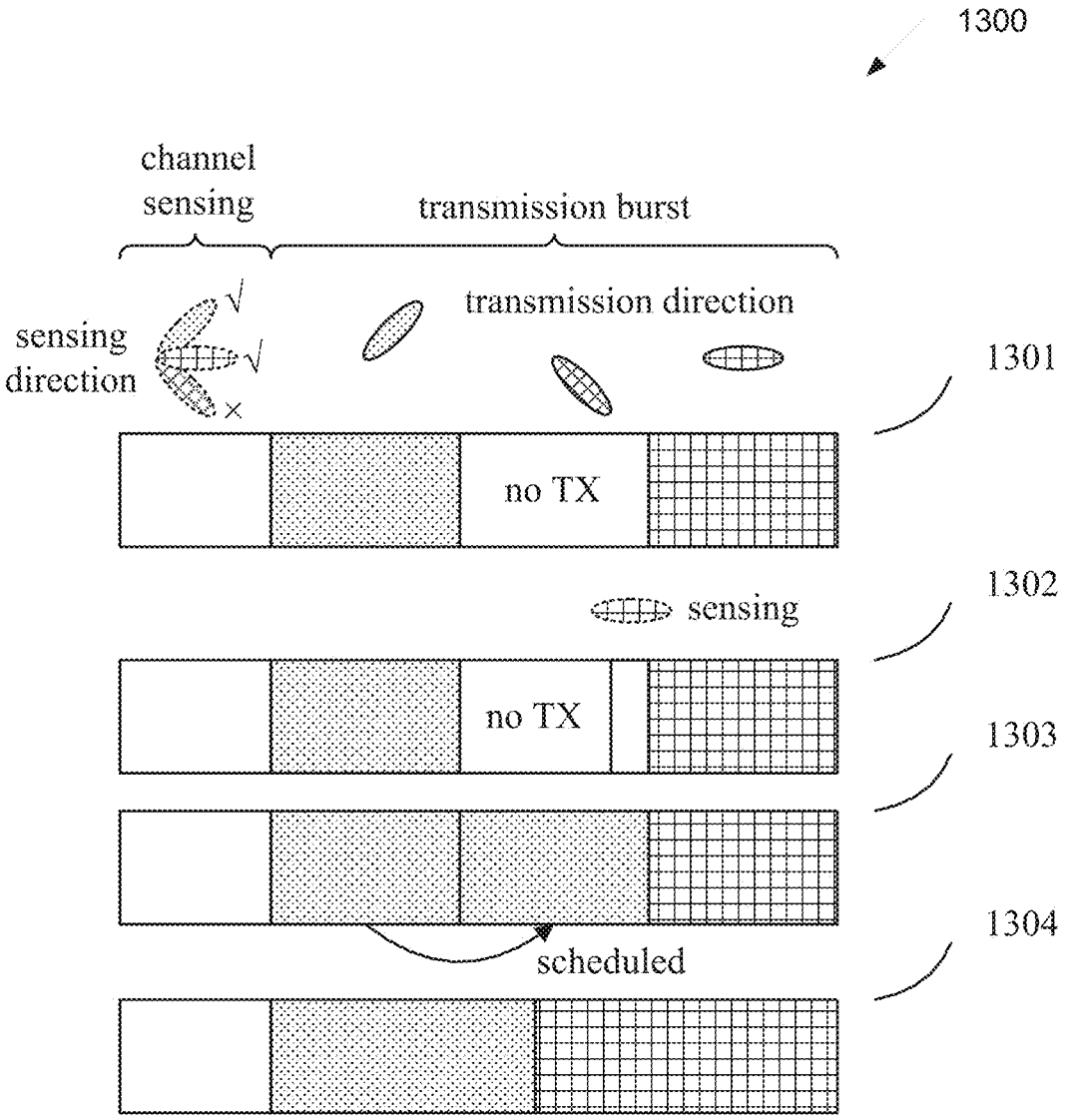

1300
channel sensing
transmission burst
sensing direction
√
√
×
transmission direction
1301
no TX
1302
sensing
no TX
1303
1304
scheduled

FIG. 13

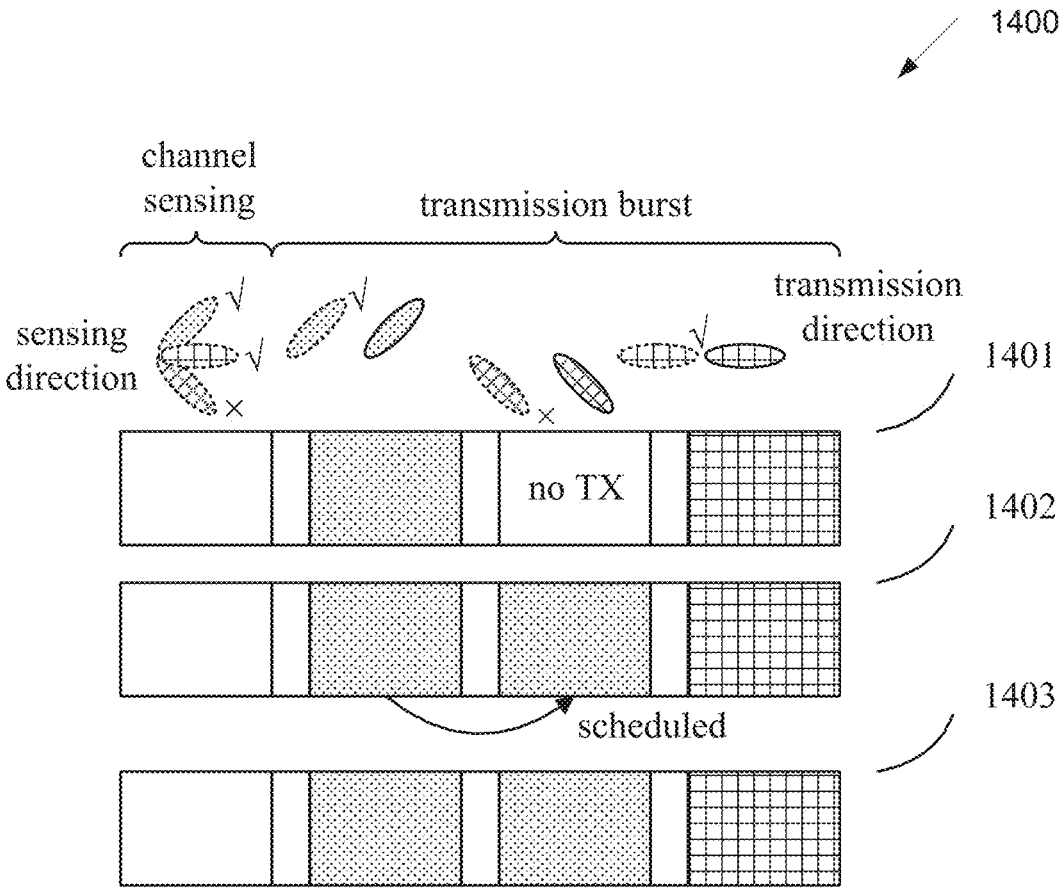

1400
channel sensing
transmission burst
transmission direction
sensing direction
1401
no TX
1402
scheduled
1403

FIG. 14

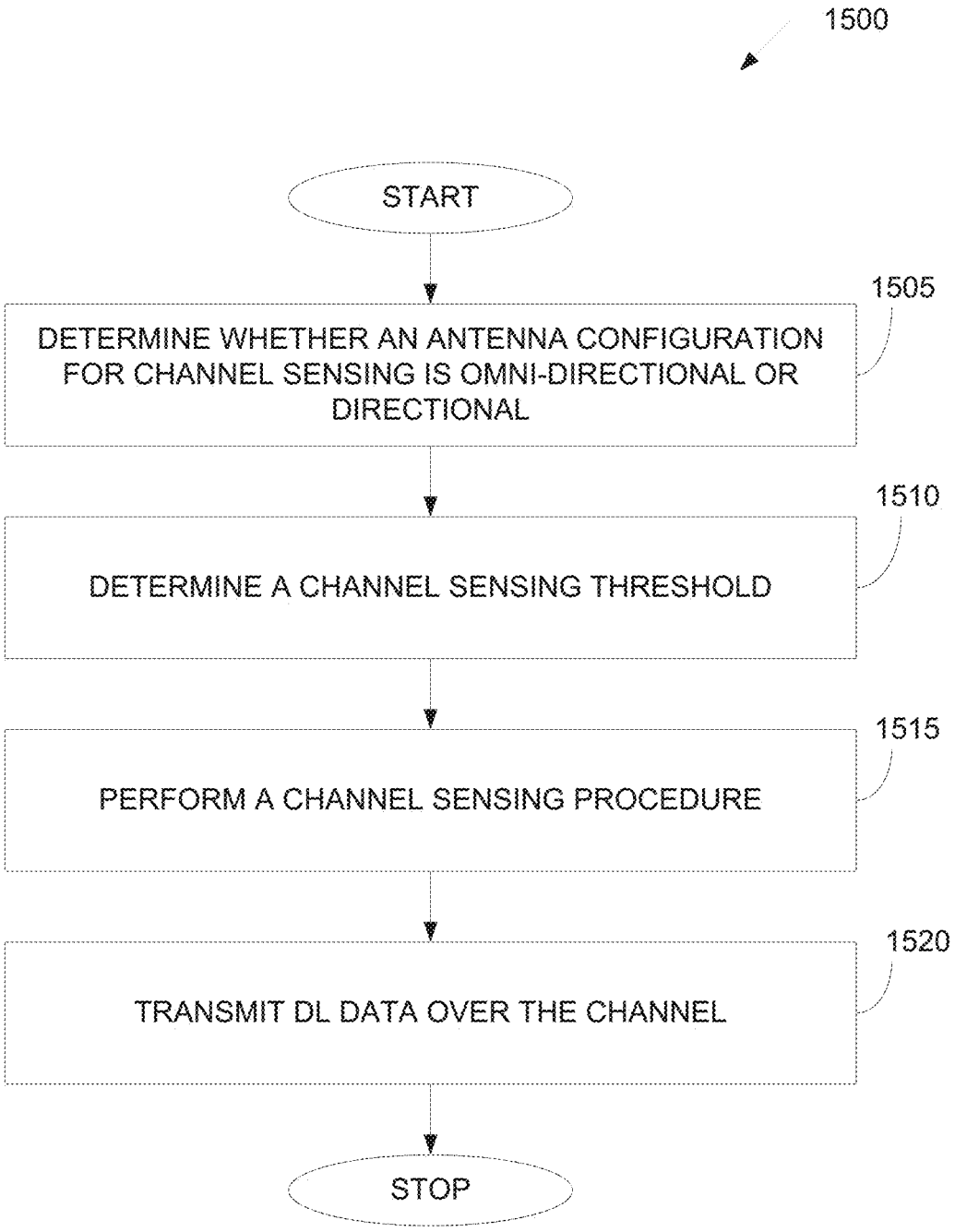

1500
START
1505
DETERMINE WHETHER AN ANTENNA CONFIGURATION FOR CHANNEL SENSING IS OMNI-DIRECTIONAL OR DIRECTIONAL
1510
DETERMINE A CHANNEL SENSING THRESHOLD
1515
PERFORM A CHANNEL SENSING PROCEDURE
1520
TRANSMIT DL DATA OVER THE CHANNEL
STOP

FIG. 15

# METHOD AND APPARATUS FOR ADAPTING A CHANNEL SENSING THRESHOLD

## CROSS-REFERENCE TO RELATED APPLICATIONS AND CLAIM OF PRIORITY

**[0001]** The present application claims priority to U.S. Provisional Patent Application No. 62/969,848, filed on Feb. 4, 2020 and U.S. Provisional Patent Application No. 62/976,461, filed on Feb. 14, 2020. The content of the above-identified patent document is incorporated herein by reference.

## TECHNICAL FIELD

**[0002]** The present disclosure relates generally to wireless communication systems and, more specifically, the present disclosure relates to adapting a channel sensing threshold in a wireless communication system.

## BACKGROUND

**[0003]** 5th generation (5G) or new radio (NR) mobile communications is recently gathering increased momentum with all the worldwide technical activities on the various candidate technologies from industry and academia. The candidate enablers for the 5G/NR mobile communications include massive antenna technologies, from legacy cellular frequency bands up to high frequencies, to provide beamforming gain and support increased capacity, new waveform (e.g., a new radio access technology (RAT)) to flexibly accommodate various services/applications with different requirements, new multiple access schemes to support massive connections, and so on.

## SUMMARY

**[0004]** The present disclosure relates to wireless communication systems and, more specifically, the present disclosure relates to adapting a channel sensing threshold in a wireless communication system.

**[0005]** In one embodiment, a base station (BS) in a wireless communication system operating with shared spectrum channel access is provided. The BS includes a processor configured to determine whether an antenna configuration for channel sensing is omni-directional or directional and determine a channel sensing threshold. The channel sensing threshold includes two parts: a first part of the channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the channel sensing threshold depending on the antenna configuration. The processor is further configured to perform a channel sensing procedure based on the antenna configuration and the channel sensing threshold. The BS also includes a transceiver operably connected to the processor. The transceiver is configured to transmit downlink (DL) data over a channel, if the channel is sensed as idle in the channel sensing procedure.

**[0006]** In another embodiment, a method of a BS in a wireless communication system operating with shared spectrum channel access is provided. The method includes determining whether an antenna configuration for channel sensing is omni-directional or directional and determining a channel sensing threshold. The channel sensing threshold includes two parts: a first part of the channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the channel sensing threshold depending on the antenna configuration. The method further includes performing a channel sensing procedure based on the antenna configuration and the channel sensing threshold and transmitting DL data over a channel based on the channel being sensed as idle in the channel sensing procedure.

**[0007]** In yet another embodiment, a user equipment (UE) in a wireless communication system operating with shared spectrum channel access is provided. The UE includes a processor configured to determine whether a channel sensing threshold is configured, determine whether an antenna configuration for channel sensing is omni-directional or directional, and determine a default channel sensing threshold, if the channel sensing threshold is not configured. The default channel sensing threshold includes two parts: a first part of the default channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the default channel sensing threshold depending on the antenna configuration. The processor is further configured to perform a channel sensing procedure based on the antenna configuration and the default channel sensing threshold. The UE further includes a transceiver operably connected to the processor. The transceiver is configured to transmit DL data over a channel, if the channel is sensed as idle in the channel sensing procedure.

**[0008]** In yet another embodiment, a method of a UE in a wireless communication system operating with shared spectrum channel access is provided. The method includes determining whether a channel sensing threshold is configured, determining whether an antenna configuration for channel sensing is omni-directional or directional, and determining a default channel sensing threshold based on determining that the channel sensing threshold is not configured. The default channel sensing threshold includes two parts: a first part of the default channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the default channel sensing threshold depending on the antenna configuration. The method further includes performing a channel sensing procedure based on the antenna configuration and the default channel sensing threshold and transmitting DL data over a channel based on the channel being sensed as idle in the channel sensing procedure.

**[0009]** Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

**[0010]** Before undertaking the DETAILED DESCRIPTION below, it may be advantageous to set forth definitions of certain words and phrases used throughout this patent document. The term "couple" and its derivatives refer to any direct or indirect communication between two or more elements, whether or not those elements are in physical contact with one another. The terms "transmit," "receive," and "communicate," as well as derivatives thereof, encompass both direct and indirect communication. The terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation. The term "or" is inclusive, meaning and/or. The phrase "associated with," as well as derivatives thereof, means to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, have a relationship to or with, or the like. The term "controller" means any device, system,

or part thereof that controls at least one operation. Such a controller may be implemented in hardware or a combination of hardware and software and/or firmware. The functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. The phrase "at least one of," when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one item in the list may be needed. For example, "at least one of: A, B, and C" includes any of the following combinations: A, B, C, A and B, A and C, B and C, and A and B and C.

**[0011]** Moreover, various functions described below can be implemented or supported by one or more computer programs, each of which is formed from computer readable program code and embodied in a computer readable medium. The terms "application" and "program" refer to one or more computer programs, software components, sets of instructions, procedures, functions, objects, classes, instances, related data, or a portion thereof adapted for implementation in a suitable computer readable program code. The phrase "computer readable program code" includes any type of computer code, including source code, object code, and executable code. The phrase "computer readable medium" includes any type of medium capable of being accessed by a computer, such as read only memory (ROM), random access memory (RAM), a hard disk drive, a compact disc (CD), a digital video disc (DVD), or any other type of memory. A "non-transitory" computer readable medium excludes wired, wireless, optical, or other communication links that transport transitory electrical or other signals. A non-transitory computer readable medium includes media where data can be permanently stored and media where data can be stored and later overwritten, such as a rewritable optical disc or an erasable memory device.

**[0012]** Definitions for other certain words and phrases are provided throughout this patent document. Those of ordinary skill in the art should understand that in many if not most instances, such definitions apply to prior as well as future uses of such defined words and phrases.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0013]** For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:

**[0014]** FIG. **1** illustrates an example wireless network according to embodiments of the present disclosure;

**[0015]** FIG. **2** illustrates an example gNB according to embodiments of the present disclosure;

**[0016]** FIG. **3** illustrates an example UE according to embodiments of the present disclosure;

**[0017]** FIGS. **4** and **5** illustrate example wireless transmit and receive paths according to this disclosure;

**[0018]** FIG. **6** illustrate an example adaptation of channel sensing threshold based on antenna configuration for channel sensing according to embodiments of the present disclosure;

**[0019]** FIG. **7** illustrates an example one transmission burst associated with a plurality of channel sensing thresholds according to embodiments of the present disclosure;

**[0020]** FIGS. **8**A, **8**B, and **8**C illustrates a flowchart of a method of a UE for adapting channel sensing threshold according to embodiments of the present disclosure;

**[0021]** FIG. **9** illustrates an example channel access procedure according to embodiments of the present disclosure;

**[0022]** FIG. **10** illustrates another example channel access procedure according to embodiments of the present disclosure;

**[0023]** FIG. **11** illustrates yet another example channel access procedure according to embodiments of the present disclosure;

**[0024]** FIG. **12** illustrates yet another example channel access procedure according to embodiments of the present disclosure;

**[0025]** FIG. **13** illustrates an example discontinuity in a transmission burst for channel access procedure according to embodiments of the present disclosure;

**[0026]** FIG. **14** illustrates another example discontinuity in a transmission burst for channel access procedure according to embodiments of the present disclosure; and

**[0027]** FIG. **15** illustrates a flow chart of a method for adapting channel sensing threshold according to embodiments of the present disclosure.

## DETAILED DESCRIPTION

**[0028]** FIG. **1** through FIG. **15**, discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably arranged system or device.

**[0029]** The following documents are hereby incorporated by reference into the present disclosure as if fully set forth herein: 3GPP TS 38.211 v15.7.0, "NR; Physical channels and modulation"; 3GPP TS 38.212 v15.7.0, "NR; Multiplexing and Channel coding"; 3GPP TS 38.213 v15.7.0, "NR; Physical Layer Procedures for Control"; 3GPP TS 38.214 v15.7.0, "NR; Physical Layer Procedures for Data"; and 3GPP TS 38.331 v15.7.0, "NR; Radio Resource Control (RRC) Protocol Specification."

**[0030]** FIGS. **1-3** below describe various embodiments implemented in wireless communications systems and with the use of orthogonal frequency division multiplexing (OFDM) or orthogonal frequency division multiple access (OFDMA) communication techniques. The descriptions of FIGS. **1-3** are not meant to imply physical or architectural limitations to the manner in which different embodiments may be implemented. Different embodiments of the present disclosure may be implemented in any suitably-arranged communications system.

**[0031]** FIG. **1** illustrates an example wireless network according to embodiments of the present disclosure. The embodiment of the wireless network shown in FIG. **1** is for illustration only. Other embodiments of the wireless network **100** could be used without departing from the scope of this disclosure.

**[0032]** As shown in FIG. **1**, the wireless network includes a gNB **101** (e.g., base station, BS), a gNB **102**, and a gNB **103**. The gNB **101** communicates with the gNB **102** and the gNB **103**. The gNB **101** also communicates with at least one network **130**, such as the Internet, a proprietary Internet Protocol (IP) network, or other data network.

**[0033]** The gNB **102** provides wireless broadband access to the network **130** for a first plurality of user equipments (UEs) within a coverage area **120** of the gNB **102**. The first plurality of UEs includes a UE **111**, which may be located

in a small business; a UE **112**, which may be located in an enterprise (E); a UE **113**, which may be located in a WiFi hotspot (HS); a UE **114**, which may be located in a first residence (R); a UE **115**, which may be located in a second residence (R); and a UE **116**, which may be a mobile device (M), such as a cell phone, a wireless laptop, a wireless PDA, or the like. The gNB **103** provides wireless broadband access to the network **130** for a second plurality of UEs within a coverage area **125** of the gNB **103**. The second plurality of UEs includes the UE **115** and the UE **116**. In some embodiments, one or more of the gNBs **101-103** may communicate with each other and with the UEs **111-116** using 5G/NR, LTE, LTE-A, WiMAX, WiFi, or other wireless communication techniques.

**[0034]** Depending on the network type, the term "base station" or "BS" can refer to any component (or collection of components) configured to provide wireless access to a network, such as transmit point (TP), transmit-receive point (TRP), an enhanced base station (eNodeB or eNB), a 5G/NR base station (gNB), a macrocell, a femtocell, a WiFi access point (AP), or other wirelessly enabled devices. Base stations may provide wireless access in accordance with one or more wireless communication protocols, e.g., 5G/NR 3GPP NR, long term evolution (LTE), LTE advanced (LTE-A), high speed packet access (HSPA), Wi-Fi 802.11a/b/g/n/ac, etc. For the sake of convenience, the terms "BS" and "TRP" are used interchangeably in this patent document to refer to network infrastructure components that provide wireless access to remote terminals. Also, depending on the network type, the term "user equipment" or "UE" can refer to any component such as "mobile station," "subscriber station," "remote terminal," "wireless terminal," "receive point," or "user device." For the sake of convenience, the terms "user equipment" and "UE" are used in this patent document to refer to remote wireless equipment that wirelessly accesses a BS, whether the UE is a mobile device (such as a mobile telephone or smartphone) or is normally considered a stationary device (such as a desktop computer or vending machine).

**[0035]** Dotted lines show the approximate extents of the coverage areas **120** and **125**, which are shown as approximately circular for the purposes of illustration and explanation only. It should be clearly understood that the coverage areas associated with gNBs, such as the coverage areas **120** and **125**, may have other shapes, including irregular shapes, depending upon the configuration of the gNBs and variations in the radio environment associated with natural and man-made obstructions.

**[0036]** As described in more detail below, one or more of the UEs **111-116** include circuitry, programing, or a combination thereof, for beam management and coverage enhancements for adapting a channel sensing threshold. In certain embodiments, and one or more of the gNBs **101-103** includes circuitry, programing, or a combination thereof, for adapting a channel sensing threshold.

**[0037]** Although FIG. **1** illustrates one example of a wireless network, various changes may be made to FIG. **1**. For example, the wireless network could include any number of gNBs and any number of UEs in any suitable arrangement. Also, the gNB **101** could communicate directly with any number of UEs and provide those UEs with wireless broadband access to the network **130**. Similarly, each gNB **102-103** could communicate directly with the network **130** and provide UEs with direct wireless broadband access to the network **130**. Further, the gNBs **101**, **102**, and/or **103** could provide access to other or additional external networks, such as external telephone networks or other types of data networks.

**[0038]** FIG. **2** illustrates an example gNB **102** according to embodiments of the present disclosure. The embodiment of the gNB **102** illustrated in FIG. **2** is for illustration only, and the gNBs **101** and **103** of FIG. **1** could have the same or similar configuration. However, gNBs come in a wide variety of configurations, and FIG. **2** does not limit the scope of this disclosure to any particular implementation of a gNB.

**[0039]** As shown in FIG. **2**, the gNB **102** includes multiple antennas **205***a*-**205***n*, multiple RF transceivers **210***a*-**210***n*, transmit (TX) processing circuitry **215**, and receive (RX) processing circuitry **220**. The gNB **102** also includes a controller/processor **225**, a memory **230**, and a backhaul or network interface **235**.

**[0040]** The RF transceivers **210***a*-**210***n* receive, from the antennas **205***a*-**205***n*, incoming RF signals, such as signals transmitted by UEs in the network **100**. The RF transceivers **210***a*-**210***n* down-convert the incoming RF signals to generate IF or baseband signals. The IF or baseband signals are sent to the RX processing circuitry **220**, which generates processed baseband signals by filtering, decoding, and/or digitizing the baseband or IF signals. The RX processing circuitry **220** transmits the processed baseband signals to the controller/processor **225** for further processing.

**[0041]** The TX processing circuitry **215** receives analog or digital data (such as voice data, web data, e-mail, or interactive video game data) from the controller/processor **225**. The TX processing circuitry **215** encodes, multiplexes, and/or digitizes the outgoing baseband data to generate processed baseband or IF signals. The RF transceivers **210***a*-**210***n* receive the outgoing processed baseband or IF signals from the TX processing circuitry **215** and up-converts the baseband or IF signals to RF signals that are transmitted via the antennas **205***a*-**205***n*.

**[0042]** The controller/processor **225** can include one or more processors or other processing devices that control the overall operation of the gNB **102**. For example, the controller/processor **225** could control the reception of forward channel signals and the transmission of reverse channel signals by the RF transceivers **210***a*-**210***n*, the RX processing circuitry **220**, and the TX processing circuitry **215** in accordance with well-known principles. The controller/processor **225** could support additional functions as well, such as more advanced wireless communication functions. For instance, the controller/processor **225** could support beam forming or directional routing operations in which outgoing/incoming signals from/to multiple antennas **205***a*-**205***n* are weighted differently to effectively steer the outgoing signals in a desired direction. Any of a wide variety of other functions could be supported in the gNB **102** by the controller/processor **225**.

**[0043]** The controller/processor **225** is also capable of executing programs and other processes resident in the memory **230**, such as an OS. The controller/processor **225** can move data into or out of the memory **230** as required by an executing process.

**[0044]** The controller/processor **225** is also coupled to the backhaul or network interface **235**. The backhaul or network interface **235** allows the gNB **102** to communicate with other devices or systems over a backhaul connection or over a network. The interface **235** could support communications

over any suitable wired or wireless connection(s). For example, when the gNB **102** is implemented as part of a cellular communication system (such as one supporting 5G/NR, LTE, or LTE-A), the interface **235** could allow the gNB **102** to communicate with other gNBs over a wired or wireless backhaul connection. When the gNB **102** is implemented as an access point, the interface **235** could allow the gNB **102** to communicate over a wired or wireless local area network or over a wired or wireless connection to a larger network (such as the Internet). The interface **235** includes any suitable structure supporting communications over a wired or wireless connection, such as an Ethernet or RF transceiver.

**[0045]** The memory **230** is coupled to the controller/processor **225**. Part of the memory **230** could include a RAM, and another part of the memory **230** could include a Flash memory or other ROM.

**[0046]** Although FIG. **2** illustrates one example of gNB **102**, various changes may be made to FIG. **2**. For example, the gNB **102** could include any number of each component shown in FIG. **2**. As a particular example, an access point could include a number of interfaces **235**, and the controller/processor **225** could support routing functions to route data between different network addresses. As another particular example, while shown as including a single instance of TX processing circuitry **215** and a single instance of RX processing circuitry **220**, the gNB **102** could include multiple instances of each (such as one per RF transceiver). Also, various components in FIG. **2** could be combined, further subdivided, or omitted and additional components could be added according to particular needs.

**[0047]** FIG. **3** illustrates an example UE **116** according to embodiments of the present disclosure. The embodiment of the UE **116** illustrated in FIG. **3** is for illustration only, and the UEs **111-115** of FIG. **1** could have the same or similar configuration. However, UEs come in a wide variety of configurations, and FIG. **3** does not limit the scope of this disclosure to any particular implementation of a UE.

**[0048]** As shown in FIG. **3**, the UE **116** includes an antenna **305**, a radio frequency (RF) transceiver **310**, TX processing circuitry **315**, a microphone **320**, and receive (RX) processing circuitry **325**. The UE **116** also includes a speaker **330**, a processor **340**, an input/output (I/O) interface (IF) **345**, a touchscreen **350**, a display **355**, and a memory **360**. The memory **360** includes an operating system (OS) **361** and one or more applications **362**.

**[0049]** The RF transceiver **310** receives, from the antenna **305**, an incoming RF signal transmitted by a gNB of the network **100**. The RF transceiver **310** down-converts the incoming RF signal to generate an intermediate frequency (IF) or baseband signal. The IF or baseband signal is sent to the RX processing circuitry **325**, which generates a processed baseband signal by filtering, decoding, and/or digitizing the baseband or IF signal. The RX processing circuitry **325** transmits the processed baseband signal to the speaker **330** (such as for voice data) or to the processor **340** for further processing (such as for web browsing data).

**[0050]** The TX processing circuitry **315** receives analog or digital voice data from the microphone **320** or other outgoing baseband data (such as web data, e-mail, or interactive video game data) from the processor **340**. The TX processing circuitry **315** encodes, multiplexes, and/or digitizes the outgoing baseband data to generate a processed baseband or IF signal. The RF transceiver **310** receives the outgoing processed baseband or IF signal from the TX processing circuitry **315** and up-converts the baseband or IF signal to an RF signal that is transmitted via the antenna **305**.

**[0051]** The processor **340** can include one or more processors or other processing devices and execute the OS **361** stored in the memory **360** in order to control the overall operation of the UE **116**. For example, the processor **340** could control the reception of forward channel signals and the transmission of reverse channel signals by the RF transceiver **310**, the RX processing circuitry **325**, and the TX processing circuitry **315** in accordance with well-known principles. In some embodiments, the processor **340** includes at least one microprocessor or microcontroller.

**[0052]** The processor **340** is also capable of executing other processes and programs resident in the memory **360**, such as processes for beam management. The processor **340** can move data into or out of the memory **360** as required by an executing process. In some embodiments, the processor **340** is configured to execute the applications **362** based on the OS **361** or in response to signals received from gNBs or an operator. The processor **340** is also coupled to the I/O interface **345**, which provides the UE **116** with the ability to connect to other devices, such as laptop computers and handheld computers. The I/O interface **345** is the communication path between these accessories and the processor **340**.

**[0053]** The processor **340** is also coupled to the touchscreen **350** and the display **355**. The operator of the UE **116** can use the touchscreen **350** to enter data into the UE **116**. The display **355** may be a liquid crystal display, light emitting diode display, or other display capable of rendering text and/or at least limited graphics, such as from web sites.

**[0054]** The memory **360** is coupled to the processor **340**. Part of the memory **360** could include a random access memory (RAM), and another part of the memory **360** could include a Flash memory or other read-only memory (ROM).

**[0055]** Although FIG. **3** illustrates one example of UE **116**, various changes may be made to FIG. **3**. For example, various components in FIG. **3** could be combined, further subdivided, or omitted and additional components could be added according to particular needs. As a particular example, the processor **340** could be divided into multiple processors, such as one or more central processing units (CPUs) and one or more graphics processing units (GPUs). Also, while FIG. **3** illustrates the UE **116** configured as a mobile telephone or smartphone, UEs could be configured to operate as other types of mobile or stationary devices.

**[0056]** To meet the demand for wireless data traffic having increased since deployment of 4G communication systems and to enable various vertical applications, efforts have been made to develop and deploy an improved 5G/NR or pre-5G/NR communication system. Therefore, the 5G/NR or pre-5G/NR communication system is also called a "beyond 4G network" or a "post LTE system." The 5G/NR communication system is considered to be implemented in higher frequency (mmWave) bands, e.g., 28 GHz or 60 GHz bands, so as to accomplish higher data rates or in lower frequency bands, such as 6 GHz, to enable robust coverage and mobility support. The present disclosure may also be applied to deployment of 5G communication system, 6G or even later release which may use terahertz (THz) bands. To decrease propagation loss of the radio waves and increase the transmission distance, the beamforming, massive multiple-input multiple-output (MIMO), full dimensional

MIMO (FD-MIMO), array antenna, an analog beam forming, large scale antenna techniques are discussed in 5G/NR communication systems.

**[0057]** In addition, in 5G/NR communication systems, development for system network improvement is under way based on advanced small cells, cloud radio access networks (RANs), ultra-dense networks, device-to-device (D2D) communication, wireless backhaul, moving network, cooperative communication, coordinated multi-points (CoMP), reception-end interference cancellation and the like.

**[0058]** A communication system includes a downlink (DL) that refers to transmissions from a base station or one or more transmission points to UEs and an uplink (UL) that refers to transmissions from UEs to a base station or to one or more reception points.

**[0059]** A time unit for DL signaling or for UL signaling on a cell is referred to as a slot and can include one or more symbols. A symbol can also serve as an additional time unit. A frequency (or bandwidth (BW)) unit is referred to as a resource block (RB). One RB includes a number of sub-carriers (SCs). For example, a slot can have duration of 0.5 milliseconds or 1 millisecond, include 14 symbols and an RB can include 12 SCs with inter-SC spacing of 15 KHz or 30 KHz, and so on.

**[0060]** DL signals include data signals conveying information content, control signals conveying DL control information (DCI), and reference signals (RS) that are also known as pilot signals. A gNB transmits data information or DCI through respective physical DL shared channels (PDSCHs) or physical DL control channels (PDCCHs). A PDSCH or a PDCCH can be transmitted over a variable number of slot symbols including one slot symbol. For brevity, a DCI format scheduling a PDSCH reception by a UE is referred to as a DL DCI format and a DCI format scheduling a physical uplink shared channel (PUSCH) transmission from a UE is referred to as an UL DCI format.

**[0061]** A gNB transmits one or more of multiple types of RS including channel state information RS (CSI-RS) and demodulation RS (DMRS). A CSI-RS is primarily intended for UEs to perform measurements and provide CSI to a gNB. For channel measurement, non-zero power CSI-RS (NZP CSI-RS) resources are used. For interference measurement reports (IMRs), CSI interference measurement (CSI-IM) resources associated with a zero power CSI-RS (ZP CSI-RS) configuration are used. A CSI process includes NZP CSI-RS and CSI-IM resources.

**[0062]** A UE can determine CSI-RS transmission parameters through DL control signaling or higher layer signaling, such as radio resource control (RRC) signaling, from a gNB. Transmission instances of a CSI-RS can be indicated by DL control signaling or be configured by higher layer signaling. A DMRS is transmitted only in the BW of a respective PDCCH or PDSCH and a UE can use the DMRS to demodulate data or control information.

**[0063]** FIG. **4** and FIG. **5** illustrate example wireless transmit and receive paths according to this disclosure. In the following description, a transmit path **400** may be described as being implemented in a gNB (such as the gNB **102**), while a receive path **500** may be described as being implemented in a UE (such as a UE **116**). However, it may be understood that the receive path **500** can be implemented in a gNB and that the transmit path **400** can be implemented in a UE. In some embodiments, the receive path **500** is configured to support adapting a channel sensing threshold as described in embodiments of the present disclosure.

**[0064]** The transmit path **400** as illustrated in FIG. **4** includes a channel coding and modulation block **405**, a serial-to-parallel (S-to-P) block **410**, a size N inverse fast Fourier transform (IFFT) block **415**, a parallel-to-serial (P-to-S) block **420**, an add cyclic prefix block **425**, and an up-converter (UC) **430**. The receive path **500** as illustrated in FIG. **5** includes a down-converter (DC) **555**, a remove cyclic prefix block **560**, a serial-to-parallel (S-to-P) block **565**, a size N fast Fourier transform (FFT) block **570**, a parallel-to-serial (P-to-S) block **575**, and a channel decoding and demodulation block **580**.

**[0065]** As illustrated in FIG. **400**, the channel coding and modulation block **405** receives a set of information bits, applies coding (such as a low-density parity check (LDPC) coding), and modulates the input bits (such as with quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM)) to generate a sequence of frequency-domain modulation symbols.

**[0066]** The serial-to-parallel block **410** converts (such as de-multiplexes) the serial modulated symbols to parallel data in order to generate N parallel symbol streams, where N is the IFFT/FFT size used in the gNB **102** and the UE **116**. The size N IFFT block **415** performs an IFFT operation on the N parallel symbol streams to generate time-domain output signals. The parallel-to-serial block **420** converts (such as multiplexes) the parallel time-domain output symbols from the size N IFFT block **415** in order to generate a serial time-domain signal. The add cyclic prefix block **425** inserts a cyclic prefix to the time-domain signal. The up-converter **430** modulates (such as up-converts) the output of the add cyclic prefix block **425** to an RF frequency for transmission via a wireless channel. The signal may also be filtered at baseband before conversion to the RF frequency.

**[0067]** A transmitted RF signal from the gNB **102** arrives at the UE **116** after passing through the wireless channel, and reverse operations to those at the gNB **102** are performed at the UE **116**.

**[0068]** As illustrated in FIG. **5**, the down-converter **555** down-converts the received signal to a baseband frequency, and the remove cyclic prefix block **560** removes the cyclic prefix to generate a serial time-domain baseband signal. The serial-to-parallel block **565** converts the time-domain baseband signal to parallel time domain signals. The size N FFT block **570** performs an FFT algorithm to generate N parallel frequency-domain signals. The parallel-to-serial block **575** converts the parallel frequency-domain signals to a sequence of modulated data symbols. The channel decoding and demodulation block **580** demodulates and decodes the modulated symbols to recover the original input data stream.

**[0069]** Each of the gNBs **101-103** may implement a transmit path **400** as illustrated in FIG. **4** that is analogous to transmitting in the downlink to UEs **111-116** and may implement a receive path **500** as illustrated in FIG. **5** that is analogous to receiving in the uplink from UEs **111-116**. Similarly, each of UEs **111-116** may implement the transmit path **400** for transmitting in the uplink to the gNBs **101-103** and may implement the receive path **500** for receiving in the downlink from the gNBs **101-103**.

**[0070]** Each of the components in FIG. **4** and FIG. **5** can be implemented using only hardware or using a combination of hardware and software/firmware. As a particular example, at least some of the components in FIG. **4** and FIG. **5** may be implemented in software, while other components may be implemented by configurable hardware or a mixture of software and configurable hardware. For instance, the FFT block **570** and the IFFT block **515** may be implemented as configurable software algorithms, where the value of size N may be modified according to the implementation.

**[0071]** Furthermore, although described as using FFT and IFFT, this is by way of illustration only and may not be construed to limit the scope of this disclosure. Other types of transforms, such as discrete Fourier transform (DFT) and inverse discrete Fourier transform (IDFT) functions, can be used. It may be appreciated that the value of the variable N may be any integer number (such as 1, 2, 3, 4, or the like) for DFT and IDFT functions, while the value of the variable

N may be any integer number that is a power of two (such as 1, 2, 4, 8, 16, or the like) for FFT and IFFT functions.

**[0072]** Although FIG. **4** and FIG. **5** illustrate examples of wireless transmit and receive paths, various changes may be made to FIG. **4** and FIG. **5**. For example, various components in FIG. **4** and FIG. **5** can be combined, further subdivided, or omitted and additional components can be added according to particular needs. Also, FIG. **4** and FIG. **5** are meant to illustrate examples of the types of transmit and receive paths that can be used in a wireless network. Any other suitable architectures can be used to support wireless communications in a wireless network.

**[0073]** This disclosure focuses on adaptation of channel sensing threshold based on the antenna configuration for sensing the channel. The channel sensing threshold can be associated with the intended transmission direction and be indicated to the UE by a higher layer parameter or a PHY layer parameter. More precisely, the following components are provided in this disclosure: a directional channel sensing threshold; channel sensing threshold association; a channel sensing threshold determination; and/or a UE procedure for a utilizing channel sensing threshold.

**[0074]** For operation with a shared spectrum channel access (e.g., unlicensed or shared spectrum), a transmitter may perform sensing that evaluates the availability of a channel for performing transmissions. For energy detection based sensing, a basic unit for sensing is defined as a sensing slot. A channel with a duration of s sensing slot is declared as idle, if the transmitter senses the channel during the sensing slot duration and determines that the detected power for a given portion of the sensing slot duration is less than a sensing threshold $X_{Thresh}$, or declared as busy otherwise.

**[0075]** In NR Rel-16, an operation with shared spectrum channel access has been supported for 5 GHz unlicensed band and 6 GHz unlicensed band. More precisely, for 5 GHz unlicensed band and 6 GHz unlicensed band, the sensing slot is defined as $T_{s1}$=9 us, and the sensing threshold can be adapted according to a maximum energy detection threshold.

**[0076]** In a DL, a gNB accessing a channel on which transmission(s) are performed, may set the energy detection threshold ($X_{Thresh}$) to be less than or equal to the maximum energy detection threshold $X_{Thresh_max}$, wherein $X_{Thresh_max}$ is determined as shown in TABLE 1.

TABLE 1

| Energy detection threshold determination |
|---|
| If the absence of any other technology sharing the channel can be guaranteed on a long-term basis (e.g., by level of regulation) then: $X_{Tresh_max} = \min\left\{ \begin{matrix} T_{max} + 10\ \text{dB}, \\ X_r \end{matrix} \right\}$ $X_r$ is Maximum energy detection threshold defined by regulatory requirements in dBm when such requirements are defined, otherwise $X_r = T_{max} + 10$ dB<br>Otherwise, $X_{Tresh_max} = \max\left\{ \begin{matrix} -72 + 10 \cdot \log10(\text{BWMHz}/20\ \text{MHz})\ \text{dBm}, \\ \min\left\{ \begin{matrix} T_{max}, \\ T_{max} - T_A + (P_H + 10 \cdot \log10(\text{BWMHz}/20\ \text{MHz}) - P_{TX}) \end{matrix} \right\} \end{matrix} \right\}$ |

TABLE 1-continued

| Energy detection threshold determination |
|---|
| Where:<br>$T_A$ = 10 dB for transmission(s) including PDSCH;<br>$T_A$ = 5 dB for transmissions including discovery burst(s);<br>$P_H$ = 23 dBm;<br>$P_{TX}$ is the set maximum eNB/gNB output power in dBm for the channel;<br>eNB/gNB uses the set maximum transmission power over a single channel irrespective of whether single channel or multi-channel transmission is employed<br>$T_{max}$(dBm) = 10 · log 10 ($3.16228 \cdot 10^{-8}$ (mW/MHz) · BWMHz (MHz));<br>BWMHz is the single channel bandwidth in MHz. |

**[0077]** In an UL, a UE accessing a channel on which UL transmission(s) are performed, may set the energy detection threshold ($X_{Thresh}$) to be less than or equal to the maximum energy detection threshold $X_{Thresh_max}$, wherein $X_{Thresh_max}$ is determined as shown in TABLE 2.

TABLE 2

| Energy detection threshold determination |
|---|
| If the UE is configured with higher layer parameter maxEnergyDetectionThreshold-r14 or maxEnergyDetectionThreshold-r16,<br>$X_{Thresh_max}$ is set equal to the value signaled by the higher layer parameter.<br>otherwise<br>the UE may determine $X'_{Thresh_max}$ as follow.<br>if the UE is configured with higher layer parameter energyDetectionThresholdOffset-r14 or energyDetectionThresholdOffset-r16<br>$X_{Thresh_max}$ is set by adjusting $X'_{Thresh_max}$ according to the offset value signaled by the higher layer parameter<br>otherwise<br>The UE may set $X_{Thresh_max} = X'_{Thresh_max}$ |

**[0078]** If the higher layer parameter absenceOfAnyOtherTechnology-r16 is not configured to a UE, and the higher layer parameter ULtoDL-CO-SharingED-Threshold-r16 is configured to the UE, the gNB may use the gNB's transmit power in determining the resulting energy detection threshold ULtoDL-CO-SharingED-Threshold-r16.

**[0079]** For the case where a UE performs channel access procedures and shares the corresponding channel occupancy time with the gNB, $X_{Thresh_max}$ is set equal to the value provided by the higher layer parameter ULtoDL-CO-SharingED-Threshold-r16, if provided.

**[0080]** If the higher layer parameter absenceOfAnyOtherTechnology-r14 or absenceOfAnyOtherTechnology-r16, parameters are provided as shown in TABLE 3.

TABLE 3

| Parameters |
|---|
| $X'_{Tresh_max} = \min\left\{ \begin{matrix} T_{max} + 10\ \text{dB} \\ X_r \end{matrix} \right\}$ $X_r$ is Maximum energy detection threshold defined by regulatory requirements in dBm when such requirements are defined, otherwise $X_r = T_{max} + 10$ dB<br>otherwise |

TABLE 3-continued

| Parameters |
|---|
| $X'_{Tresh_max} = \max\left\{ \begin{array}{l} -72 + 10 \cdot \log10(\text{BWMHz}/20\ \text{MHz})\text{dBm}, \\ \min\left\{ \begin{array}{l} T_{max}, \\ T_{max} - T_A + (P_H + 10 \cdot \log10(\text{BWMHz}/20\ \text{MHz}) - P_{TX}) \end{array} \right\} \end{array} \right\}$ |
| Where<br>$T_A$ = 10 dB<br>$P_H$ = 23 dBm;<br>$P_{TX}$ is the set to the value of $P_{CMAX_H,c}$.<br>$T_{max}$(dBm) = 10 · log 10 (3.16228 · $10^{-8}$ (mW/MHz) · BWMHz (MHz));<br>BWMHz is the single channel bandwidth in MHz. |

**[0081]** For higher carrier frequency range, for example 60 GHz unlicensed spectrum, transmissions may utilize highly-directional beamforming. To support this, the corresponding channel sensing could also be configured to be highly-directional, in order to save sensing energy on directions not related to the intended transmission, wherein the new type of sensing is referred to as directional channel sensing, to be distinguished from classical omni-directional channel sensing. This disclosure specifies the adaptation on the channel sensing threshold.

**[0082]** Although exemplary descriptions and embodiments to follow assume OFDM or OFDMA, this disclosure can be extended to other OFDM-based transmission waveforms or multiple access schemes such as filtered OFDM (F-OFDM).

**[0083]** This disclosure covers several components which can be used in conjunction or in combination with one another or can operate as standalone schemes.

**[0084]** In one embodiment, a channel sensing threshold can be adapted based on the antenna configuration for channel sensing.

**[0085]** In one example, whether the channel sensing threshold is adapted based on the antenna configuration for channel sensing can be indicated in the system information.

**[0086]** In one example, whether the channel sensing threshold is adapted based on the antenna configuration for channel sensing can be configured by a RRC parameter.

**[0087]** In one example, there can be a channel sensing threshold offset applied to a common channel sensing threshold regardless of the antenna configuration (e.g. the maximum channel sensing threshold $X_{Thresh_max}$), wherein the channel sensing threshold offset can be denoted as $X_{Thresh_offset}$, and the channel sensing threshold offset is based on the antenna configuration for channel sensing.

**[0088]** FIG. **6** illustrate an example adaptation of channel sensing threshold **600** based on antenna configuration for channel sensing according to embodiments of the present disclosure. An embodiment of the adaptation of channel sensing threshold **600** shown in FIG. **6** is for illustration only.

**[0089]** In one example, the channel sensing threshold offset can be applicable to directional channel sensing, wherein the antenna configuration for channel sensing is directional, e.g. $X_{Thresh_offset}>0$, if the antenna configuration for channel sensing is directional.

**[0090]** In one example, the channel sensing threshold offset can be determined as $X_{Thresh_offset}=0$, if the antenna configuration for channel sensing is omni-directional.

**[0091]** In one example, whether the channel sensing threshold offset is applicable can be based on the configuration that whether the channel sensing threshold is adapted based on the antenna configuration for channel sensing.

**[0092]** In one example, the maximum channel sensing threshold $X_{Thresh_max}$ can be based on the antenna configuration for channel sensing. These examples are illustrated in **601** and **602** of FIG. **6**.

**[0093]** In one example, the channel sensing threshold can be different for the antenna configuration for channel sensing being directional or omni-directional.

**[0094]** In one example, if the configuration indicates that the channel sensing threshold is adapted based on the antenna configuration for channel sensing, the channel sensing threshold can be different for the antenna configuration for channel sensing being directional or omni-directional; otherwise, the channel sensing threshold maintains the same.

**[0095]** In one example, the adaptation of the channel sensing threshold can be based on a number of antenna configurations (e.g., number of directions/beams). In this example, the channel sensing threshold for all the antenna configurations (e.g., directions/beams) are the same, e.g., a common $X_{Thresh_max}$ or $X_{Thresh_offset}$ based on the number of antenna configurations (e.g., number of directions/beams). For instance, $X_{Thresh_offset}=f(N_{beam})$ or $X_{Thresh_max}=f(N_{beam})$, where $N_{beam}$ is the number of antenna configurations (e.g., number of directions/beams).

**[0096]** In another example, the adaptation of the channel sensing threshold can be based on one or a group of antenna configurations. In this example, the channel sensing threshold can be direction-specific or group-of-direction-specific, e.g., $X_{Thresh_max}$ or $X_{Thresh_offset}$ is based on a direction or a group of directions. For instance, $X_{Thresh_max}(i_{beam})=f(i_{beam})$, or $X_{Thresh_offset}(i_{beam})=f(i_{beam})$, wherein $i_{beam}$ is the index of a direction or a group of directions.

**[0097]** In one embodiment, there is an association between the channel sensing threshold and an antenna configuration.

**[0098]** In one example, there can be an association between an antenna port and a channel sensing threshold. In one example, when transmitting signal(s) and/or channel(s) using the antenna port, the associated channel censing threshold may be utilized.

**[0099]** In one example, a gNB can configure a channel sensing threshold and/or a channel sensing threshold offset to be associated with an antenna port. In one example, the configuration can be indicated in the system information. In one example, the configuration can be indicated in a dedicated RRC parameter.

**[0100]** In one example, the association between an antenna port and a channel sensing threshold and/or a channel sensing threshold offset can be hard coded and fixed in the specification.

**[0101]** In one example, there can be an association between a reference signal and a channel sensing threshold.

**[0102]** In one example, at least signals in a synchronization signal/physical broadcasting channel (SS/PBCH) block can be the reference signal to be associated with a channel sensing threshold. In one example, a gNB can configure a channel sensing threshold and/or a channel sensing threshold offset to be associated with an index of SS/PBCH block. In one example, the association can be indicated in a RRC

parameter. In another example, the association can be indicated in a DCI format. For one instance of this example, RRC parameter can configure a set of possible values for the channel sensing threshold and/or channel sensing threshold offset, and the DCI format indicates the association between the index of SS/PBCH block and the value of channel sensing threshold and/or channel sensing threshold offset.

**[0103]** In another example of a reference signal, at least a CSI-RS can be the reference signal to be associated with a channel sensing threshold. In one example, a gNB can configure a channel sensing threshold and/or a channel sensing threshold offset to be associated with an index of CSI-RS resource. In one example, the association can be indicated in a RRC parameter. In another example, the association can be indicated in a DCI format. For one instance of this example, RRC parameter can configure a set of possible values for the channel sensing threshold and/or channel sensing threshold offset, and the DCI format indicates the association between the index of CSI-RS resource and the value of channel sensing threshold and/or channel sensing threshold offset.

**[0104]** In yet another example of the reference signal, at least an SRS can be the reference signal to be associated with a channel sensing threshold. In one example, a gNB can configure a channel sensing threshold and/or a channel sensing threshold offset to be associated with an index of SRS resource.

**[0105]** In one example, there can be an association between a quasi co-location (QCL) assumption and a channel sensing threshold.

**[0106]** In one example, signals with the same QCL assumption can be associated with the same channel sensing threshold.

**[0107]** In one example, there can be an association between a transmission configuration indication state (TCI-state) and a channel sensing threshold.

**[0108]** For one example, a gNB can configure a channel sensing threshold and/or a channel sensing threshold offset to be associated with a TCI-state. In one example, the association can be indicated in a RRC parameter. In one example, the association can be indicated in a DCI format. For example, RRC parameter can configure a set of possible values for the channel sensing threshold and/or channel sensing threshold offset, and the DCI format indicates the association between the TCI-state and the value of channel sensing threshold and/or channel sensing threshold offset.

**[0109]** In one example, there can be an association between a spatial filter for physical uplink control channel (PUCCH) (e.g., PUCCH-SpatialRelationInfo) and a channel sensing threshold.

**[0110]** In one example, a gNB can configure a channel sensing threshold and/or a channel sensing threshold offset to be associated with a spatial filter for PUCCH (e.g., PUCCH-SpatialRelationInfo). In one instance, the association can be indicated in a RRC parameter.

**[0111]** In one example, there can be an association between an indication of a direction/beam or a group of directions/beams and a channel sensing threshold.

**[0112]** In one example, the indication of a direction/beam can be a bit in a bitmap, wherein the bitmap indicates all the directions/beams for transmission or channel sensing. In one sub-example, the bitmap can be a bitmap for a burst of SS/PBCH blocks within a period.

**[0113]** In one embodiment, a transmission burst can include signal(s) and/or channel(s) being associated with at least one channel sensing threshold, wherein the association can be according to examples in this disclosure.

**[0114]** In one example, if signal(s) and/or channel(s) in a transmission burst are associated with only one channel sensing threshold, then the transmitter (e.g., a gNB or a UE) may perform channel sensing according to the associated channel sensing threshold.

**[0115]** In one example, signal(s) and/or channel(s) in one transmission burst can be associated with a plurality of channel sensing thresholds. An illustration of this example is shown in FIG. **7**, wherein a first part of the transmission burst is associated with a first channel sensing threshold, and a second part of the transmission burst is associated with a second part of sensing threshold.

**[0116]** FIG. **7** illustrates an example one transmission burst associated with a plurality of channel sensing thresholds **700** according to embodiments of the present disclosure. An embodiment of the one transmission burst associated with a plurality of channel sensing thresholds **700** shown in FIG. **7** is for illustration only.

**[0117]** In one example, the channel sensing threshold applied to initialize the transmission burst may be no larger than the minimum of all the associated channel sensing thresholds.

**[0118]** In one example, the channel sensing threshold applied to initialize the transmission burst may be no larger than the maximum of all the associated channel sensing thresholds.

**[0119]** In one example, the channel sensing threshold applied to initialize the transmission burst may be no larger than the average of all the associated channel sensing thresholds.

**[0120]** In one embodiment, a UE can be configured a channel sensing threshold or a channel sensing threshold offset, wherein the channel sensing threshold or the channel sensing threshold offset can be adapted based on antenna configuration for a UE's transmission.

**[0121]** In one embodiment, if the UE is not provided a channel sensing threshold or a channel sensing threshold offset by the higher layer, the UE uses the default channel sensing threshold to perform channel sensing, wherein the default channel sensing threshold does not include the impact from directional antenna configuration for the UE's transmission (e.g., assuming omni-directional antenna configuration).

**[0122]** In another embodiment, if the UE is provided a channel sensing threshold or a channel sensing threshold offset by the higher layer, but the provided channel sensing threshold or channel sensing threshold offset is not associated with the directional antenna configuration for the UE's transmission, the UE uses the default channel sensing threshold to perform channel sensing, wherein the default channel sensing threshold does not include the impact from directional antenna configuration for the UE's transmission (e.g., assuming omni-directional antenna configuration).

**[0123]** In yet another embodiment, if the UE is provided a channel sensing threshold, wherein the channel sensing threshold is associated with the directional antenna configuration for the UE's transmission, the UE uses the provided channel sensing threshold to perform channel sensing.

**[0124]** In yet another embodiment, if the UE is provided a channel sensing threshold offset, wherein the channel

sensing threshold offset is associated with the directional antenna configuration for the UE's transmission, the UE applies the provided channel sensing threshold offset to the default channel sensing threshold and to calculate a new channel sensing threshold and uses the new channel sensing threshold to perform channel sensing.

**[0125]** FIG. **8**A illustrates a flowchart of a method **800** of a UE for adapting channel sensing threshold according to embodiments of the present disclosure as may be performed by a UE, such as UE **116** in FIG. **1**. An embodiment of the method **800** shown in FIG. **8**A is for illustration only. An embodiment of the method **800** shown in FIG. **8**A is for illustration only. One or more of the components illustrated in FIG. **8**A can be implemented in specialized circuitry configured to perform the noted functions or one or more of the components can be implemented by one or more processors executing instructions to perform the noted functions.

**[0126]** FIG. **8**B illustrates another flowchart of a method **850** of a UE for adapting channel sensing threshold according to embodiments of the present disclosure as may be performed by a UE, such as UE **116** in FIG. **1**. An embodiment of the method **850** shown in FIG. **8**B is for illustration only. An embodiment of the method **850** shown in FIG. **8**B is for illustration only. One or more of the components illustrated in FIG. **8**B can be implemented in specialized circuitry configured to perform the noted functions or one or more of the components can be implemented by one or more processors executing instructions to perform the noted functions.

**[0127]** FIG. **8**C illustrates yet another flowchart of a method **870** of a UE for adapting channel sensing threshold according to embodiments of the present disclosure as may be performed by a UE, such as UE **116** in FIG. **1**. An embodiment of the method **870** shown in FIG. **8**C is for illustration only. An embodiment of the method **870** shown in FIG. **8**C is for illustration only. One or more of the components illustrated in FIG. **8**C can be implemented in specialized circuitry configured to perform the noted functions or one or more of the components can be implemented by one or more processors executing instructions to perform the noted functions.

**[0128]** Example UE procedures for an adapting channel sensing threshold are shown in FIGS. **8**A, **8**B, and **8**C.

**[0129]** This disclosure focuses on the channel access procedure using directional channel sensing, wherein a case of channel access procedure can be applicable based on the composition of the transmission burst. Examples/embodiments to deal with the potential discontinuity of transmission burst are also covered by this disclosure. More precisely, the following components are included in this disclosure: channel access procedure based on directional sensing; channel access procedure based on composition of transmission burst; transmission discontinuity in a Case-3B channel access procedure; and/or transmission discontinuity in a Case-4B channel access procedure.

**[0130]** In NR Rel-16, an operation with shared spectrum channel access has been supported for 5 GHz unlicensed band and 6 GHz unlicensed band. More precisely, two types channel access procedures are supported, wherein Type 1 channel access procedure includes a random time duration of channel sensing before a downlink transmission, and Type 2 channel access procedure includes a deterministic time duration (e.g., including zero duration) of channel sensing before a downlink transmission.

**[0131]** In one embodiment, at least one of the following cases of channel access procedures can be supported for transmitting a transmission burst with at least one transmission directions.

**[0132]** In one example of Case-1, the antenna for channel sensing before a transmission burst can be configured to be omni-directional or quasi-omni-directional, and one transmission burst follows a channel sensing duration using the omni-directional or quasi-omni-directional antenna.

**[0133]** In one example, the channel sensing duration can be either random (Type 1 channel sensing procedure) or deterministic (Type 2 channel sensing procedure). Note that Type 2 channel sensing procedure includes a zero sensing duration procedure, which implies transmission can start without channel sensing. In another example, the transmission direction for a transport block included in the transmission burst can be any direction, and there can be one or multiple transmission directions associated with transport block(s) included in the transmission burst, as shown in **901** or **902** of FIG. **9**, respectively.

**[0134]** FIG. **9** illustrates an example channel access procedure **900** according to embodiments of the present disclosure. An embodiment of the channel access procedure **900** shown in FIG. **9** is for illustration only.

**[0135]** In one example of Case-2, the antenna for channel sensing before a transmission burst can be configured to be directional for a certain direction, and one transmission burst follows a channel sensing duration using the directional antenna. In one example, the channel sensing duration can be either random (Type 1 channel sensing procedure) or deterministic (Type 2 channel sensing procedure). Note that Type 2 channel sensing procedure includes a zero sensing duration procedure, which implies transmission can start without channel sensing. In another example, the direction for channel sensing may be aligned with the direction for transmission. For example, the antenna filter configuration for channel sensing is identical to the antenna filter configuration for transmission. An illustration of this case is shown in FIG. **10**.

**[0136]** FIG. **10** illustrates another example channel access procedure **1000** according to embodiments of the present disclosure. An embodiment of the channel access procedure **1000** shown in FIG. **10** is for illustration only.

**[0137]** In one example of Case-3, the antenna for channel sensing before a transmission burst can be configured to be directional for a set of directions, and one transmission burst follows a channel sensing duration using the directional antenna for the set of directions. In one example, the channel sensing duration can be either random (Type 1 channel sensing procedure) or deterministic (Type 2 channel sensing procedure). Note that Type 2 channel sensing procedure refers to a zero sensing duration procedure, which implies transmission can start without channel sensing; or a positive value sensing duration procedure, which implies transmission can start after sensing a fixed time duration of the channel to be idle. In another example, the directions for channel sensing may be aligned with the directions for transmission. For example, the antenna filter configurations for channel sensing are identical to the antenna filter configurations for transmission. An illustration of this case is shown in FIG. **11**. For another example, the antenna filter

configurations for channel sensing are a super set of the antenna filter configurations for transmission.

**[0138]** FIG. **11** illustrates yet another example channel access procedure **1100** according to embodiments of the present disclosure. An embodiment of the channel access procedure **1100** shown in FIG. **11** is for illustration only.

**[0139]** In one example of Case-3A, the transmission burst can start regardless of the sensing result from channel sensing. An example with two directions is shown in TABLE 4.

**[0140]** In one example of Case-3B, the transmission burst can start but only according to the direction sensed as idle. An example with two directions is shown in TABLE 4.

**[0141]** In one example of Case-3C, the transmission burst cannot start if any of the sensing direction is busy, which is equivalent as all sensing directions are idle. An example with two directions is shown in TABLE 4.

TABLE 4

Channel access procedure for the third case.

| Sensing result | Case-3A | Case-3B | Case-3C |
|---|---|---|---|
| 1st direction idle, 2nd direction idle | Transmit on 1st and/or 2nd direction | Transmit on 1st and/or 2nd direction | Transmit on 1st and/or 2nd direction |
| 1st direction idle, 2nd direction busy | Transmit on 1st and/or 2nd direction | Transmit on 1st direction | Cannot transmit |
| 1st direction busy, 2nd direction idle | Transmit on 1st and/or 2nd direction | Transmit on 2nd direction | Cannot transmit |
| 1st direction busy, 2nd direction busy | Transmit on 1st and/or 2nd direction | Cannot transmit | Cannot transmit |

**[0142]** In one example of Case-4, the antenna for channel sensing before a transmission burst can be configured to be directional for a set of directions, and one transmission burst follows a channel sensing duration using the directional antenna for the set of directions. Meanwhile, within the transmission burst, before the transmission of a direction, another channel sensing with antenna configured for that direction is performed.

**[0143]** In one example, the channel sensing duration before the transmission burst can be random (Type 1 channel sensing procedure). In one example, the channel sensing duration within the transmission burst can be deterministic (Type 2 channel sensing procedure). Note that Type 2 channel sensing procedure includes a zero sensing duration procedure, which implies transmission within a transmission burst can start without channel sensing. In one example, the directions for channel sensing may be aligned with the directions for transmission. For example, the antenna filter configurations for channel sensing are identical to the antenna filter configurations for transmission. For yet another example, the first sensing duration within the transmission burst can be set as 0. An illustration of this case is shown in FIG. **11**.

**[0144]** For this case, the sensing within transmission burst is performed only when the sensing before the transmission burst succeeds (e.g., channel is sensed as idle).

**[0145]** In one example of Case-4A, the transport block in the transmission burst can be transmitted regardless of result of associated directional channel sensing.

**[0146]** In one example of Case-4B, and the transport block in the transmission burst can be transmitted only when associated directional channel sensing succeeds (e.g., channel for that particular direction is sensed as idle).

**[0147]** FIG. **12** illustrates yet another example channel access procedure **1200** according to embodiments of the present disclosure. An embodiment of the channel access procedure **1200** shown in FIG. **12** is for illustration only.

**[0148]** In one embodiment, a channel access procedure according to example case in this disclosure can be applicable to a transmission based on the composition of transmission burst. For one example, the applicable case(s) of channel access procedure depend on the type of signal(s) and/or channel(s) included in the transmission. For another example, the applicable case(s) of channel access procedure depend on the duration of signal(s) and/or channel(s) included in the transmission. For yet another example, the applicable case(s) of channel access procedure depend on the duty cycle of signal(s) and/or channel(s) included in the transmission.

**[0149]** In one example, when the transmission burst includes discovery burst only, the Case-3 channel access procedure can be applicable, wherein the discovery burst can include a burst of SS/PBCH blocks, and/or configured PDCCH and/or PDSCH of remaining minimum system information (RMSI) associated with the SS/PBCH blocks, and/or configured CSI-RS.

**[0150]** In one example, the Case-3A channel access procedure can be applicable, when the transmission burst includes discovery burst only. In this example, the discovery burst can be transmitted without channel sensing or regardless of the channel sensing result.

**[0151]** In one example, the Case-3C channel access procedure can be applicable, when the transmission burst includes discovery burst only. In this example, the transmission burst can be transmitted only when all the directions are sensed to be idle.

**[0152]** In one example, the Case-3B channel access procedure cannot be applicable, when the transmission burst includes discovery burst only. In this example, the transmission burst has to be transmitted as a whole.

**[0153]** In one example, when the transmission burst includes discovery burst only, the Case-4 channel access procedure can be applicable, wherein the discovery burst can include a burst of SS/PBCH blocks, and/or configured PDCCH and/or PDSCH of RMSI associated with the SS/PBCH blocks, and/or configured CSI-RS.

**[0154]** In one example, the Case-4A channel access procedure can be applicable, when the transmission burst includes discovery burst only. In this example, the discovery burst can be transmitted without channel sensing or regardless of the channel sensing result.

**[0155]** In one example, the Case-4B channel access procedure cannot be applicable, when the transmission burst includes discovery burst only. In this example, the transmission burst including discovery burst only has to be transmitted as a whole.

**[0156]** In one example, the channel access procedure for non-unicast DL signal(s) and/or channel(s) follows the channel access procedure for discovery burst, when the non-unicast signal(s) and/or channel(s) are multiplexed with the discovery burst as one whole transmission burst.

**[0157]** In one example, the Case-3 channel access procedure can be applicable, when the transmission burst includes non-unicast DL signal(s) and/or channel(s) only.

**[0158]** In one example, the Case-3C channel access procedure can be applicable, when the transmission burst includes non-unicast DL signal(s) and/or channel(s) only, and if the burst of non-unicast DL signal(s) and/or channel (s) has a QCL assumption association with a burst of SS/PBCH blocks. In this example, the transmission burst including non-unicast DL signal(s) and/or channel(s) only has to be transmitted as a whole.

**[0159]** In one example, the Case-3B channel access procedure can be applicable, when the transmission burst includes non-unicast DL signal(s) and/or channel(s) only, and if the burst of non-unicast DL signal(s) and/or channel (s) does not have a QCL assumption association with a burst of SS/PBCH blocks.

**[0160]** In one example, the Case-4 channel access procedure can be applicable, when the transmission burst includes non-unicast DL signal(s) and/or channel(s) only.

**[0161]** In one example, the Case-4B channel access procedure can be applicable, when the transmission burst includes non-unicast DL signal(s) and/or channel(s) only, and if the burst of non-unicast DL signal(s) and/or channel (s) does not have a QCL assumption association with a burst of SS/PBCH blocks.

**[0162]** In one example, the Case-3B channel access procedure can be applicable, when the transmission burst includes unicast DL signal(s) and/or channel(s).

**[0163]** In one example, the Case-4B channel access procedure can be applicable, when the transmission burst includes unicast DL signal(s) and/or channel(s).

**[0164]** In one example, the Case-3C channel access procedure can be applicable, when the transmission burst includes scheduled UL signal(s) and/or channel(s).

**[0165]** In one example, the Case-3B channel access procedure can be applicable, when the transmission burst includes non-scheduled UL signal(s) and/or channel(s).

**[0166]** In one example, the Case-4B channel access procedure can be applicable, when the transmission burst includes non-scheduled UL signal(s) and/or channel(s).

**[0167]** For transmission burst in Case-3B, if a directional sensing provides a sensing result as busy, the transmission segment included in the transmission burst cannot be transmitted. Based on this channel access procedure, the transmission burst may not be continuous in time domain. An illustration of examples is shown in FIG. **13**.

**[0168]** FIG. **13** illustrates an example discontinuity in a transmission burst for channel access **1300** procedure according to embodiments of the present disclosure. An embodiment of the discontinuity in a transmission burst for channel access **1300** shown in FIG. **13** is for illustration only.

**[0169]** In one example, if one of the directional sensing is busy, the corresponding transmission segment cannot be transmitted, and the resources corresponding to the transmission segment can be left as empty. An example is shown in **1301** of FIG. **13**.

**[0170]** In one example, the transmission burst is a downlink burst, and the segments in the downlink burst have predefined time domain occasions for transmission, such as at least one from SS/PBCH block, PDCCH and/or PDSCH of system information (e.g., system information block (SIM)), or paging.

**[0171]** In one example, the transmission burst is an uplink burst, and the segments in the uplink burst have predefined time domain occasions for transmission, such as at least one from random access channel (RACH) preambles, or a scheduled uplink transmission burst.

**[0172]** In one example, if one of the directional sensing is busy, the corresponding transmission segment cannot be transmitted, and the resources corresponding to the transmission segment can be left as empty. If there are other transmission segments in the transmission burst, a directional channel sensing corresponding to the transmission direction of next transmission segment is required to be performed to resume transmission. In one example, the channel sensing duration of the directional channel sensing deterministic (Type 2 channel sensing procedure). An example is shown in **1302** of FIG. **13**.

**[0173]** In one example, the transmission burst is a downlink burst, and the segments in the downlink burst have predefined time domain occasions for transmission, such as at least one from SS/PBCH block, PDCCH and/or PDSCH of system information (e.g., SIBx), or paging.

**[0174]** In one example, the transmission burst is an uplink burst, and the segments in the uplink burst have predefined time domain occasions for transmission, such as at least one from RACH preambles, or a scheduled uplink transmission burst.

**[0175]** In one example, if one of the directional sensing is busy, the corresponding transmission segment cannot be transmitted, and the resources corresponding to the transmission segment can be used for transmissions with direction sensed to be idle.

**[0176]** In one example, the scheduling of the resources corresponding to the cancelled transmission segment can be included in a previous transmitted segment, such as a PDCCH and/or PDSCH in the transmission segment. An illustration of this example is shown in **1303** of FIG. **13**.

**[0177]** In one example, the resources corresponding to the cancelled transmission segment can be used for transmission according to the successful directions, and the scheduling information (e.g., included in DCI format carried by PDCCH) can be known to the receiver. An illustration of this example is shown in **1304** of FIG. **13**.

**[0178]** For transmission burst in Case-4B, if a directional sensing provides a sensing result as busy, the transmission segment included in the transmission burst cannot be transmitted. Based on this channel access procedure, the transmission burst may not be continuous in time domain. An illustration of examples is shown in FIG. **14**.

**[0179]** FIG. **14** illustrates another example discontinuity in a transmission burst for channel access procedure **1400** according to embodiments of the present disclosure. An embodiment of the discontinuity in a transmission burst for channel access procedure **1400** shown in FIG. **14** is for illustration only.

**[0180]** In one example, if one of the directional sensing is busy, the corresponding transmission segment cannot be transmitted, and the resources corresponding to the transmission segment can be left as empty. An example is shown in **1401** of FIG. **14**.

**[0181]** In one example, the transmission burst is a downlink burst, and the segments in the downlink burst have predefined time domain occasions for transmission, such as at least one from SS/PBCH block, PDCCH and/or PDSCH of system information (e.g., SIBx), or paging.

**[0182]** In one example, the transmission burst is an uplink burst, and the segments in the uplink burst have predefined time domain occasions for transmission, such as at least one from RACH preambles, or scheduled uplink transmission burst.

**[0183]** In one example, if one of the directional sensing is busy, the corresponding transmission segment cannot be transmitted, and the resources corresponding to the transmission segment can be used for transmissions with direction sensed to be idle.

**[0184]** In one example, the scheduling of the resources corresponding to the cancelled transmission segment can be included in a previous transmitted segment, such as a PDCCH and/or PDSCH in the transmission segment. An illustration of this example is shown in **1402** of FIG. **14**.

**[0185]** In one example, the resources corresponding to the cancelled transmission segment can be used for transmission according to the successful directions, and the scheduling information (e.g., included in DCI format carried by PDCCH) can be known to the receiver. An illustration of this example is shown in **1403** of FIG. **14**.

**[0186]** FIG. **15** illustrates a flow chart of a method for adapting a channel sensing threshold according to embodiments of the present disclosure, as may be performed by a UE (e.g., as **111-116** as illustrated in FIG. **1**) and/or BS (e.g., BS **102** in FIG. **1**). An embodiment of the method **1500** shown in FIG. **15** is for illustration only. One or more of the components illustrated in FIG. **15** can be implemented in specialized circuitry configured to perform the noted functions or one or more of the components can be implemented by one or more processors executing instructions to perform the noted functions.

**[0187]** In this embodiment, the method **1500** is performed in a wireless communication system operating with shared spectrum channel access by a UE or BS, collectively referred to as "the device." The method begins with the device determining whether an antenna configuration for channel sensing is omni-directional or directional (step **1505**). For example, in step **1505**, if the antenna configuration for channel sensing is determined to be directional, the device determines one or more beam directions for the antenna configuration and each beam direction is quasi-co-located (QCLed) with a reference signal. In some embodiments, the one or more beam directions for the antenna configuration for channel sensing are aligned with one or more beam directions for DL transmissions.

**[0188]** The device then determines a channel sensing threshold (step **1510**). For example, in step **1510**, the device may determine the channel sensing threshold based on two parts of channel sensing threshold. A first part of the channel sensing threshold is common for omni-directional and directional antenna configurations. A second part of the channel sensing threshold is dependent on the antenna configuration. In some embodiments, the second part of the channel sensing threshold is zero, if the antenna configuration is determined to be omni-directional. Additionally, the second part of the channel sensing threshold may be greater than zero, if the antenna configuration is determined to be directional.

**[0189]** Thereafter, the device performs a channel sensing procedure (step **1515**). For example, in step **1515**, the device performs a channel sensing procedure to determine whether the channel is idle based on the antenna configuration and the channel sensing threshold. In some embodiments, the channel is determined to be idle in the channel sensing procedure, if energy detection for each beam direction of the one or more beam directions is below the channel sensing threshold. The device then transmits DL data over the channel (step **1520**). For example, in step **1520**, the device transmits DL data over the channel if the channel is sensed as idle in the channel sensing procedure.

**[0190]** The above flowcharts illustrate example methods that can be implemented in accordance with the principles of the present disclosure and various changes could be made to the methods illustrated in the flowcharts herein. For example, while shown as a series of steps, various steps in each figure could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.

**[0191]** Although the present disclosure has been described with exemplary embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompass such changes and modifications as fall within the scope of the appended claims. None of the description in this application should be read as implying that any particular element, step, or function is an essential element that must be included in the claims scope. The scope of patented subject matter is defined by the claims.

What is claimed is:

**1**. A base station (BS) in a wireless communication system operating with shared spectrum channel access, the BS comprising:

a processor configured to:

determine whether an antenna configuration for channel sensing is omni-directional or directional;

determine a channel sensing threshold, wherein the channel sensing threshold includes two parts: a first part of the channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the channel sensing threshold depending on the antenna configuration; and

perform a channel sensing procedure based on the antenna configuration and the channel sensing threshold; and

a transceiver operably connected to the processor, the transceiver configured to transmit downlink (DL) data over a channel, if the channel is sensed as idle in the channel sensing procedure.

**2**. The BS of claim **1**, wherein:

the second part of the channel sensing threshold is zero, if the antenna configuration is determined to be omni-directional; and

the second part of the channel sensing threshold is greater than zero, if the antenna configuration is determined to be directional.

**3**. The BS of claim **1**, wherein:

the processor is further configured to determine one or more beam directions for the antenna configuration, if the antenna configuration for channel sensing is determined to be directional, and

each beam direction is quasi-co-located (QCLed) with a reference signal.

**4**. The BS of claim **3**, wherein the one or more beam directions for the antenna configuration for channel sensing are aligned with one or more beam directions for DL transmissions.

5. The BS of claim 4, wherein the channel is determined to be idle in the channel sensing procedure, if energy detection for each beam direction of the one or more beam directions is below the channel sensing threshold.

6. A method of a base station (BS) in a wireless communication system operating with shared spectrum channel access, the method comprising:
- determining whether an antenna configuration for channel sensing is omni-directional or directional;
- determining a channel sensing threshold, wherein the channel sensing threshold includes two parts: a first part of the channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the channel sensing threshold depending on the antenna configuration;
- performing a channel sensing procedure based on the antenna configuration and the channel sensing threshold; and
- transmitting downlink (DL) data over a channel based on the channel being sensed as idle in the channel sensing procedure.

7. The method of claim 6, wherein:
- the second part of the channel sensing threshold is zero, if the antenna configuration is determined to be omni-directional; and
- the second part of the channel sensing threshold is greater than zero, if the antenna configuration is determined to be directional.

8. The method of claim 6, further comprising:
- determining one or more beam directions for the antenna configuration based on determining that the antenna configuration for channel sensing is directional,
- wherein each beam direction is quasi-co-located (QCLed) with a reference signal.

9. The method of claim 8, wherein the one or more beam directions for the antenna configuration for channel sensing are aligned with one or more beam directions for DL transmissions.

10. The method of claim 9, wherein the channel is determined to be idle in the channel sensing procedure based on energy detection for each beam direction of the one or more beam directions being below the channel sensing threshold.

11. A user equipment (UE) in a wireless communication system operating with shared spectrum channel access, the UE comprising:
- a processor configured to:
  - determine whether a channel sensing threshold is configured;
  - determine whether an antenna configuration for channel sensing is omni-directional or directional;
  - determine a default channel sensing threshold, if the channel sensing threshold is not configured, wherein the default channel sensing threshold includes two parts: a first part of the default channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the default channel sensing threshold depending on the antenna configuration; and
  - perform a channel sensing procedure based on the antenna configuration and the default channel sensing threshold; and
- a transceiver operably connected to the processor, the transceiver configured to transmit downlink (DL) data over a channel, if the channel is sensed as idle in the channel sensing procedure.

12. The UE of claim 11, wherein:
- the second part of the default channel sensing threshold is zero, if the antenna configuration is determined to be omni-directional; and
- the second part of the default channel sensing threshold is greater than zero, if the antenna configuration is determined to be directional.

13. The UE of claim 11, wherein:
- the processor is further configured to determine one or more beam directions for the antenna configuration, if the antenna configuration for channel sensing is determined to be directional, and
- each beam direction is quasi-co-located (QCLed) with a reference signal.

14. The UE of claim 13, wherein the one or more beam directions for the antenna configuration for channel sensing are aligned with one or more beam directions for DL transmissions.

15. The UE of claim 14, wherein the channel is determined to be idle in the channel sensing procedure, if energy detection for each beam direction of the one or more beam directions is below the default channel sensing threshold.

16. A method of a user equipment (UE) in a wireless communication system operating with shared spectrum channel access, the method comprising:
- determining whether a channel sensing threshold is configured;
- determining whether an antenna configuration for channel sensing is omni-directional or directional;
- determining a default channel sensing threshold based on determining that the channel sensing threshold is not configured, wherein the default channel sensing threshold includes two parts: a first part of the default channel sensing threshold being common for omni-directional and directional antenna configurations and a second part of the default channel sensing threshold depending on the antenna configuration;
- performing a channel sensing procedure based on the antenna configuration and the default channel sensing threshold; and
- transmitting downlink (DL) data over a channel based on the channel being sensed as idle in the channel sensing procedure.

17. The method of claim 16, wherein:
- the second part of the default channel sensing threshold is zero, if the antenna configuration is determined to be omni-directional; and
- the second part of the default channel sensing threshold is greater than zero, if the antenna configuration is determined to be directional.

18. The method of claim 16, further comprising:
- determining one or more beam directions for the antenna configuration based on determining that the antenna configuration for channel sensing is directional, and
- each beam direction is quasi-co-located (QCLed) with a reference signal.

19. The method of claim 18, wherein the one or more beam directions for the antenna configuration for channel sensing are aligned with one or more beam directions for DL transmissions.

20. The method of claim 19, wherein the channel is determined to be idle in the channel sensing procedure based

on energy detection for each beam direction of the one or more beam directions being below the default channel sensing threshold.

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