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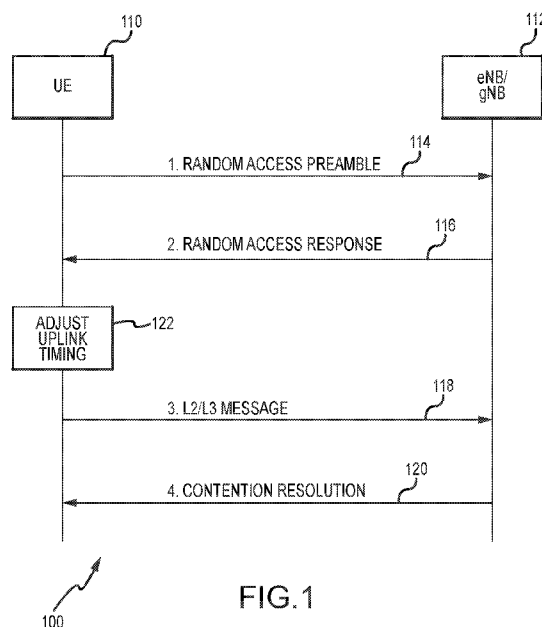


FIG. 1

(57) Abstract: Briefly, in accordance with one or more embodiments, an apparatus of a user equipment (UE) comprises one or more baseband processors to process a set of reciprocity offset thresholds received from an NR Node B (gNB), and to determine a repetition level to transmit a Fifth Generation (5G) physical random-access channel (PRACH) L number of times according to the set of reciprocity offset thresholds or via configuration by higher layers, and a memory to store the repetition level.

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ENHANCED PHYSICAL RANDOM-ACCESS CHANNEL TRANSMISSION IN NEW RADIO STANDARD

CROSS-REFERENCE TO RELATED APPLICATIONS

5 The present application claims the benefit of US Provisional Application No. 62/372,660 (P108042Z) filed August 9, 2016. Said Application No. 62/372,660 is hereby incorporated herein by reference in its entirety.

BACKGROUND

10 Mobile communication has evolved significantly from early voice systems to today's highly sophisticated integrated communication platform. The next generation wireless communication system, Fifth Generation (5G), will provide access to information and sharing of data anywhere, anytime by various users and applications. 5G is expected to be a unified network and/or system that target to meet vastly different and sometime conflicting performance dimensions and services. Such diverse multi-dimensional requirements are driven by different services and applications. In general, 5G will evolve based on the Third Generation Partnership Project (3GPP) Long Term Evolution Advanced (LTE-Advanced) with additional potential new Radio Access Technologies (RATs) to enrich lives with better, simpler, and more seamless wireless connectivity solutions. 5G will enable everything connected by wireless and deliver fast and rich contents and services.

20 For a 5G system, high frequency band communication has attracted significantly attention from the industry, since a 5G system can provide wider bandwidth to support the future integrated communication system. Beamforming is an important technology for the implementation of a high frequency band system due to the fact that the beamforming gain can compensate for the severe path loss caused by atmospheric attenuation, increase the signal-to-noise ratio (SNR), and enlarge the coverage area. By aligning the transmission beam to the target user equipment (UE), radiated energy is focused for higher energy efficiency, and mutual UE interference is suppressed.

30 For centimeter Wave (cmWave) and millimeter Wave (mmWave) systems, a beam reference signal (BRS) or synchronization signal (SS) block is transmitted from the evolved Node B (eNodeB) to allow the UE to measure RS received power (RSRP) and obtain the best eNodeB transmission (Tx) beam and UE receive (Rx) beam. If a one-to-one association rule is defined between the 5G physical random-access channel (PRACH) transmission resource and SS block antenna port (AP), the UE may transmit a PRACH for uplink synchronization using the best UE Rx beam acquired during initial beam acquisition stage, on a time or frequency resource which is associated with the best 5G Node B (gNB) Tx beam. This is primarily due to the assumption of

perfect downlink and uplink reciprocity for Time Division Duplex (TDD) system. In the case of non-ideal reciprocity between Tx and Rx beams, certain mechanisms should be considered for the PRACH transmission for initial access.

DESCRIPTION OF THE DRAWING FIGURES

5 Claimed subject matter is particularly pointed out and distinctly claimed in the concluding portion of the specification. However, such subject matter may be understood by reference to the following detailed description when read with the accompanying drawings in which:

FIG. 1 is a diagram of a procedure for contention based random-access in accordance with one or more embodiments;

10 FIG. 2 is a diagram of a procedure for contention free random-access in accordance with one or more embodiments;

FIG. 3 is a diagram of a random-access channel procedure in a perfect reciprocity scenario in accordance with one or more embodiments;

15 FIG. 4 is a diagram of a physical random-access procedure in a non-ideal reciprocity scenario in accordance with one or more embodiments;

FIG. 5 is a diagram of a first option of physical random-access channel frequency hopping in accordance with one or more embodiments;

FIG. 6 is a diagram of a second option of physical random-access channel frequency hopping in accordance with one or more embodiments;

20 FIG. 7 is a diagram of a third option of physical random-access channel frequency hopping in accordance with one or more embodiments;

FIG. 8 is a diagram of physical random-access channel transmission timing in accordance with one or more embodiments;

25 FIG. 9 is a diagram of dynamic panel switching for physical random-access channel transmission in accordance with one or more embodiments; and

FIG. 10 is a diagram of example components of a device in accordance with some embodiments.

30 It will be appreciated that for simplicity and/or clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, if considered appropriate, reference numerals have been repeated among the figures to indicate corresponding and/or analogous elements.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth to provide a thorough understanding of claimed subject matter. It will, however, be understood by those skilled in the art that claimed subject matter may be practiced without these specific details. In other instances, well-known methods, procedures, components and/or circuits have not been described in detail.

Referring now to FIG. 1, a diagram of a procedure for contention based random-access in accordance with one or more embodiments will be discussed. In the example of FIG. 1, a four-operation procedure 100 may be used for initial contention based random-access in accordance with a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) specification. In a first operation 114, user equipment (UE) 110 transmits a physical random-access channel (PRACH) in the uplink (UL) by randomly selecting one preamble signature which may allow an evolved NodeB (eNB) 112 to estimate the delay between eNB 112 and UE 110 for subsequent UL timing adjustment. In a Fifth Generation (5G) New Radio (NR) standard, eNB 112 may comprise a gNB 112, although the scope of the claimed subject matter is not limited in this respect. Subsequently, in a second operation 116, eNB feeds back the random-access response (RAR) which carries timing advanced (TA) command information for uplink timing adjustment 122 and uplink grant for the uplink transmission in the third operation (L2/L3 message) 118. The UE 110 expects to receive the RAR within a time window, of which the start and end may be configured by via a system information block (SIB). Finally, contention resolution message may occur at operation 120 sent from the eNB 112 to the UE 110.

Referring now to FIG. 2, a diagram of a procedure for contention free random-access in accordance with one or more embodiments will be discussed. In order to reduce the random-access latency for certain scenarios including handover and resumption of downlink traffic for a UE 110, the UE 110 may be requested to perform a contention free random-access procedure 200, which may be triggered by physical downlink control channel (PDCCH) order. In particular, eNB 112 would allocate a dedicated PRACH preamble signature to the UE 10 at operation 210, which may be outside the preamble sets used for contention-based random-access. The random-access preamble is then sent by the UE 110 to the eNB 112. Note that the contention free random-access procedure terminates with the RAR message at operation 214.

Referring now to FIG. 3, a diagram of a random-access channel procedure in a perfect reciprocity scenario in accordance with one or more embodiments will be discussed. As mentioned above, in the case of perfect reciprocity, a Fifth Generation (5G) physical random-access channel (PRACH) resource may be selected by the UE 110 from a time or frequency PRACH resources, which may be associated with the best 5G New Radio (NR) NodeB (gNB) Transmission (Tx)

beam or beam reference signal (BRS) or SS block antenna port (AP). In one or more embodiments, a beam reference signal (BRS) may include, but is not limited to, a synchronization signal (SS) block for downlink (DL) transmit (Tx) beam measurement, for example a primary synchronization signal (PSS), a secondary synchronization signal (SSS), or a physical broadcast channel (PBCH),
 5 or a combination thereof, and the scope of the claimed subject matter is not limited in this respect.

One example of a RACH procedure in the case of perfect reciprocity is shown in FIG. 3. The association between downlink (DL) beams or APs and the corresponding PRACH resource in time or frequency is cell-specific and may be signaled as part of system information such that each DL Tx beam has a dedicated associated PRACH resource in the uplink (UL). Alternatively, the
 10 one-to-one or multiple-to-one association between beam index, that is the BRS resource index, and PRACH resource, for example in a time, frequency and/or sequence domain, may be predefined, for example based on the group index or symbol index. In any event, such an association should be known by a UE 110 in idle mode before the RACH procedure is initiated. In the example shown in FIG. 3, in slot #0 denoted by 310, the UE 110 measures the received
 15 power based on BRS and determines the best gNB Tx beam. As shown in FIG. 3, for UE #1, the best Tx beam of gNB 112 is located at BRS beam group #0 and the third orthogonal frequency-division multiplexing (OFDM) symbol 312. According to the association rule, UE 110 may correspondingly transmit the PRACH in the associated PRACH resource, that is in the third PRACH slot 314 in the slot #5 denoted by 316.

20 In order to increase the random-access capacity, UE 110 may randomly select one frequency resource for PRACH transmission. As shown in FIG. 3, UE 110 may choose PRACH frequency resource #1 for PRACH transmission. Alternatively, UE 110 may properly select a PRACH resource from an available set of PRACH resources associated with the best Tx beam based at least in part on the potential message size, which is the data available for transmission
 25 plus MAC header and optionally MAC control elements, and measured pathloss based on BRS of best beam. More particularly, if the message payload size is greater than a signaled threshold A, and if the pathloss is less than a threshold B, then UE 110 shall select from a first PRACH group. Otherwise, UE 110 may select one from a second PRACH group.

In one or more embodiments, the reciprocity offset may be defined as $I_{reciprocity}$ which
 30 may be used to indicate the offset between non-ideal reciprocity and perfect reciprocity. Based on the offset, eNB 112 may configure a set of thresholds to allow UE 110 to autonomously derive the repetition level L for the transmission of the PRACH based on the offset value of $I_{reciprocity}$ using a selected beam. In one embodiment, the repetition level L may refer to the number of times the PRACH is transmitted, although the scope of the claimed subject matter is not limited in this

respect. In one embodiment, three levels of thresholds may be configured by higher layers via a 5G master information block (MIB), a 5G system information block (SIB), or via radio resource control (RRC) signaling, for example *Threshold_0*, *Threshold_1*, and *Threshold_2*. In one or more embodiments, higher layers may include layers higher than the Physical layer, for example at the Media Access Control (MAC) layer, Radio Link Control (RLC) layer, Packet Data Convergence Protocol (PDCP) layer, Radio Resource Control (RRC) layer, or Non-Access Stratum (NAS) layer, and so on, although the scope of the claimed subject matter is not limited in this respect. In the case where thresholds are configured by higher layers, UE 110 may derive the repetition level based on the following equation:

$$\begin{cases} L = 1, I_{reciprocity} \leq Threshold_0 \\ L = 2, Threshold_0 < I_{reciprocity} \leq Threshold_1 \\ L = 3, Threshold_1 < I_{reciprocity} \leq Threshold_2 \\ L = 4, I_{reciprocity} > Threshold_2 \end{cases}$$

As a further extension, $I_{reciprocity}$ may be beam specific, and one set of thresholds may be configured by higher layers. In this case, for each particular beam, UE 110 may compare $I_{reciprocity}$ with the threshold list and determine the best Rx beam and corresponding repeated times for PRACH transmission.

It should be noted that a repeated PRACH may be transmitted in a continuous or non-continuous manner in the time domain. In the time domain case, UE 110 may transmit PRACH L number of times in the resources which correspond to L number of best beam reference signal (BRS) antenna port (APs), where L may be configured by higher layers via MIB or SIB or RRC signaling or determined as mentioned above. Given that one-to-one resource association between BRS antenna port and PRACH resource in time domain can be defined, UE 110 may derive the corresponding time resource for PRACH transmission.

Furthermore, UE 110 may use the same PRACH preamble signature, which may allow gNB 112 to perform combining to improve the detection performance. In particular, UE 110 may randomly select one PRACH preamble signature and use the selected PRACH preamble signature for subsequent PRACH transmission. Alternatively, UE 110 may randomly select one PRACH preamble for each transmission, which may reduce the collision probability.

To allow gNB 112 to identify whether UE 110 is in non-ideal or perfect reciprocity condition, dedicated resource may be allocated for UE 110 with non-ideal reciprocity condition. In particular, such dedicated PRACH resources and the resources for UE 110 with perfect

reciprocity may be multiplexed in a time division combination. Furthermore, the partition of this group of dedicated resources for UE 110 with non-ideal and perfect reciprocity may be predefined or configured by higher layer via MIB, SIB, or RRC signaling.

In one example, one or more of signatures, time or frequency resources may be reserved for PRACH for UE 110 with non-ideal reciprocity to transmit PRACH. Further, a combination of time-division multiplexing (TDM), frequency-division multiplexing (FDM), and/or code-division multiplexing (CDM) based multiplexed schemes may be used to separate the resource for UE 110 with non-ideal and perfect reciprocity.

In another example, the preamble signature for each PRACH transmission may be different. The preamble signature may be divided into two groups: group A and group B. Group A denotes that the present PRACH resource is determined by the best DL beam index. Group B denotes that this PRACH resource is determined by the other DL beam index. The preamble signature in group A and group B should be one-to-one mapped. A UE 110 could randomly select a preamble signature within group A, and then select the preamble signature in group B which is one-to-one mapped to the one selected in group A. Thus, the gNB 112 could know which beam is the best DL beam for the UE 110 and use this DL beam to transmit the RAR.

In one or more embodiments, an association between one or multiple occasions for downlink DL broadcast channel and/or signal and a subset of RACH or PRACH resources is informed to UE 110 by gNB 112 by broadcast system information or otherwise may be known to UE 110. Based at least in part on the DL measurement and the corresponding association, UE 110 may select the subset of PRACH preamble indices. One or more UE transmit (Tx) beams for one or more preamble transmissions may be selected by UE 110. During a PRACH transmission occasion of a single or multiple and/or repeated preambles as informed by broadcast system information, UE 110 may use the same UE Tx beam, although the scope of the claimed subject matter is not limited in this respect. In one or more embodiments, PRACH transmissions may occur in accordance with a Third Generation Partnership Project (3GPP) New Radio (NR) standard such as according to 3GPP Technical Specification (TS) 38.211 or 3GPP TS 38.212, or as described in 3GPP Technical Report (TR) 38.802 version 14.1.0 (2017-06), although the scope of the claimed subject matter is not limited in this respect.

In one or more embodiments, RACH procedure including RACH preamble, message 1 (Msg. 1), random access response, message 3 (Msg. 2), message 3, and message 4 is assumed for New Radio (NR) standard from physical layer perspective. Random access procedure is supported for both IDLE mode and CONNECTED mode UEs 110. For a 4-step RACH procedure, a RACH

transmission occasion may be defined as the time-frequency resource on which a PRACH message 1 is transmitted using the configured PRACH preamble format with a single particular Tx beam.

RACH resource also may be defined as a time-frequency resource to send RACH preamble. Whether UE 110 is to transmit one or multiple and/or repeated preamble within a subset of RACH resources can be informed by broadcast system information, for example to cover gNB Rx beam sweeping in case of NO Tx/Rx beam correspondence at the gNB 112.

Regardless of whether Tx/Rx beam correspondence is available or not at gNB 112 at least for multiple beams operation, the following RACH procedure may be considered for at least UE 110 in idle mode. Association between one or multiple occasions for downlink (DL) broadcast channel and/or signal and a subset of RACH resources may be informed to UE 110 by broadcast system information or known to UE 110. Based at least in part on the DL measurement and the corresponding association, UE 110 may select the subset of RACH preamble indices. One or more UE Tx beams for one or more preamble transmissions may be selected by the UE 110. During a RACH transmission occasion of single or multiple and/or repeated preambles as informed by broadcast system information, UE 110 may use the same UE Tx beam. The NR standard at least supports transmission of a single message 1 before the end of a monitored random access response (RAR) window.

At least for the case without gNB Tx/Rx beam correspondence, gNB 112 may configure an association between DL signal and/or channel, and a subset of RACH resources and/or a subset of preamble indices, for determining Msg2 DL Tx beam. Based at least in part on the DL measurement and the corresponding association, UE 110 may select the subset of RACH resources and/or the subset of RACH preamble indices. A preamble index consists of preamble sequence index and orthogonal cover code (OCC) index, if OCC is supported. It should be noted that a subset of preambles may be indicated by OCC indices.

Regardless of whether Tx/Rx beam correspondence is available or not at gNB 112 at least for multiple beams operation, at gNB 112, the DL Tx beam for message 2 may be obtained based on the detected RACH preamble/resource and the corresponding association. Uplink (UL) grant in message 2 may indicate the transmission timing of message 3. As baseline UE 110 behavior, UE 110 assumes single RAR reception within a given RAR window.

At least for UE 110 in idle mode, UL Tx beam for message 3 transmission may be determined by UE 110. UE 110 may use the same UL Tx beam used for message 1 transmission. Different PRACH configurations may be supported, for example considering different numerologies case and whether Tx/Rx beam correspondence is available or not at gNB 112.

For NR RACH message 1 retransmission at least for multi-beam operation, NR supports power ramping. If UE 110 does not change a beam, the counter of power ramping may continue increasing. It should be noted that UE 110 may derive the uplink transmit power using a most or more recent estimate of path loss. Whether UE 110 performs UL beam switching during retransmissions may be up to implementation by UE 110. It should be further noted that which beam UE 110 switches to also may be up to implementation by UE 110.

Referring now to FIG. 4, a diagram of a physical random-access procedure in a non-ideal reciprocity scenario in accordance with one or more embodiments will be discussed. One example of PRACH transmissions in two orthogonal frequency-division multiplexing (OFDM) symbols is shown in FIG. 4. Furthermore, UE 110 may measure BRS received powers and determine two best BRS APs in symbol #2 410 and symbol #3 412 as shown FIG. 4. Based at least in part on one-to-one association, UE 110 may repeat PRACH in three different PRACH slots in slot #2 and #3 in the configured slot. This transmission scheme may enhance the PRACH detection performance in the case of non-ideal reciprocity.

Referring now to FIG. 5, a diagram of a first option of physical random-access channel frequency hopping in accordance with one or more embodiments will be discussed. In one or more embodiments, if multiple frequency resources are configured for PRACH transmission, UE 110 may perform frequency hopping on multiple PRACH transmission to exploit the benefits of frequency diversity. A first option, option 1, is shown in FIG. 5 wherein if L consecutive PRACH transmissions are performed, a constant frequency resource offset between two consecutive PRACH transmissions may be applied. More specifically, UE 110 may randomly select one frequency resource in the first PRACH slot, and apply the frequency hopping on the subsequent PRACH transmission. In one example, the constant frequency resource offset can be $[M/2]$, where M is the total number of PRACH frequency resources which are configured by higher layers. FIG. 5 illustrates one example of PRACH frequency hopping for option 1. In this example, UE 110 randomly selects the PRACH frequency resource #3 for the first PRACH transmission 510 in PRACH slot 0 at 512, and performs frequency hopping on the subsequent transmissions. In particular, UE 110 transmits three PRACH transmissions with transmission 512 in frequency resource #1 at PRACH slot 1, transmission 514 in frequency resource #3 at PRACH slot 2, and transmission 516 in frequency resource #1 at PRACH slot 3, although the scope of the claimed subject matter is not limited in this respect.

Referring now to FIG. 6, a diagram of a second option of physical random-access channel frequency hopping in accordance with one or more embodiments will be discussed. In a second option, option 2, UE 110 performs frequency hopping on PRACH transmission between two

PRACH frequency resources. More specifically, UE 110 transmits a first $[L/2]$ PRACH using a first frequency resource, and a second $[L/2]$ PRACH using a second frequency resource. The first frequency resource may be randomly selected by UE 110, and the distance between first and second frequency resource may be predefined or configured by higher layers. In one example, frequency distance may be $[M/2]$. FIG. 6 illustrates one example of PRACH frequency hopping for option 2. In this example, UE 110 randomly selects the PRACH frequency resource #3 for the first PRACH transmission 610, and performs frequency hopping on the subsequent transmissions. In particular, UE transmits three PRACH transmissions, transmission 612 in frequency resource #3, transmission 614 in frequency resource #1, and transmission 616 in frequency resource #1, although the scope of the claimed subject matter is not limited in this respect.

Referring now to FIG. 7, a diagram of a third option of physical random-access channel frequency hopping in accordance with one or more embodiments will be discussed. In a third option, option 3, UE 110 performs frequency hopping on multiple PRACH transmissions according to a frequency hopping pattern. In particular, the frequency hopping pattern may be defined as a function of at least one or more following parameters: cell ID, the frequency resource for the first PRACH transmission, symbol and/or slot index for PRACH transmission, and UE ID, for example a Cell Radio Network Temporary Identifier (C-RNTI). In one example, the frequency resource index for each PRACH transmission may be given by:

$$I_{freq} = f(N_{ID}^{cell}, n_{sf}) \bmod(M)$$

where N_{ID}^{cell} is the physical cell ID, n_{sf} is the slot index, and I_{freq} is the frequency resource index for PRACH transmission. FIG. 7 illustrates one example of PRACH frequency hopping for option 3. In this example, UE 110 randomly selects the PRACH frequency resource #3 for the first PRACH transmission 710, and performs frequency hopping on the subsequent transmissions. In particular, UE 110 transmits three PRACH transmissions, transmission 712 in frequency resource #0, transmission 714 in frequency resource #1, and transmission 716 in frequency resource #3, although the scope of the claimed subject matter is not limited in this respect.

Referring now to FIG. 8, a diagram of physical random-access channel transmission timing in accordance with one or more embodiments will be discussed. Similar to the approach used in LTE, for contention free random-access, gNB 112 would assign dedicated PRACH preamble signature for PRACH transmission. For a 5G system, an embodiment of enhancement on contention free random-access may be provided as follows. In one embodiment, multiple PRACH formats may be defined in the specification. A 5G PRACH format indicator may be included in

the downlink control information (DCI) format via a PDCCH order to trigger contention free PRACH transmission. In another embodiment, PRACH transmission timing and/or frequency resource may be indicated in the DCI format via PDCCH order to trigger contention free PRACH transmission.

5 A slot structure for PRACH transmission may be based on a self-contained slot structure, wherein PDCCH may be transmitted at the beginning of the slot and PUCCH may be transmitted at the last part of the slot. In one example, PRACH may be transmitted in the last part of the slot and multiplexed with PUCCH in a frequency-division multiplexing (FDM) manner.

Furthermore, PRACH transmission timing or the transmission gap between PDCCH order
10 and PRACH transmission slot may be explicitly indicated in the DCI format. As a further extension, a set of PRACH transmission timing may be predefined or configured by higher layers. A field in the DCI format may be used to indicate which transmission timing is applied for the PRACH transmission from the set of PRACH transmission timing. A PRACH transmission timing or gap of value 0 may be viewed as a self-contained PRACH transmission, that is the PRACH is
15 transmitted in the same slot where PDCCH is transmitted.

FIG. 8 illustrates two examples of PRACH transmission timing. In the first example, a self-contained PRACH transmission is triggered, that is the PRACH transmission delay $k = 0$ wherein the PRACH transmission 810 occurs at the end of one slot 814, after a guard time (GT). In the second example, the gap between PDCCH and PRACH is 1 slot, that is $k = 1$ wherein the
20 PRACH transmission 812 occurs at the end of two slots, slot 814 and slot 816, and after a guard time (GT).

In another embodiment, in the case of non-ideal reciprocity, the number of PRACH transmissions may be indicated in the DCI format via a PDCCH order to trigger contention free PRACH transmission. Moreover, an indicator to indicate whether PRACH frequency hopping
25 may be applied for multiple PRACH transmissions can be included in the DCI format. In one example, bit 1 may indicate that frequency hopping for PRACH transmission is enabled while bit 0 may indicate that frequency hopping for PRACH transmission is disabled.

Referring now to FIG. 9, a diagram of dynamic panel switching for physical random-access channel transmission in accordance with one or more embodiments will be discussed. In another
30 embodiment of the invention, in case when UE is equipped with two or multiple sub-arrays or panels such as panel (Panel 0) 910 and panel (Panel 1) 912, the beam or sub-array or panel index may be indicated in the downlink control information (DCI) format via the PDCCH order to trigger contention free PRACH transmission in a cross-beam manner. Such an arrangement may allow

dynamic beam triggering and switching for PRACH transmission to further increase the PRACH detection performance and connection robustness.

FIG. 9 illustrates one example of dynamic panel switching for PRACH transmission. In this example, UE 110 may measure the beam reference signal received power (B-RSRP) using two panels, panel (Panel 0) 910 and panel (Panel 1) 912 and report the corresponding B-RSRP for the two panels to gNB 112. After receiving the B-RSRP from UE 110, gNB 112 may select the panel with stronger B-RSRP and inform UE 110 to transmit the PRACH using that panel. As shown in FIG. 9, panel (Panel 1) 912 may have a stronger B-RSRP from beam 916 of gNB 112 than the B-RSRP from beam 914 of gNB 112 at panel (Panel 0) 910 wherein gNB 112 is operating as a transmission/reception point (TRP). In such a case, panel (Panel 1) 912 may be indicated in the DCI and used for PRACH transmission, although the scope of the claimed subject matter is not limited in this respect.

Referring now to FIG. 10, a diagram of example components of a device in accordance with some embodiments will be discussed. FIG. 10 illustrates example components of a device 1000 in accordance with some embodiments. In some embodiments, the device 1000 may include application circuitry 1002, baseband circuitry 1004, Radio Frequency (RF) circuitry 1006, front-end module (FEM) circuitry 1008, one or more antennas 1010, and power management circuitry (PMC) 1012 coupled together at least as shown. The components of the illustrated device 1000 may be included in a UE or a RAN node. In some embodiments, the device 1000 may include less elements (e.g., a RAN node may not utilize application circuitry 1002, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 1000 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

The application circuitry 1002 may include one or more application processors. For example, the application circuitry 1002 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 1000. In some embodiments, processors of application circuitry 1002 may process IP data packets received from an EPC.

The baseband circuitry 1004 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1004 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 1006 and to generate baseband signals for a transmit signal path of the RF circuitry 1006. Baseband processing circuitry 1004 may interface with the application circuitry 1002 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1006. For example, in some embodiments, the baseband circuitry 1004 may include a third generation (3G) baseband processor 1004A, a fourth generation (4G) baseband processor 1004B, a fifth generation (5G) baseband processor 1004C, or other baseband processor(s) 1004D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 1004 (e.g., one or more of baseband processors 1004A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1006. In other embodiments, some or all of the functionality of baseband processors 1004A-D may be included in modules stored in the memory 1004G and executed via a Central Processing Unit (CPU) 1004E. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 1004 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1004 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 1004 may include one or more audio digital signal processor(s) (DSP) 1004F. The audio DSP(s) 1004F may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1004 and the application circuitry 1002 may be implemented together such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 1004 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the

baseband circuitry 1004 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1004 is configured to support radio communications of more than one
5 wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 1006 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1006 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1006 may include a receive signal path which may include circuitry
10 to down-convert RF signals received from the FEM circuitry 1008 and provide baseband signals to the baseband circuitry 1004. RF circuitry 1006 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1004 and provide RF output signals to the FEM circuitry 1008 for transmission.

In some embodiments, the receive signal path of the RF circuitry 1006 may include mixer
15 circuitry 1006a, amplifier circuitry 1006b and filter circuitry 1006c. In some embodiments, the transmit signal path of the RF circuitry 1006 may include filter circuitry 1006c and mixer circuitry 1006a. RF circuitry 1006 may also include synthesizer circuitry 1006d for synthesizing a frequency for use by the mixer circuitry 1006a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1006a of the receive signal path may be
20 configured to down-convert RF signals received from the FEM circuitry 1008 based on the synthesized frequency provided by synthesizer circuitry 1006d. The amplifier circuitry 1006b may be configured to amplify the down-converted signals and the filter circuitry 1006c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be
25 provided to the baseband circuitry 1004 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1006a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 1006a of the transmit signal path may be
30 configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1006d to generate RF output signals for the FEM circuitry 1008. The baseband signals may be provided by the baseband circuitry 1004 and may be filtered by filter circuitry 1006c.

In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a of the transmit signal path may be configured for super-heterodyne operation.

In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 1006 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1004 may include a digital baseband interface to communicate with the RF circuitry 1006.

In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect. In some embodiments, the synthesizer circuitry 1006d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 1006d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider. The synthesizer circuitry 1006d may be configured to synthesize an output frequency for use by the mixer circuitry 1006a of the RF circuitry 1006 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1006d may be a fractional $N/N+1$ synthesizer.

In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1004 or the applications processor 1002 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 1002.

Synthesizer circuitry 1006d of the RF circuitry 1006 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a

dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

In some embodiments, synthesizer circuitry 1006d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 1006 may include an IQ/polar converter.

FEM circuitry 1008 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1010, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1006 for further processing. FEM circuitry 1008 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1006 for transmission by one or more of the one or more antennas 1010. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 1006, solely in the FEM 1008, or in both the RF circuitry 1006 and the FEM 1008.

In some embodiments, the FEM circuitry 1008 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1006). The transmit signal path of the FEM circuitry 1008 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1006), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1010).

In some embodiments, the PMC 1012 may manage power provided to the baseband circuitry 1004. In particular, the PMC 1012 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 1012 may often be included when the device

1000 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 1012 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

While FIG. 10 shows the PMC 1012 coupled only with the baseband circuitry 1004. However, in other embodiments, the PMC 1012 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 1002, RF circuitry 1006, or FEM 1008.

In some embodiments, the PMC 1012 may control, or otherwise be part of, various power saving mechanisms of the device 1000. For example, if the device 1000 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 1000 may power down for brief intervals of time and thus save power.

If there is no data traffic activity for an extended period of time, then the device 1000 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 1000 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 1000 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

Processors of the application circuitry 1002 and processors of the baseband circuitry 1004 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 1004, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 1004 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

As used herein, the terms "circuit" or "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware. Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software.

The following are example implementations of the subject matter described herein. It should be noted that any of the examples and the variations thereof described herein may be used in any permutation or combination of any other one or more examples or variations, although the scope of the claimed subject matter is not limited in these respects.

In example one, an apparatus of a user equipment (UE) comprises one or more baseband processors to process a set of reciprocity offset thresholds received from a New Radio (NR) NodeB (gNB), and to determine a repetition level to transmit a Fifth Generation (5G) physical random-access channel (PRACH) L number of times according to the set of reciprocity offset thresholds or configured by higher layers, and a memory to store the repetition level. Example two may include the subject matter of example one or any of the examples described herein, further comprising a radio-frequency transceiver to transmit a PRACH a number of times to the gNB according to the repetition level. Example three may include the subject matter of example one or any of the examples described herein, wherein the set of reciprocity offset thresholds is configured by higher layers via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling. Example four may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to select a PRACH resource from an available set of PRACH resources associated with a best gNB transmit (Tx) beam based at least in part on a potential message size comprising data available for transmission, a media access control (MAC) header, or MAC control elements, or a combination thereof, and a measured pathloss based at least in part on a beam reference signal (BRS) or synchronization signal (SS) block of the best gNB Tx beam. Example five may include the subject matter of example one or any of the examples described herein, wherein a reciprocity offset in the set of reciprocity offset thresholds is beam specific, and wherein the one or more baseband processors are to compare the reciprocity offset with a threshold list and to determine a best receive (Rx) beam and corresponding repetition level for PRACH transmission. Example six

may include the subject matter of example one or any of the examples described herein, wherein one or more baseband processor are to determine if PRACH is to be transmitted in a continuous or non-continuous manner in the time domain, and to configure PRACH to be transmitted L number of times in a resource corresponding to L best beam reference signal (BRS) or synchronization signal (SS) block antenna ports (APs), wherein L may be configured by higher layers via MIB, SIB or RRC signaling. Example seven may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to randomly select one PRACH preamble signature and to configure the selected PRACH preamble signature for subsequent repeated PRACH transmission, and wherein the one or more baseband processors are to randomly select one PRACH preamble for repeated transmission. Example eight may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to configure frequency hopping on multiple PRACH transmissions if multiple frequency resources are configured for PRACH transmission. Example nine may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to apply a constant frequency resource offset between two consecutive PRACH transmissions. Example ten may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to configure frequency hopping on PRACH transmission between two PRACH frequency resources, and wherein the one or more baseband processors are to configure transmission of a first $[L/2]$ PRACH using first frequency resource and a second $[L/2]$ PRACH using a second frequency resource. Example eleven may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to configure frequency hopping on multiple PRACH transmissions according to a frequency hopping pattern, wherein the frequency hopping pattern is defined as a function of at least one or more following parameters: cell identifier (ID), the frequency resource for a first PRACH transmission, a symbol or slot index for PRACH transmission, Cell Radio Network Temporary Identifier (C-RNTI), or a UE ID, or a combination thereof.

In example twelve, an apparatus of a New Radio (NR) NodeB (gNB) comprises one or more baseband processors to configure a set of reciprocity offset thresholds for a user equipment (UE), and to process a Fifth Generation (5G) physical random-access channel (PRACH) received from the UE according to the set of reciprocity offset thresholds, and a memory to store the repetition level. Example thirteen may include the subject matter of example twelve or any of the examples described herein, wherein the one or more baseband processors are to allocate dedicated resources for the UE with non-ideal reciprocity condition, wherein the dedicated resources with

non-ideal reciprocity condition and resources with perfect reciprocity are to be multiplexed in time division multiplexing (TDM), frequency division multiplexing (FDM), or code division multiplexing (CDM), or a combination thereof, wherein a partition of the dedicated resources with non-ideal and with perfect reciprocity are predefined or configured by higher layer via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling. Example fourteen may include the subject matter of example twelve or any of the examples described herein, wherein the one or more baseband processors are to encode a PRACH format indicator, a PRACH transmission timing, or a PRACH time and frequency resource, or a combination thereof, in a downlink control information (DCI) format via PDCCH order to trigger contention free PRACH transmission. Example fifteen may include the subject matter of example twelve or any of the examples described herein, wherein for non-ideal reciprocity the one or more baseband processors are to encode a number of PRACH transmissions in a downlink control information (DCI) format via an PDCCH order to trigger contention free PRACH transmission, and an indicator to indicate if PRACH frequency hopping is to be applied for multiple PRACH transmissions. Example sixteen may include the subject matter of example twelve or any of the examples described herein, wherein the one or more baseband processors are to encode a beam or sub-array or panel index in a downlink control information (DCI) format via PDCCH order to trigger contention free PRACH transmission in a cross-beam manner if the UE includes two or more sub-arrays or panels.

In example seventeen, one or more machine-readable media may have instructions stored thereon that, if executed by a user equipment (UE), result in processing a set of reciprocity offset thresholds received from a New Radio (NR) NodeB (gNB), determining a repetition level to transmit a Fifth Generation (5G) physical random-access channel (PRACH) L number of times according to the set of reciprocity offset thresholds or configured by higher layers, and storing the repetition level in a memory. Example eighteen may include the subject matter of example seventeen or any of the examples described herein, wherein the instructions, if executed, further result in causing a radio-frequency transceiver to transmit a PRACH a number of times to the gNB according to the repetition level. Example nineteen may include the subject matter of example seventeen or any of the examples described herein, wherein the set of reciprocity offset thresholds is configured by higher layers via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling. Example twenty may include the subject matter of example seventeen or any of the examples described herein, wherein the instructions, if executed, further result in selecting a PRACH resource from an available set of PRACH resources associated with a best gNB transmit (Tx) beam based at least in part on a

potential message size comprising data available for transmission, a media access control (MAC) header, or MAC control elements, or a combination thereof, and a measured pathloss based at least in part on a beam reference signal (BRS) or synchronization signal (SS) block of the best gNB Tx beam. Example twenty-one may include the subject matter of example seventeen or any of the
5 examples described herein, wherein a reciprocity offset in the set of reciprocity offset thresholds is beam specific, and wherein the one or more baseband processors are to compare the reciprocity offset with a threshold list and to determine a best receive (Rx) beam and corresponding repetition level for PRACH transmission.

In example twenty-two, one or machine-readable media may have instructions stored
10 thereon that, if executed by a New Radio (NR) NodeB (gNB), result in configuring a set of reciprocity offset thresholds for a user equipment (UE), processing a Fifth Generation (5G) physical random-access channel (PRACH) received from the UE according to the set of reciprocity offset thresholds, and storing the repetition level in a memory. Example twenty-three may include the subject matter of example twenty-two or any of the examples described herein, wherein the
15 instructions, if executed, further result in allocating dedicated resources for the UE with non-ideal reciprocity condition, wherein the dedicated resources with non-ideal reciprocity condition and resources with perfect reciprocity are to be multiplexed in time division multiplexing (TDM), frequency division multiplexing (FDM), or code division multiplexing (CDM), or a combination thereof, wherein a partition of the dedicated resources with non-ideal and with perfect reciprocity
20 are predefined or configured by higher layer via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling. Example twenty-four may include the subject matter of example twenty-two or any of the examples described herein, wherein the instructions, if executed, further result in encoding a PRACH format indicator, a PRACH transmission timing, or a PRACH time and frequency resource, or a
25 combination thereof, in a downlink control information (DCI) format via PDCCH order to trigger contention free PRACH transmission. Example twenty-five may include the subject matter of example twenty-two or any of the examples described herein, wherein for non-ideal reciprocity the one or more baseband processors are to encode a number of PRACH transmissions in a downlink control information (DCI) format via an PDCCH order to trigger contention free
30 PRACH transmission, and an indicator to indicate if PRACH frequency hopping is to be applied for multiple PRACH transmissions.

In example twenty-six, an apparatus of a user equipment (UE) comprises means for processing a set of reciprocity offset thresholds received from a New Radio (NR) NodeB (gNB), means for determining a repetition level to transmit a Fifth Generation (5G) physical random-

access channel (PRACH) L number of times according to the set of reciprocity offset thresholds or configured by higher layers, and means for storing the repetition level. Example twenty-seven may include the subject matter of example twenty-six or any of the examples described herein, wherein the instructions, further comprising means for transmitting a PRACH a number of times
5 to the gNB according to the repetition level. Example twenty-eight may include the subject matter of example twenty-six or any of the examples described herein, wherein the set of reciprocity offset thresholds is configured by higher layers via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling. Example twenty-nine may include the subject matter of example twenty-six or any of the examples
10 described herein, further comprising means for selecting a PRACH resource from an available set of PRACH resources associated with a best gNB transmit (Tx) beam based at least in part on a potential message size comprising data available for transmission, a media access control (MAC) header, or MAC control elements, or a combination thereof, and a measured pathloss based at least in part on a beam reference signal (BRS) or synchronization signal (SS) block of the best gNB Tx
15 beam. Example thirty may include the subject matter of example twenty-six or any of the examples described herein, wherein a reciprocity offset in the set of reciprocity offset thresholds is beam specific, and wherein the one or more baseband processors are to compare the reciprocity offset with a threshold list and to determine a best receive (Rx) beam and corresponding repetition level for PRACH transmission.

20 In example thirty-one, an apparatus of a New Radio (NR) NodeB (gNB) comprises means for configuring a set of reciprocity offset thresholds for a user equipment (UE), means for processing a Fifth Generation (5G) physical random-access channel (PRACH) received from the UE according to the set of reciprocity offset thresholds, and means for storing the repetition level. Example thirty-two may include the subject matter of example thirty-one or any of the examples
25 described herein, further comprising means for allocating dedicated resources for the UE with non-ideal reciprocity condition, wherein the dedicated resources with non-ideal reciprocity condition and resources with prefect reciprocity are to be multiplexed in time division multiplexing (TDM), frequency division multiplexing (FDM), or code division multiplexing (CDM), or a combination thereof, wherein a partition of the dedicated resources with non-ideal and with perfect reciprocity
30 are predefined or configured by higher layer via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling. Example thirty-three may include the subject matter of example thirty-one or any of the examples described herein, further comprising means for encoding a PRACH format indicator, a PRACH transmission timing, or a PRACH time and frequency resource, or a combination thereof, in a downlink control

information (DCI) format via PDCCH order to trigger contention free PRACH transmission. Example thirty-four may include the subject matter of example thirty-one or any of the examples described herein, further comprising means for encoding a number of PRACH transmissions in a downlink control information (DCI) format via an PDCCH order to trigger contention free PRACH transmission, and an indicator to indicate if PRACH frequency hopping is to be applied for multiple PRACH transmissions. In example thirty-five, machine-readable storage may include machine-readable instructions, when executed, to realize an apparatus as claimed in any preceding claim.

In the description herein and/or claims, the terms coupled and/or connected, along with their derivatives, may be used. In particular embodiments, connected may be used to indicate that two or more elements are in direct physical and/or electrical contact with each other. Coupled may mean that two or more elements are in direct physical and/or electrical contact. Coupled, however, may also mean that two or more elements may not be in direct contact with each other, but yet may still cooperate and/or interact with each other. For example, "coupled" may mean that two or more elements do not contact each other but are indirectly joined together via another element or intermediate elements. Finally, the terms "on," "overlying," and "over" may be used in the following description and claims. "On," "overlying," and "over" may be used to indicate that two or more elements are in direct physical contact with each other. It should be noted, however, that "over" may also mean that two or more elements are not in direct contact with each other. For example, "over" may mean that one element is above another element but not contact each other and may have another element or elements in between the two elements. Furthermore, the term "and/or" may mean "and", it may mean "or", it may mean "exclusive-or", it may mean "one", it may mean "some, but not all", it may mean "neither", and/or it may mean "both", although the scope of claimed subject matter is not limited in this respect. In the description herein and/or claims, the terms "comprise" and "include," along with their derivatives, may be used and are intended as synonyms for each other.

Although the claimed subject matter has been described with a certain degree of particularity, it should be recognized that elements thereof may be altered by persons skilled in the art without departing from the spirit and/or scope of claimed subject matter. It is believed that the subject matter pertaining to enhanced physical random-access channel transmission in new radio standard and many of its attendant utilities will be understood by the forgoing description, and it will be apparent that various changes may be made in the form, construction and/or arrangement of the components thereof without departing from the scope and/or spirit of the claimed subject matter or without sacrificing all of its material advantages, the form herein before described being

merely an explanatory embodiment thereof, and/or further without providing substantial change thereto. It is the intention of the claims to encompass and/or include such changes.

CLAIMS

What is claimed is:

5 1. An apparatus of a user equipment (UE), comprising:
one or more baseband processors to process a set of reciprocity offset thresholds received
from a New Radio (NR) NodeB (gNB), and to determine a repetition level to transmit a Fifth
Generation (5G) physical random-access channel (PRACH) L number of times according to the
set of reciprocity offset thresholds or via configuration by higher layers; and
10 a memory to store the repetition level.

2. The apparatus of claim 1, further comprising a radio-frequency transceiver to transmit
a PRACH a number of times to the gNB according to the repetition level.

15 3. The apparatus of any one of claims 1-2, wherein the set of reciprocity offset thresholds
is configured by higher layers via a 5G master information block (MIB), via a 5G system
information block (SIB), or via Radio Resource Control (RRC) signaling.

4. The apparatus of any one of claims 1-3, wherein the one or more baseband processors
20 are to select a PRACH resource from an available set of PRACH resources associated with a best
gNB transmit (Tx) beam based at least in part on a potential message size comprising data available
for transmission, a media access control (MAC) header, or MAC control elements, or a
combination thereof, and a measured pathloss based at least in part on a beam reference signal
(BRS) or synchronization signal (SS) block of the best gNB Tx beam.

25 5. The apparatus of any one of claims 1-4, wherein a reciprocity offset in the set of
reciprocity offset thresholds is beam specific, and wherein the one or more baseband processors
are to compare the reciprocity offset with a threshold list and to determine a best receive (Rx)
beam and corresponding repetition level for PRACH transmission.

30 6. The apparatus of any one of claims 1-5, wherein one or more baseband processor are to
determine if PRACH is to be transmitted in a continuous or non-continuous manner in the time
domain, and to configure PRACH to be transmitted L number of times in a resource corresponding

to L best beam reference signal (BRS) or synchronization signal (SS) block antenna ports (APs), wherein L may be configured by higher layers via MIB, SIB or RRC signaling.

7. The apparatus of claim 6, wherein the one or more baseband processors are to randomly
5 select one PRACH preamble signature and to configure the selected PRACH preamble signature for subsequent repeated PRACH transmission, and wherein the one or more baseband processors are to randomly select one PRACH preamble for repeated transmission.

8. The apparatus of any one of claims 1-7, wherein the one or more baseband processors
10 are to configure frequency hopping on multiple PRACH transmissions if multiple frequency resources are configured for PRACH transmission.

9. The apparatus of claim 8, wherein the one or more baseband processors are to apply a constant frequency resource offset between two consecutive PRACH transmissions.

10. The apparatus of claim 8 wherein the one or more baseband processors are to configure frequency hopping on PRACH transmission between two PRACH frequency resources, and wherein the one or more baseband processors are to configure transmission of a first $[L/2]$ PRACH using first frequency resource and a second $[L/2]$ PRACH using a second frequency resource.

11. The apparatus of claim 8, wherein the one or more baseband processors are to configure frequency hopping on multiple PRACH transmissions according to a frequency hopping pattern, wherein the frequency hopping pattern is defined as a function of at least one or more following parameters: cell identifier (ID), the frequency resource for a first PRACH transmission,
25 a symbol or slot index for PRACH transmission, Cell Radio Network Temporary Identifier (C-RNTI), or a UE ID, or a combination thereof.

12. An apparatus of a New Radio (NR) NodeB (gNB), comprising:
one or more baseband processors to configure a set of reciprocity offset thresholds for a user equipment (UE), and to process a Fifth Generation (5G) physical random-access channel
30 (PRACH) received from the UE according to the set of reciprocity offset thresholds; and
a memory to store the repetition level.

13. The apparatus of claim 12, wherein the one or more baseband processors are to allocate dedicated resources for the UE with non-ideal reciprocity condition, wherein the dedicated

resources with non-ideal reciprocity condition and resources with perfect reciprocity are to be multiplexed in time division multiplexing (TDM), frequency division multiplexing (FDM), or code division multiplexing (CDM), or a combination thereof, wherein a partition of the dedicated resources with non-ideal and with perfect reciprocity are predefined or configured by higher layer
5 via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling.

14. The apparatus of any one of claims 12-13, wherein the one or more baseband processors are to encode a PRACH format indicator, a PRACH transmission timing, or a PRACH
10 time and frequency resource, or a combination thereof, in a downlink control information (DCI) format via PDCCH order to trigger contention free PRACH transmission.

15. The apparatus of any one of claims 12-14, wherein for non-ideal reciprocity the one or more baseband processors are to encode a number of PRACH transmissions in a downlink control information (DCI) format via an PDCCH order to trigger contention free PRACH
15 transmission, and an indicator to indicate if PRACH frequency hopping is to be applied for multiple PRACH transmissions.

16. The method of any one of claims 12-15, wherein the one or more baseband processors
20 are to encode a beam or sub-array or panel index in a downlink control information (DCI) format via PDCCH order to trigger contention free PRACH transmission in a cross-beam manner if the UE includes two or more sub-arrays or panels.

17. One or more machine-readable media having instructions stored thereon that, if executed by a user equipment (UE), result in:
25 processing a set of reciprocity offset thresholds received from a New Radio (NR) NodeB (gNB);
determining a repetition level to transmit a Fifth Generation (5G) physical random-access channel (PRACH) L number of times according to the set of reciprocity offset thresholds or according to configuration by higher layers; and
30 storing the repetition level in a memory.

18. The one or more machine-readable media of claim 17, wherein the instructions, if executed, further result in causing a radio-frequency transceiver to transmit a PRACH a number of times to the gNB according to the repetition level.

19. The one or more machine-readable media of any one of claims 17-18, wherein the set of reciprocity offset thresholds is configured by higher layers via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling.

5

20. The one or more machine-readable media of any one of claims 17-19, wherein the instructions, if executed, further result in selecting a PRACH resource from an available set of PRACH resources associated with a best gNB transmit (Tx) beam based at least in part on a potential message size comprising data available for transmission, a media access control (MAC) header, or MAC control elements, or a combination thereof, and a measured pathloss based at least in part on a beam reference signal (BRS) or synchronization signal (SS) block of the best gNB Tx beam.

10

21. The one or more machine-readable media of any one of claims 17-20, wherein a reciprocity offset in the set of reciprocity offset thresholds is beam specific, and wherein the one or more baseband processors are to compare the reciprocity offset with a threshold list and to determine a best receive (Rx) beam and corresponding repetition level for PRACH transmission.

15

22. One or machine-readable media having instructions stored thereon that, if executed by a New Radio (NR) NodeB (gNB), result in:

20

configuring a set of reciprocity offset thresholds for a user equipment (UE);

processing a Fifth Generation (5G) physical random-access channel (PRACH) received from the UE according to the set of reciprocity offset thresholds; and

25

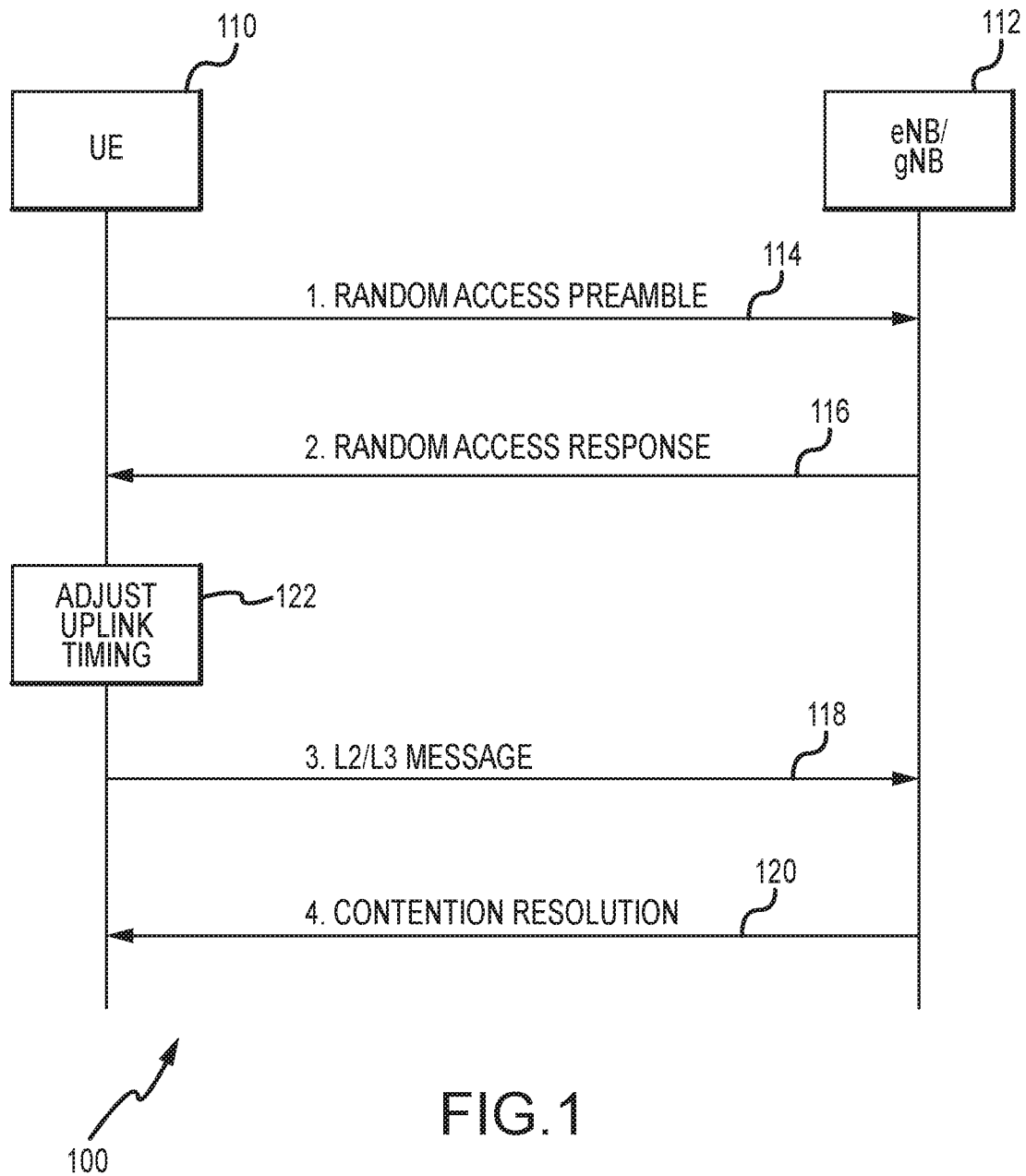
storing the repetition level in a memory.

23. The one or machine-readable media of claim 22, wherein the instructions, if executed, further result in allocating dedicated resources for the UE with non-ideal reciprocity condition, wherein the dedicated resources with non-ideal reciprocity condition and resources with perfect reciprocity are to be multiplexed in time division multiplexing (TDM), frequency division multiplexing (FDM), or code division multiplexing (CDM), or a combination thereof, wherein a partition of the dedicated resources with non-ideal and with perfect reciprocity are predefined or configured by higher layer via a 5G master information block (MIB), via a 5G system information block (SIB), or via Radio Resource Control (RRC) signaling.

30

24. The one or machine-readable media of any one of claims 22-23 wherein the instructions, if executed, further result in encoding a PRACH format indicator, a PRACH transmission timing, or a PRACH time and frequency resource, or a combination thereof, in a downlink control information (DCI) format via PDCCH order to trigger contention free PRACH transmission.

25. The one or machine-readable media of any one of claims 22-24, wherein for non-ideal reciprocity the one or more baseband processors are to encode a number of PRACH transmissions in a downlink control information (DCI) format via an PDCCH order to trigger contention free PRACH transmission, and an indicator to indicate if PRACH frequency hopping is to be applied for multiple PRACH transmissions.



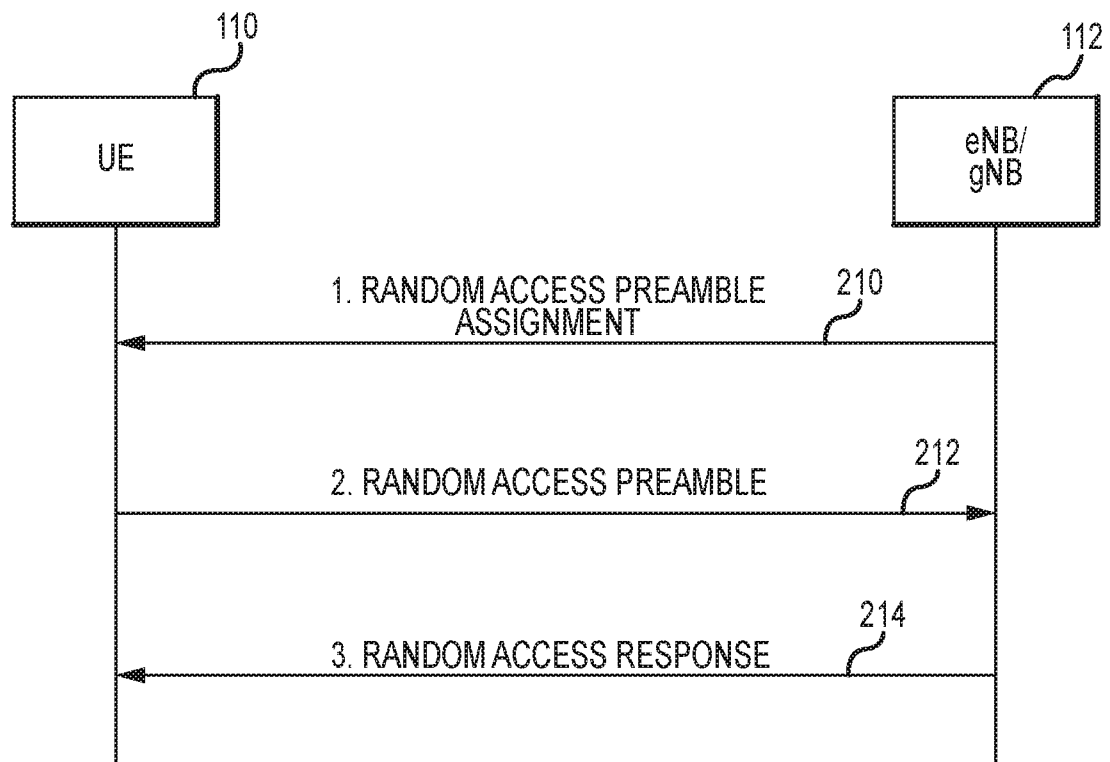


FIG.2

200

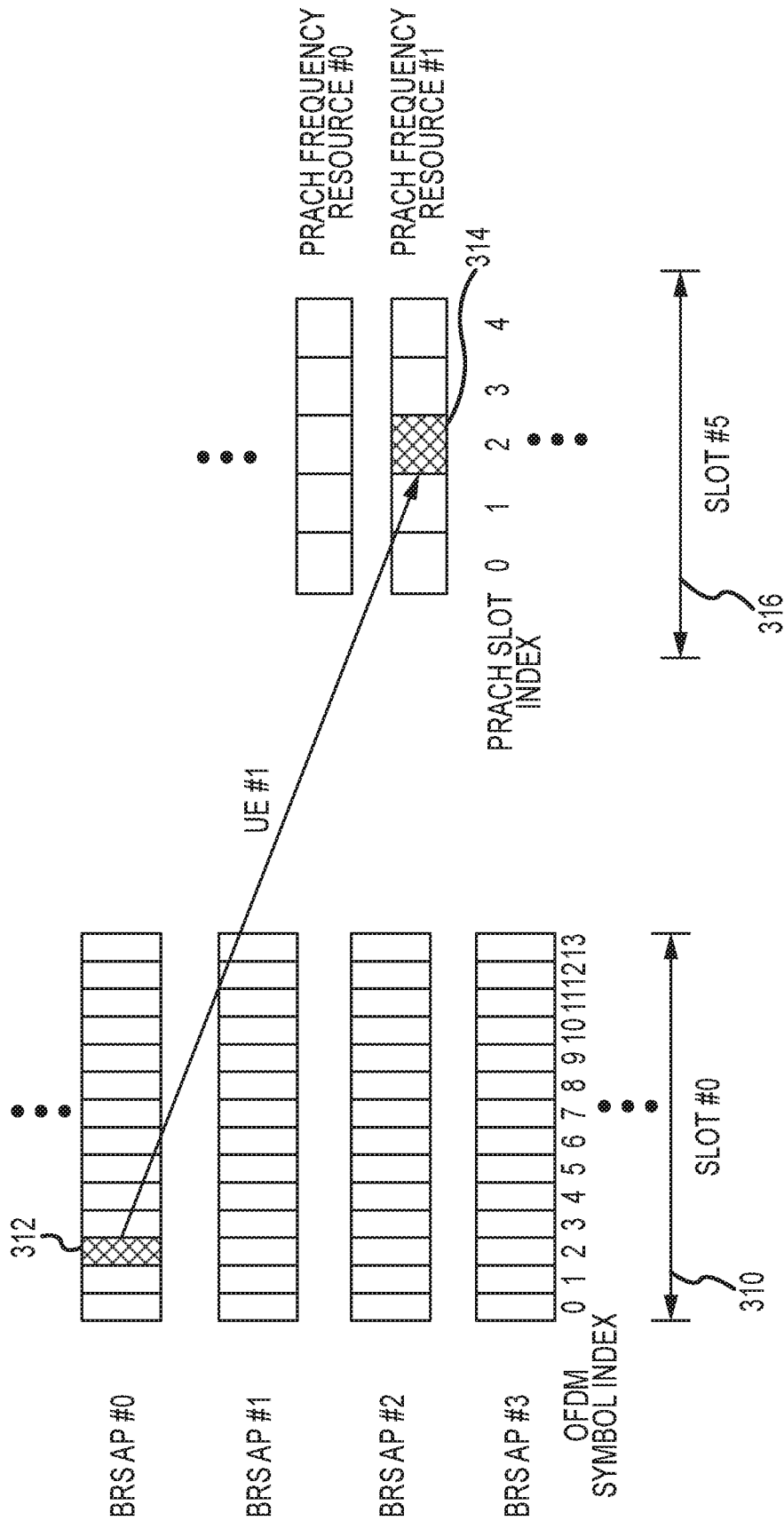
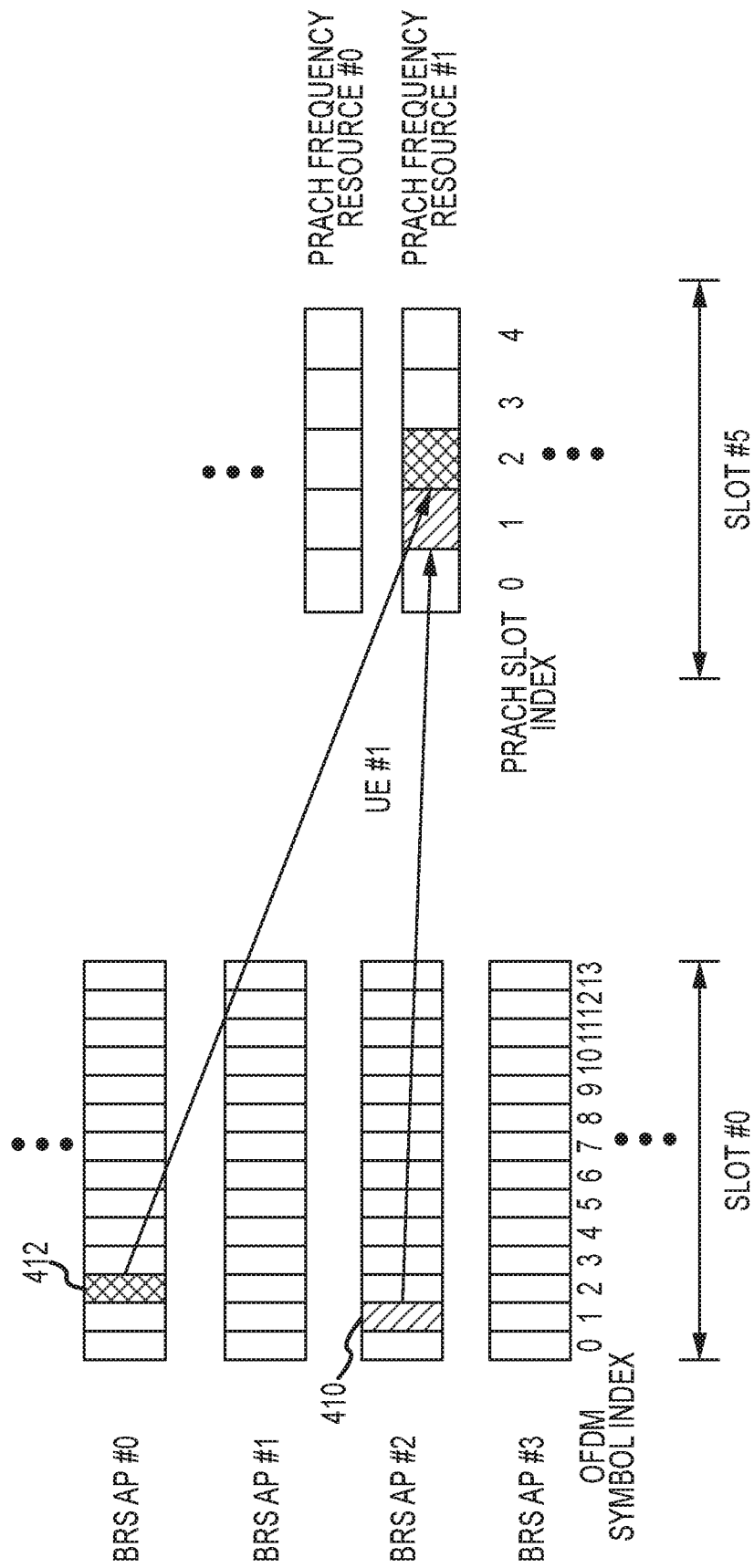


FIG.3



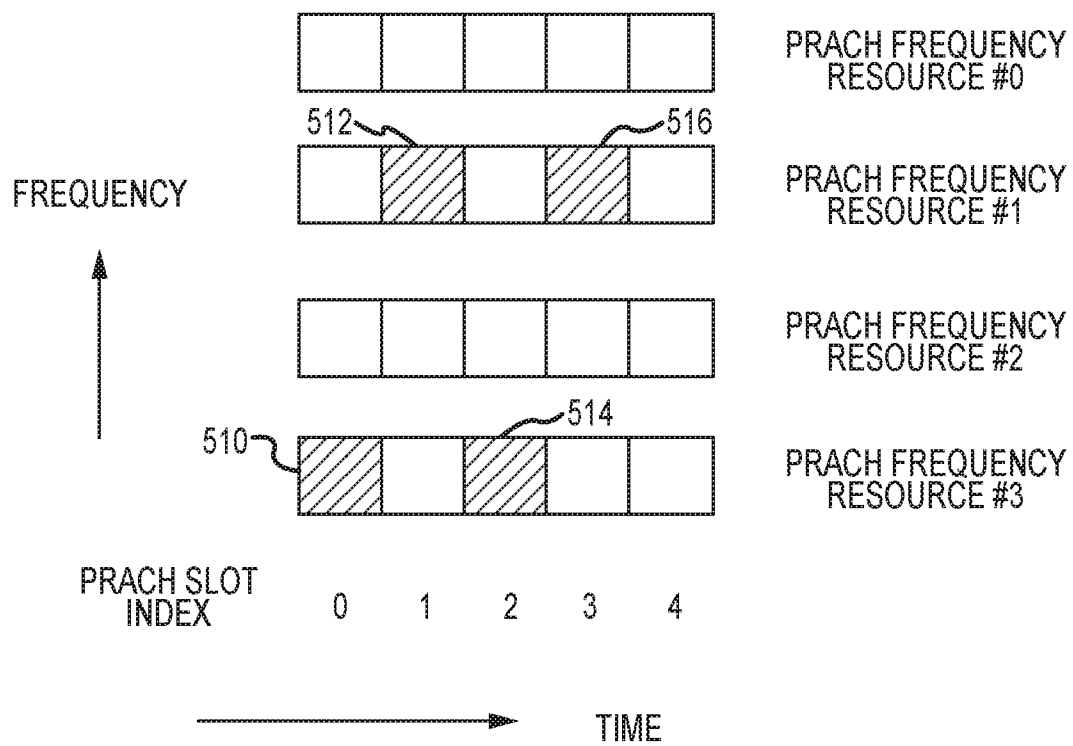


FIG.5

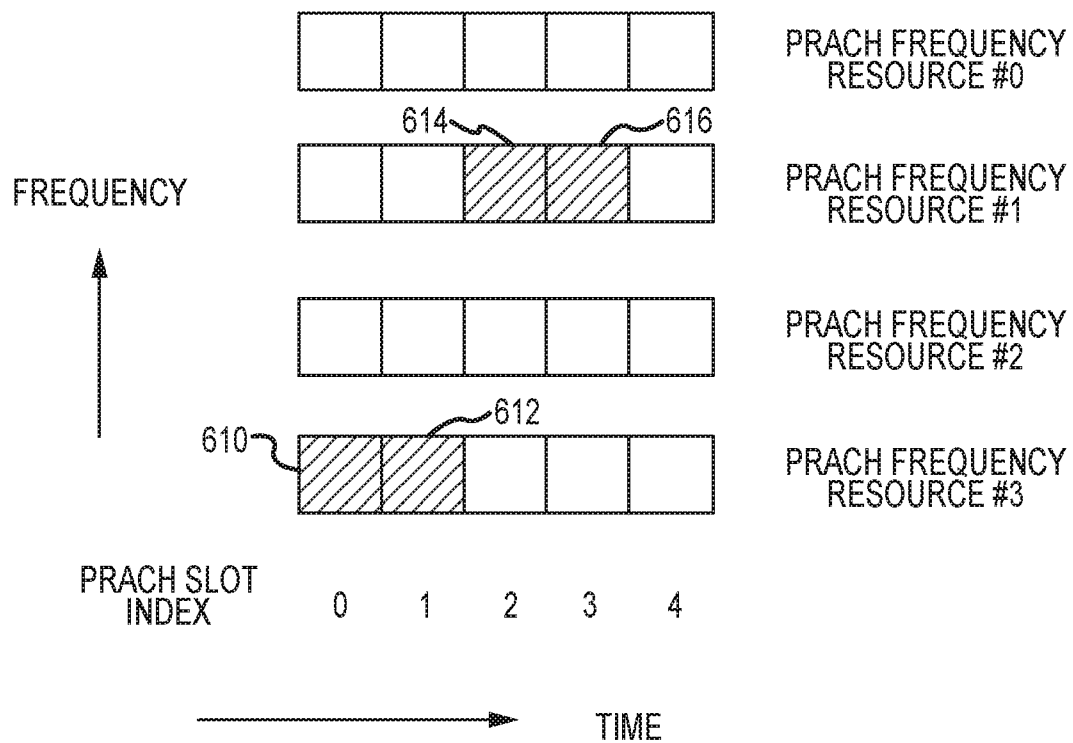


FIG.6

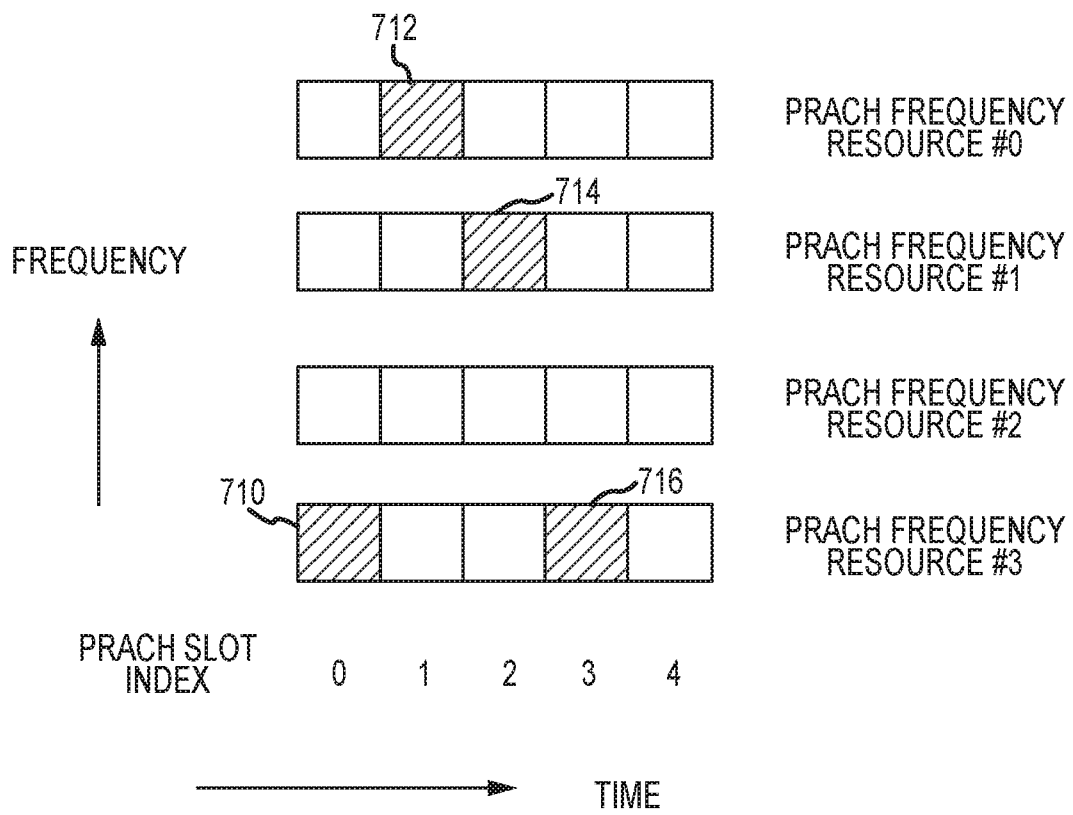


FIG. 7

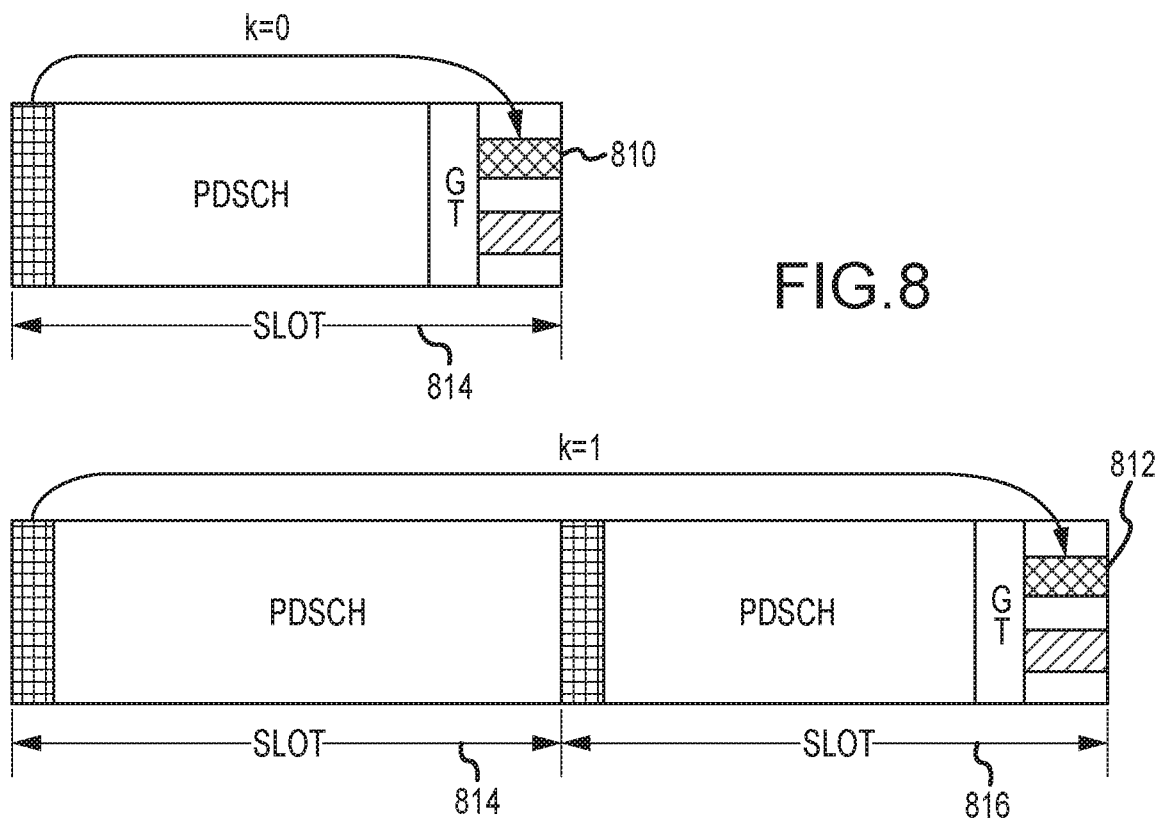


FIG. 8

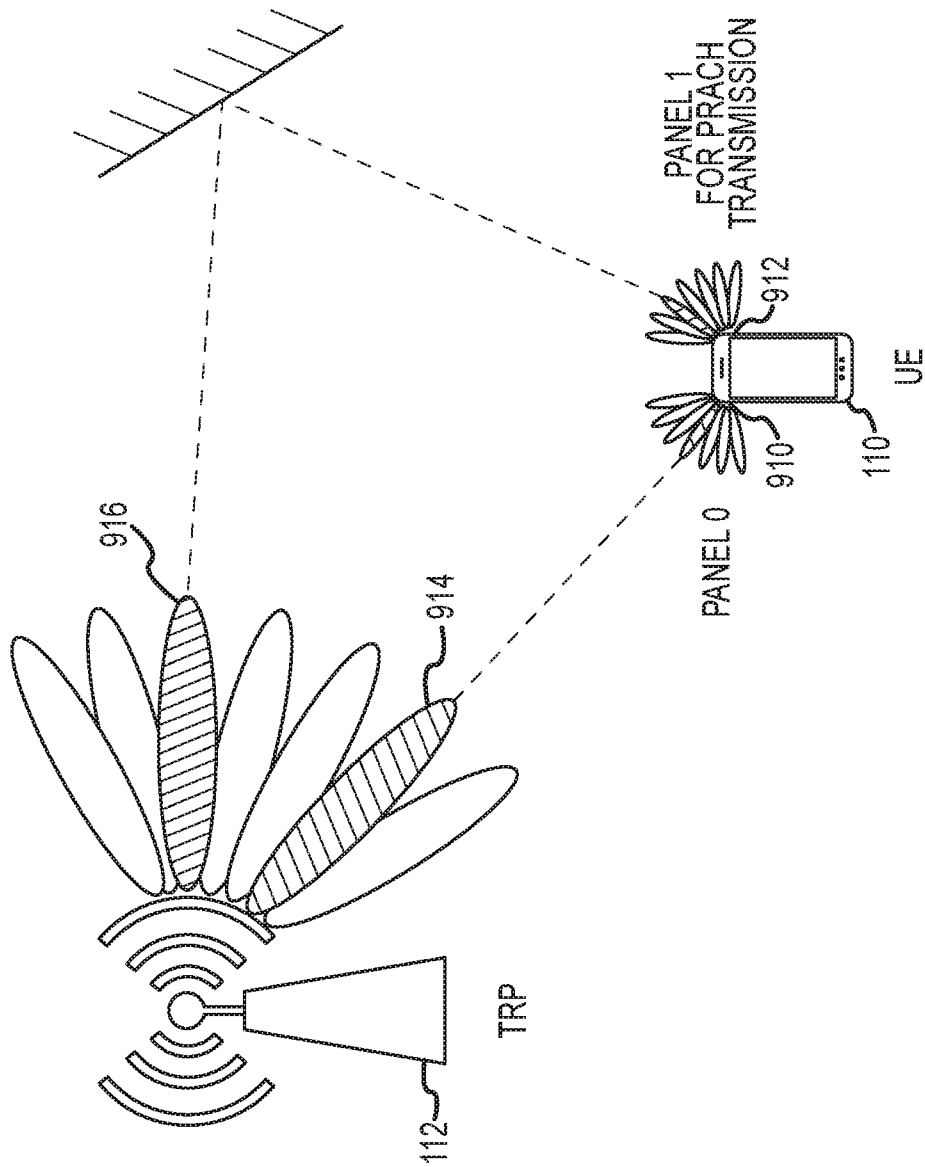


FIG.9

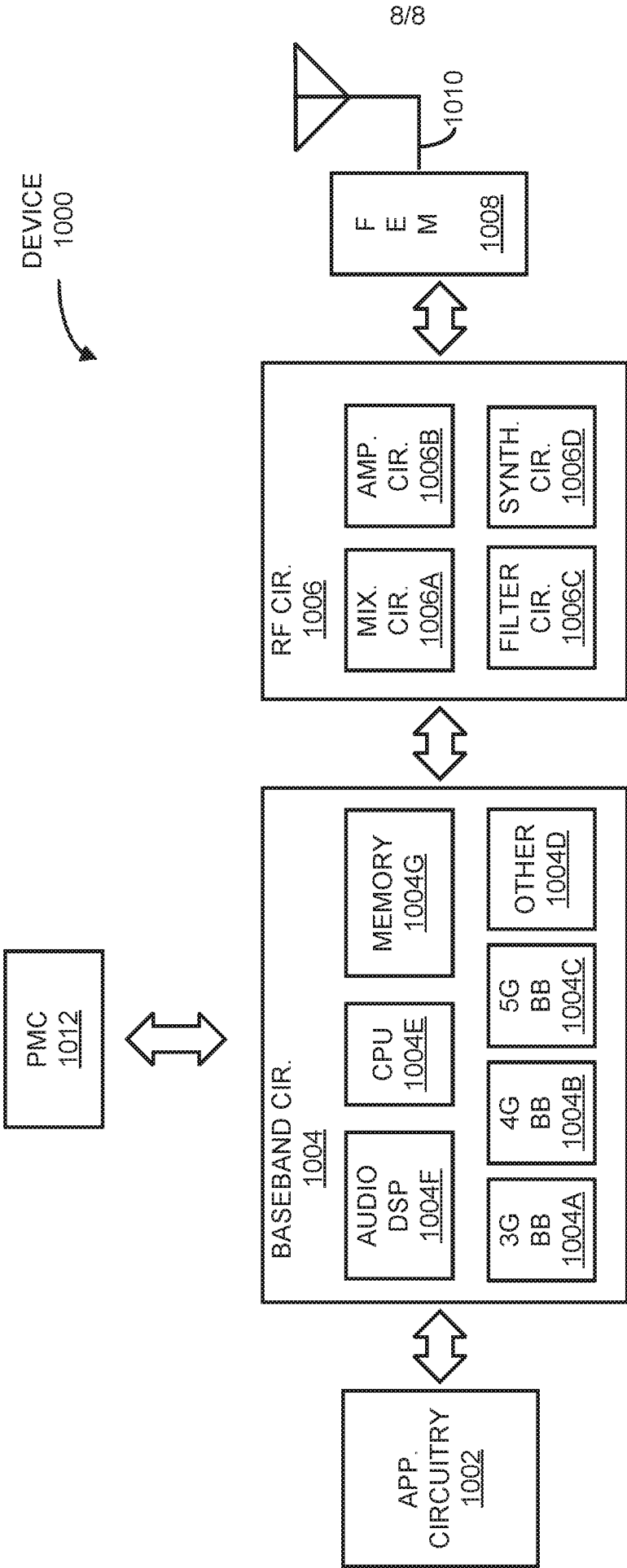


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/044848

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ERICSSON: "Random access for NB-IOT", 3GPP DRAFT; R2-160470 - RANDOM ACCESS FOR NB-IOT, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Budapest, HU; 20160119 - 20160121 18 January 2016 (2016-01-18), XP051054757, Retrieved from the Internet: URL: http://www.3gpp.org/ftp/Meetings_3GPP_ SYNC/RAN2/Docs/ [retrieved on 2016-01-18] Box Agreements, section 2; page 1 - page 1 Section 2.2; page 3 - page 4 ----- -/-	1,2,17, 18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 October 2017

Date of mailing of the international search report

30/10/2017

Name and mailing address of the ISA/

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Authorized officer

Poort, Ingrid

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/044848

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SAMSUNG: "Random Access Procedure in NR", 3GPP DRAFT; R2-163372_RANDOM ACCESS PROCEDURE IN NR, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Nanjing, China; 20160523 - 20160527 22 May 2016 (2016-05-22), XP051104903, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_ SYNC/RAN2/Docs/ [retrieved on 2016-05-22] Section 2.2.2; page 3 - page 6 -----	1-25