

## **APPARATUS AND METHODS FOR A MULTI-PANEL UE TO CONVEY A BLACKOUT PERIOD**

### **CROSS-REFERENCE TO RELATED APPLICATION**

- [0001]** This application claims the benefit of U.S. Non-Provisional Application Serial No. 16/804,851, entitled “APPARATUS AND METHODS FOR A MULTI-PANEL UE TO CONVEY A BLACKOUT PERIOD”, filed on February 28, 2020, which claims benefit of U.S. Provisional Application Serial No. 62/812,667, entitled “APPARATUS AND METHODS FOR A MULTI-PANEL UE TO CONVEY A BLACKOUT PERIOD”, filed on March 01, 2019, the entire contents of which are expressly incorporated by reference herein in its entirety.

### **BACKGROUND**

#### **Field**

- [0002]** The present disclosure relates generally to communication systems, and more particularly, to a multi-panel UE conveying a blackout period.

#### **Background**

- [0003]** Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources. Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.
- [0004]** These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR). 5G NR is part of a continuous mobile broadband evolution promulgated by Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security,

scalability (e.g., with Internet of Things (IoT)), and other requirements. Some aspects of 5G NR may be based on the 4G Long Term Evolution (LTE) standard. There exists a need for further improvements in 5G NR technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

- [0005]** New display technologies make available flexible and foldable UEs and also raise new issues for beam management for those UEs with multi-antenna arrays or multiple antenna panels. When a UE-initiated beam failure (BF) event such as a UE display is folded, beam configurations of the UE may be changed and availability of a beam pair link (BPL) currently in service may be impacted. When an existing antenna panel or BPL is deactivated, a new, replacement panel or BPL may be activated. There is not any mechanism to inform a gNB a possible blackout period between the deactivation of an existing panel and activation of a replacement panel.

### SUMMARY

- [0006]** The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.
- [0007]** There may be a gap between the time a beam pair link (BPL) impacted by a beam failure (BF) event is deactivated and the time a replacement BPL is activated at a UE. The gap may be called a blackout period. A base station may not know the blackout period and may continue transmitting to the UE on the impacted BPL during the blackout period. This may result in a transmission failure.
- [0008]** In some aspects, some of the BF events that are initiated by the UE may be predictable. Thus, the blackout period associated with some of UE-initiated BF events may also be predictable. Examples of the UE initiated BF event may include, but are not limited to folding of a foldable UE display and shutting down of an antenna panel by the UE to conserve the battery power. When such a UE is folded, beam configurations of the UE may be changed because some antenna panels may become unavailable or deactivated

- [0009] Currently there is not any mechanism for a UE to convey to the gNB the blackout period to minimize or avoid the transmissions by the gNB on the impacted BPL during the blackout period. Disclosed herein are apparatus and methods for determining a blackout period associated with a beam failure (BF) event and communicating a blackout indication to a base station, the blackout indication including the blackout period.
- [0010] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

- [0011] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network.
- [0012] FIGs. 2A, 2B, 2C, and 2D are diagrams illustrating examples of a DL frame structure, DL channels within the DL frame structure, an UL frame structure, and UL channels within the UL frame structure, respectively.
- [0013] FIG. 3 is a diagram illustrating an example of a base station and user equipment (UE) in an access network in accordance with aspects of the present disclosure.
- [0014] FIG. 4 is a diagram illustrating a base station in communication with a UE in accordance with aspects of the present disclosure.
- [0015] FIG. 5 illustrates an example BF event in accordance with aspects of the present disclosure.
- [0016] FIG. 6 is a diagram illustrating an example blackout indication process in accordance with aspects of the present disclosure.
- [0017] FIG. 7 is a diagram illustrating example message flow between a NR 5G base station and a multi-panel UE, in accordance with aspects of the present disclosure.
- [0018] FIG. 8 is a flowchart of a method of wireless communication in accordance with various aspects of the present disclosure.

- [0019] FIG. 9 is a conceptual data flow diagram illustrating the data flow between different means/components in an exemplary apparatus in accordance with aspects of the present disclosure.
- [0020] FIG. 10 is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system in accordance with aspects of the present disclosure.
- [0021] FIG. 11 is a flowchart of a method of wireless communication in accordance with various aspects of the present disclosure.
- [0022] FIG. 12 is a conceptual data flow diagram illustrating the data flow between different means/components in an exemplary apparatus in accordance with aspects of the present disclosure.
- [0023] FIG. 13 is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system in accordance with aspects of the present disclosure.

### DETAILED DESCRIPTION

- [0024] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.
- [0025] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

**[0026]** By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a “processing system” that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

**[0027]** Accordingly, in one or more example embodiments, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

**[0028]** FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network 100. The wireless communications system (also referred to as a wireless wide area network (WWAN)) includes base stations 102, UEs 104, and an Evolved Packet Core (EPC) 160. The base stations 102 may include macro cells (high power cellular base station) and/or small cells (low power cellular base station). The

macro cells include base stations. The small cells include femtocells, picocells, and microcells.

**[0029]** The base stations 102 (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) interface with the EPC 160 through backhaul links 132 (e.g., S1 interface). In addition to other functions, the base stations 102 may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate directly or indirectly (e.g., through the EPC 160) with each other over backhaul links 134 (e.g., X2 interface). The backhaul links 134 may be wired or wireless.

**[0030]** The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. There may be overlapping geographic coverage areas 110. For example, the small cell 102' may have a coverage area 110' that overlaps the coverage area 110 of one or more macro base stations 102. A network that includes both small cell and macro cells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links 120 between the base stations 102 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to a base station 102 and/or downlink (DL) (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through one or more carriers. The base stations 102 / UEs 104 may use spectrum up to  $Y$  MHz (e.g., 5, 10, 15, 20, 100 MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of  $Yx$  MHz ( $x$  component carriers) used for transmission in each

direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or less carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

- [0031] Certain UEs 104 may communicate with each other using device-to-device (D2D) communication link 192. The D2D communication link 192 may use the DL/UL WWAN spectrum. The D2D communication link 192 may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, FlashLinQ, WiMedia, Bluetooth, ZigBee, Wi-Fi based on the IEEE 802.11 standard, LTE, or NR.
- [0032] The wireless communications system may further include a Wi-Fi access point (AP) 150 in communication with Wi-Fi stations (STAs) 152 via communication links 154 in a 5 GHz unlicensed frequency spectrum. When communicating in an unlicensed frequency spectrum, the STAs 152 / AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.
- [0033] The small cell 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell 102' may employ NR and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP 150. The small cell 102', employing NR in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network.
- [0034] The gNB 180 may operate in millimeter wave (mmW) frequencies and/or near mmW frequencies in communication with the UE 104. When the gNB 180 operates in mmW or near mmW frequencies, the gNB 180 may be referred to as an mmW base station. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW / near

mmW radio frequency band has extremely high path loss and a short range. The mmW base station 180 may utilize beamforming 184 with the UE 104 to compensate for the extremely high path loss and short range.

**[0035]** The EPC 160 may include a Mobility Management Entity (MME) 162, other MMEs 164, a Serving Gateway 166, a Multimedia Broadcast Multicast Service (MBMS) Gateway 168, a Broadcast Multicast Service Center (BM-SC) 170, and a Packet Data Network (PDN) Gateway 172. The MME 162 may be in communication with a Home Subscriber Server (HSS) 174. The MME 162 is the control node that processes the signaling between the UEs 104 and the EPC 160. Generally, the MME 162 provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway 166, which itself is connected to the PDN Gateway 172. The PDN Gateway 172 provides UE IP address allocation as well as other functions. The PDN Gateway 172 and the BM-SC 170 are connected to the IP Services 176. The IP Services 176 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services. The BM-SC 170 may provide functions for MBMS user service provisioning and delivery. The BM-SC 170 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway 168 may be used to distribute MBMS traffic to the base stations 102 belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting eMBMS related charging information.

**[0036]** The base station may also be referred to as a gNB, Node B, evolved Node B (eNB), an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), or some other suitable terminology. The base station 102 provides an access point to the EPC 160 for a UE 104. Examples of UEs 104 include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a toaster, or any other similar functioning device. Some of the UEs 104 may be referred to as IoT

devices (e.g., parking meter, gas pump, toaster, vehicles, etc.). The UE 104 may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

[0037] Referring again to FIG. 1, in certain aspects, the UE 104 / base station 180 may include a blackout determination module (198) that is configured to determine a blackout period and communicate to the base station a blackout indication.

[0038] FIG. 2A is a diagram 200 illustrating an example of a DL frame structure. FIG. 2B is a diagram 230 illustrating an example of channels within the DL frame structure. FIG. 2C is a diagram 250 illustrating an example of an UL frame structure. FIG. 2D is a diagram 280 illustrating an example of channels within the UL frame structure. Other wireless communication technologies may have a different frame structure and/or different channels. A frame (10 ms) may be divided into 10 equally sized subframes. Each subframe may include two consecutive time slots. A resource grid may be used to represent the two time slots, each time slot including one or more time concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)). The resource grid is divided into multiple resource elements (REs). For a normal cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and 7 consecutive symbols (for DL, OFDM symbols; for UL, SC-FDMA symbols) in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and 6 consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.

[0039] As illustrated in FIG. 2A, some of the REs carry DL reference (pilot) signals (DL-RS) for channel estimation at the UE. The DL-RS may include cell-specific reference signals (CRS) (also sometimes called common RS), UE-specific reference signals (UE-RS), and channel state information reference signals (CSI-RS). FIG. 2A illustrates CRS for antenna ports 0, 1, 2, and 3 (indicated as  $R_0$ ,  $R_1$ ,  $R_2$ , and  $R_3$ , respectively), UE-RS for antenna port 5 (indicated as  $R_5$ ), and CSI-RS for antenna port 15 (indicated as  $R$ ).

- [0040] FIG. 2B illustrates an example of various channels within a DL subframe of a frame. The physical control format indicator channel (PCFICH) is within symbol 0 of slot 0, and carries a control format indicator (CFI) that indicates whether the physical downlink control channel (PDCCH) occupies 1, 2, or 3 symbols (FIG. 2B illustrates a PDCCH that occupies 3 symbols). The PDCCH carries downlink control information (DCI) within one or more control channel elements (CCEs), each CCE including nine RE groups (REGs), each REG including four consecutive REs in an OFDM symbol. A UE may be configured with a UE-specific enhanced PDCCH (ePDCCH) that also carries DCI. The ePDCCH may have 2, 4, or 8 RB pairs (FIG. 2B shows two RB pairs, each subset including one RB pair). The physical hybrid automatic repeat request (ARQ) (HARQ) indicator channel (PHICH) is also within symbol 0 of slot 0 and carries the HARQ indicator (HI) that indicates HARQ acknowledgement (ACK) / negative ACK (NACK) feedback based on the physical uplink shared channel (PUSCH). The primary synchronization channel (PSCH) may be within symbol 6 of slot 0 within subframes 0 and 5 of a frame. The PSCH carries a primary synchronization signal (PSS) that is used by a UE 104 to determine subframe/symbol timing and a physical layer identity. The secondary synchronization channel (SSCH) may be within symbol 5 of slot 0 within subframes 0 and 5 of a frame. The SSCH carries a secondary synchronization signal (SSS) that is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the aforementioned DL-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSCH and SSCH to form a synchronization signal (SS) block. The MIB provides a number of RBs in the DL system bandwidth, a PHICH configuration, and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.
- [0041] As illustrated in FIG. 2C, some of the REs carry demodulation reference signals (DM-RS) for channel estimation at the base station. The UE may additionally transmit sounding reference signals (SRS) in the last symbol of a subframe. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. The SRS

may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.

**[0042]** FIG. 2D illustrates an example of various channels within an UL subframe of a frame. A physical random access channel (PRACH) may be within one or more subframes within a frame based on the PRACH configuration. The PRACH may include six consecutive RB pairs within a subframe. The PRACH allows the UE to perform initial system access and achieve UL synchronization. A physical uplink control channel (PUCCH) may be located on edges of the UL system bandwidth. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

**[0043]** FIG. 3 is a block diagram of a base station 310 in communication with a UE 350 in an access network. In the DL, IP packets from the EPC 160 may be provided to a controller/processor 375. The controller/processor 375 implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor 375 provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression / decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

- [0044]** The transmit (TX) processor 316 and the receive (RX) processor 370 implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor 316 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 374 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 350. Each spatial stream may then be provided to a different antenna 320 via a separate transmitter 318TX. Each transmitter 318TX may modulate an RF carrier with a respective spatial stream for transmission.
- [0045]** At the UE 350, each receiver 354RX receives a signal through its respective antenna 352. Each receiver 354RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 356. The TX processor 368 and the RX processor 356 implement layer 1 functionality associated with various signal processing functions. The RX processor 356 may perform spatial processing on the information to recover any spatial streams destined for the UE 350. If multiple spatial streams are destined for the UE 350, they may be combined by the RX processor 356 into a single OFDM symbol stream. The RX processor 356 then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by

determining the most likely signal constellation points transmitted by the base station 310. These soft decisions may be based on channel estimates computed by the channel estimator 358. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station 310 on the physical channel. The data and control signals are then provided to the controller/processor 359, which implements layer 3 and layer 2 functionality.

[0046] The controller/processor 359 can be associated with a memory 360 that stores program codes and data. The memory 360 may be referred to as a computer-readable medium. In the UL, the controller/processor 359 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the EPC 160. The controller/processor 359 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0047] Similar to the functionality described in connection with the DL transmission by the base station 310, the controller/processor 359 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression / decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0048] Channel estimates derived by a channel estimator 358 from a reference signal or feedback transmitted by the base station 310 may be used by the TX processor 368 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 368 may be provided to different antenna 352 via separate transmitters 354TX. Each transmitter 354TX may modulate an RF carrier with a respective spatial stream for transmission.

[0049] The UL transmission is processed at the base station 310 in a manner similar to that described in connection with the receiver function at the UE 350. Each receiver

318RX receives a signal through its respective antenna 320. Each receiver 318RX recovers information modulated onto an RF carrier and provides the information to a RX processor 370.

[0050] The controller/processor 375 can be associated with a memory 376 that stores program codes and data. The memory 376 may be referred to as a computer-readable medium. In the UL, the controller/processor 375 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 350. IP packets from the controller/processor 375 may be provided to the EPC 160. The controller/processor 375 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0051] **FIG. 4** is a diagram 400 illustrating a base station 402 in communication with a UE 404. Referring to FIG. 4, the base station 402 may transmit a beamformed signal to the UE 404 in one or more of the directions 402a, 402b, 402c, 402d, 402e, 402f, 402g, 402h. The UE 404 may receive the beamformed signal from the base station 402 in one or more receive directions 404a, 404b, 404c, 404d. The UE 404 may also transmit a beamformed signal to the base station 402 in one or more of the directions 404a-404d. The base station 402 may receive the beamformed signal from the UE 404 in one or more of the receive directions 402a-402h. The base station 402 / UE 404 may perform beam training to determine the best receive and transmit directions for each of the base station 402 / UE 404. The transmit and receive directions for the base station 402 may or may not be the same. The transmit and receive directions for the UE 404 may or may not be the same. The UE 404 may be a multi-panel UE configured to determine a blackout period and communicate a blackout indication to the base station.

[0052] **FIG. 5** is a diagram illustrating an example UE display 500. The UE display 500 has two display arrangements 501 and 511. The arrangement 501 shows the display with an 4x2 antenna array/panel 503, in a flat, unfolded arrangement. The display arrangement 511 show the UE display in a folded arrangement with three antenna arrays 513, 515, and 517 respectively. The antenna array 513, a 4x1 antenna panel, remains available after the folding of the display. The combined antenna array 515, a 4x2 antenna panel, remain largely available, but the array configuration may have changed due to the event of the UE display folding, which may result in changes of

antenna size and beamforming gain. The antenna array 517, a 4x1 antenna panel, which is not fully displayed in FIG. 5, may be hidden inside the folded display and at least some of the antenna elements may be shut down and become unavailable, as a result of the display folding.

[0053] **FIG. 5** illustrates that a BF event like UE display folding may cause some antenna array of the UE be reconfigured and some antenna panel be shut down, some other panel be activated. The UE display folding may also cause some beam pair links on the impacted antenna panels be reconfigured or/and its size and beamforming gain changed. Accordingly, the BF event like UE display folding may cause changes in received signal quality.

[0054] **FIG. 6** is a diagram illustrating an example blackout indication process 600. The blackout indication process 600 has a horizontal axis indicating time and a vertical axis indicating signal quality for a beam pair link (BPL) on an antenna panel. At time 601, around time 100 *ms*, the BPL starts shutting down, due to an BF event such as UE display folding, for example. At time 603, the UE may detect a shutting down in progress and predict that the panel will be out of service at time 605, around 200 *ms*. The UE may also know that the new panel will start warming up at time 607, around 250 *ms*. Accordingly, there is at least a blackout period from 200 *ms* to around 250 *ms*. The UE may report at time 603 to the base station the blackout period. The base station may refrain from scheduling any transmission on either the current panel or the new panel during the blackout period and this will reduce potential transmission failures.

[0055] **FIG. 7** is a diagram illustrating example message flow 700 between a base station and a multi-panel UE, in accordance with aspects of the present disclosure. The message flow 700 illustrates an example message exchange for reporting a blackout period associated with a beam failure caused by an internal event. The examples of the internal event may include a display folding at the UE and the UE shutting down a panel for power conservation. The base station 704 may be a NR 5G gNB and the UE 702 may be a 5G-capable UE with multiple antenna panels. A dotted line indicates the associated step may be optional.

[0056] At block 705, the UE 702 may detect and predict a BF caused by an event initiated by the UE itself, such as UE display folding. The UE may have multiple sensors, including a gyroscope sensor that is configured to detect a beginning of the display

folding. Once the UE is reasonably certain of the display folding event, the UE may predict and determine when the panel will be out of service. For example, the UE may determine which of the multiple panels will become unavailable and which will remain functional once the folding event is finished, based on the detected angle and movement of the display folding. Then, the UE may determine a blackout period based on a predicted time when the impacted panel will be out of service and a time that a replacement panel will be in service.

- [0057]** At block 706, upon detecting the BF event and predicting the impact of the event, the UE sends a blackout indication to the base station. The blackout indication at least informs the base station of the duration of the blackout period and affected BPLs and associated antenna panel(s). The blackout indication sent to the base station may include various information, to be discussed in details later.
- [0058]** At block 707, upon receiving the blackout indication from the UE, the base station becomes aware of which of the UE panel(s) has become unavailable for communications due to the detected BF event and how long it may take for a new panel to take over. In some example aspect, the blackout indication may not directly indicate the blackout period duration. The base station may determine the blackout period and then refrain from using any of these impacted BPLs associated the impacted panels in communicating with the UE during the blackout period.
- [0059]** At block 708, the base station may, upon ceasing monitoring the impacted BPL for the blackout period, send a confirmation message to the UE to confirm the actions taken at the base station side. The confirmation message may include other information, such as a replacement BPL.
- [0060]** At block 709, the UE, upon receiving the confirmation message from the base station, may deactivate the impacted panel(s) at the UE side and stop monitoring the impacted BPLs as well, at least to conserve the battery power of beam measurements and beam monitoring. The UE may also take some other actions, such activating the replacement BPL for communications with the base station.
- [0061]** As indicated above, FIG. 7 is provided merely as an example. Other examples with different message flow sequences are possible and may differ from what is described with regard to FIG. 7 but are still within the spirit of the present disclosure.

- [0062] **FIG. 8** is a flowchart of a method 800 of wireless communication, in accordance with various aspects of the present disclosure. The method 800 implements a process for a UE with multiple panels to report a blackout period to the base station. The method 800 may be performed by a UE such as the UE 702 of FIG. 7 or any of the UE 120s of FIG. 1. The optional steps are indicated in dotted lines.
- [0063] At 802, the method 800 includes determining a blackout period by the UE. In one example aspect, the UE may first detect a beginning of a BF event initiated by the UE such as folding of the UE display. The UE may be configured with various sensors, including one or more gyroscope (gyro) sensors. For example, a gyro sensor may be configured to detect an angular velocity, that is, the change in rotational angle per second of the UE display movement and the UE may determine that the display is being folded based on the measured angular velocity.
- [0064] In one example aspect, determining the blackout period may include identifying a configuration of the UE's receiving and transmitting components such as antenna panels. In one example aspect, when the UE is reasonably certain of the BF event, the UE may predict a time when the impacted antenna panel or an impacted BPL will be completely out of service. The UE also knows or may predict when a replacement BPL or antenna panel will come into service, because in part the UE is the one that activates the new component. Additionally, in one example aspect, the UE may also predict how long it may take for the BF event to finish and thus how long the impacted BPLs will remain available. Accordingly, the UE may determine a blackout period based on the predicted time for the impacted panel to go out service and the predicted time for a replacement component to come into service.
- [0065] At 804, the method 800 includes communicating a blackout indication to an associated gNB. The UE may send the blackout indication to the base station to request that the gNB stops monitoring the affected antenna panel(s)/BPLs. In one example aspect, the UE may transmit the blackout indication on a carrier frequency different from the current carrier frequency on the impacted BPL or on another BPL different from the impacted BPL.
- [0066] In one example aspect, the UE may transmit the blackout indication in a physical uplink control channel (PUCCH). In another example aspect, the blackout indication may be part of a regular schedule request included in an uplink control information (UCI) sent to the gNB.

- [0067] In one example aspect, communicating the blackout indication may include multiple steps. For example, the UE may first transmit a schedule request (SR) to request an uplink transmission. Then the UE may receive a downlink signaling message such as a PDCCH in response to the SR. The PDCCH may include resource allocation for transmission of the blackout indication. Upon receiving the downlink signaling message, the UE may then transmit the blackout indication based on the received downlink signaling message. In an alternative example aspect, the UE may directly transmit the blackout indication without first transmitting a SR if the UE happens to have uplink transmission resources.
- [0068] In one example aspect, the blackout indication may include a time stamp indicating a start of the blackout period, a time stamp indicating an end of the blackout period, an indication of the BPL, an identifier of an antenna panel associated with the BPL with a deactivation time stamp, an identifier of a second antenna panel associated with the BPL with an activation time stamp. The indication of the BPL may include an ID of an associated antenna panel, or may be a unique BPL ID. In one aspect, the BPL may be explicitly indicated. In another aspect, the BPL may be implicitly indicated via other resources.
- [0069] In one example aspect, the blackout indication may include an indicator of whether or not the entire UE is impacted by the BF event. The indicator is set if the current serving antenna panel is the last antenna panel in service for the UE.
- [0070] The blackout indication may include the blackout period either implicitly or explicitly. In one example aspect, if the above activation time stamp is after the above deactivation time stamp, the blackout period is implicitly indicated, by the difference of the two time stamps.
- [0071] At 806, the method 800 includes receiving a confirmation from the base station in response to the blackout indication. The UE may receive the confirmation message from the gNB in response to the blackout indication sent at block 804. In one example aspect, the confirmation message may include an identifier of a replacement BPL that the gNB suggests for the UE to use, which may be same as or different from the replacement BPL that the UE recommends. The confirmation message may also include some other information, such as UE resource allocations for uplink or downlink communications, and/or indications of the action that the gNB has taken in response to receiving the blackout indication. In some example aspect, the gNB may

not send a confirmation independently and may combine it with some other signaling messages.

[0072] At 808, the method 800 includes deactivating the impacted antenna panel(s) and ceasing monitoring the impacted BPLs. The UE may deactivate an impacted antenna panel from an active panel list, even though only some BPLs of the panel are in active service. The UE may also maintain an available BPL list to keep track all the BPLs currently in service for communications with the gNB. The UE may also deactivate the impacted BPLs.

[0073] Additionally, at 808, UE may also cease monitoring the impacted BPLs. The UE may stop monitoring the link qualities of the impacted BPLs, include measurements of reference signal received power (RSRP), signal to noise ratio (SNR), and signal to interference noise ratio (SINR) of the impacted BPL. Ceasing monitoring the impacted BPLs may also mean that the UE does not expect any traffic scheduled on the impacted BPL for the blackout period. Ceasing monitoring the impacted BPLs may also include not sending any feedback to the gNB on the impacted BPLs.

[0074] The method 800 is for illustration purpose and shows one possible process for a UE to report a blackout period to the base station. In practice, one or more steps shown in illustrative flowchart for the method 800 may be combined with other steps, performed in any suitable order, performed in parallel (e.g., simultaneously or substantially simultaneously), or removed.

[0075] **FIG. 9** is a conceptual data flow diagram 900 illustrating the data flow between different means/components in an exemplary apparatus 902. The apparatus may be a UE. The apparatus includes a reception component 904 that receives a confirmation message from an associated gNB 950, a blackout component 906 that may be configured to determine a blackout period and a blackout indication, a BPL component 908 that may be configured to detect BF event and determine and predict various times and impacts on a BPL, and a transmission component 910 that is configured to transmit at least the blackout indication to the gNB 950 to stop monitoring one or more impacted BPLs.

[0076] The apparatus may include additional components that perform each of the blocks of the algorithm in the aforementioned flowcharts of FIGs. 7 and 8. As such, each block in the aforementioned flowcharts of FIGs. 7 and 8 may be performed by a component and the apparatus may include one or more of those components. The components

may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by a processor configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by a processor, or some combination thereof.

[0077] **FIG. 10** is a diagram 1000 illustrating an example of a hardware implementation for an apparatus 902' employing a processing system 1014. The processing system 1014 may be implemented with a bus architecture, represented generally by the bus 1024. The bus 1024 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 1014 and the overall design constraints. The bus 1024 links together various circuits including one or more processors and/or hardware components, represented by the processor 1004, the components 904, 906, 908, and 908 and the computer-readable medium / memory 1006. The bus 1024 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[0078] The processing system 1014 may be coupled to a transceiver 1010. The transceiver 1010 is coupled to one or more antennas 1020. The transceiver 1010 provides a means for communicating with various other apparatus over a transmission medium. The transceiver 1010 receives a signal from the one or more antennas 1020, extracts information from the received signal, and provides the extracted information to the processing system 1014, specifically the reception component 904. In addition, the transceiver 1010 receives information from the processing system 1014, specifically the transmission component 919, and based on the received information, generates a signal to be applied to the one or more antennas 1020. The processing system 1014 includes a processor 1004 coupled to a computer-readable medium / memory 1006. The processor 1004 is responsible for general processing, including the execution of software stored on the computer-readable medium / memory 1006. The software, when executed by the processor 1004, causes the processing system 1014 to perform the various functions described *supra* for any particular apparatus. The computer-readable medium / memory 1006 may also be used for storing data that is manipulated by the processor 1004 when executing software. The processing system 1014 further includes at least one of the components 904, 906, 908, and 908. The components may be software components running in the processor 1004, resident/stored in the

computer readable medium / memory 1006, one or more hardware components coupled to the processor 1004, or some combination thereof. The processing system 1014 may be a component of the UE 350 and may include the memory 360 and/or at least one of the TX processor 368, the RX processor 356, and the controller/processor 359.

[0079] In one configuration, the apparatus 902/902' for wireless communication includes means for determining a blackout period, and means for communicating a blackout indication to an associated generic NodeB (gNB), means for receiving a confirmation from the gNB, and means for deactivating the impacted panel and ceasing monitoring the impacted BPLs. The aforementioned means may be one or more of the aforementioned components of the apparatus 1002 and/or the processing system 1014 of the apparatus 902' configured to perform the functions recited by the aforementioned means. As described *supra*, the processing system 1014 may include the TX Processor 368, the RX Processor 356, and the controller/processor 359. As such, in one configuration, the aforementioned means may be the TX Processor 368, the RX Processor 356, and the controller/processor 359 configured to perform the functions recited by the aforementioned means.

[0080] **FIG. 11** is a flowchart of a method 1100 of wireless communication in accordance with various aspects of the present disclosure. The method 1100 implements a process for a base station in collaboration with a UE with multiple panels to indicate a blackout period. The method 1100 may be performed by a base station such as the gNB 704 of FIG. 7 or any of the base stations 102s/180 of FIG. 1. The optional steps are indicated in dotted lines.

[0081] At 1102, the method 1100 includes receiving a blackout indication from the UE. The UE may send the blackout indication to the base station so that the base station may cease monitoring the affected antenna panel(s).

[0082] In one example aspect, the base station may receive the blackout indication on a carrier frequency different from the current carrier frequency on the impacted BPL or on another BPL. In one example aspect, the base station may receive the blackout indication in a physical uplink control channel (PUCCH). In another example aspect, the blackout indication may be part of a regular schedule request included in an uplink control information (UCI) sent to the base station.

- [0083] In one example aspect, the base station may receive the blackout indication in multiple steps. For example, the base station may first receive a schedule request (SR) to request an uplink transmission. Then the base station may transmit a downlink signaling message such as a PDCCH in response to the SR. The PDCCH may include resource allocation for transmission of the blackout indication. Then the base station may receive the blackout indication on the resource allocated in the transmitted downlink signaling message. In an alternative example aspect, the base station may directly receive the blackout indication without first receiving a SR if the UE happens to have uplink transmission resources.
- [0084] In one example aspect, the blackout indication may include a time stamp indicating a start of the blackout period, a time stamp indicating an end of the blackout period, an indication of the BPL, an identifier of an antenna panel associated with the BPL with a deactivation time stamp, and an identifier of a second antenna panel associated with the BPL with an activation time stamp. The indication of the BPL may include an ID of an associated antenna panel, and/or a unique BPL ID. In one example aspect, the BPL may be explicitly indicated. In another example aspect, the BPL may be implicitly indicated via other resources.
- [0085] In one example aspect, the blackout indication may include an indicator of whether or not the entire UE is impacted by the BF event. The indicator is set if the current serving antenna panel is the last antenna panel in service for the UE. If this indicator is set, the base station may cease monitoring all BPLs associated with this UE for the blackout period.
- [0086] At 1104, the method 1100 includes determining a blackout period. The base station may determine the blackout period based on the received blackout indication. The blackout period may be explicitly or implicitly indicated. If the blackout period is implicitly indicated, the base station may determine the blackout period based on other information. For example, if the above activation time stamp is greater than the deactivation time stamp, the blackout period is implicitly indicated, by the difference of the two time stamps.
- [0087] At 1106, the method 1100 includes ceasing monitoring the impacted BPLs. As a result, the base station may cease monitoring a BLP associated with the panel. Ceasing monitoring the impacted BPLs may also mean that the base station will refrain from scheduling any transmissions on the impacted BPL for the received

blackout period. Ceasing monitoring the impacted BPLs may also include not expecting any feedback from the UE on the impacted BPLs for the blackout period.

[0088] At 1108, the method 1100 includes communicating a confirmation to the UE. In one example aspect, the confirmation message may include an identifier of a replacement BPL that the base station suggests for the UE to use, which may be same as or different from the replacement BPL that the UE recommends. The confirmation message may also include some other information, such as UE resource allocations for uplink or downlink communications with the base station, and/or indications of the action that the base station has taken in response to receiving the blackout indication. In some example aspect, the base station may not send any individual confirmation and/or may combine the confirmation message with some other signaling messages.

[0089] The method 1100 is for illustration purpose and shows one possible process for a gNB to assist the UE to report a blackout period. In practice, one or more steps shown in illustrative flowchart for the method 1100 may be combined with other steps, performed in any suitable order, performed in parallel (e.g., simultaneously or substantially simultaneously), or removed.

[0090] **FIG. 12** is a conceptual data flow diagram 1200 illustrating the data flow between different means/components in an exemplary apparatus 1202. The apparatus may be a gNB. The apparatus includes a reception component 1204 that receives a blackout indication from an associated UE 1250, a blackout component 1206 that may be configured to determine a blackout period and a blackout indication, a BPL component 1208 that may be configured to detect a BF event, determine and predict impacts on a BPL, and a transmission component 1210 that is configured to transmit at least a confirmation message to the UE 1250.

[0091] The apparatus may include additional components that perform each of the blocks of the algorithm in the aforementioned flowcharts of FIGs. 7 and 11. As such, each block in the aforementioned flowcharts of FIGs. 7 and 11 may be performed by a component and the apparatus may include one or more of those components. The components may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by a processor configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by a processor, or some combination thereof.

[0092] **FIG. 13** is a diagram 1300 illustrating an example of a hardware implementation for an apparatus 1202' employing a processing system 1314. The processing system 1314 may be implemented with a bus architecture, represented generally by the bus 1324. The bus 1324 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 1314 and the overall design constraints. The bus 1324 links together various circuits including one or more processors and/or hardware components, represented by the processor 1304, the components 1204, 1206, 1208, and 1210 and the computer-readable medium / memory 1306. The bus 1324 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[0093] The processing system 1314 may be coupled to a transceiver 1310. The transceiver 1310 is coupled to one or more antennas 1320. The transceiver 1310 provides a means for communicating with various other apparatus over a transmission medium. The transceiver 1310 receives a signal from the one or more antennas 1320, extracts information from the received signal, and provides the extracted information to the processing system 1314, specifically the reception component 1204. In addition, the transceiver 1310 receives information from the processing system 1314, specifically the transmission component 1210, and based on the received information, generates a signal to be applied to the one or more antennas 1320. The processing system 1314 includes a processor 1304 coupled to a computer-readable medium / memory 1306. The processor 1304 is responsible for general processing, including the execution of software stored on the computer-readable medium / memory 1306. The software, when executed by the processor 1304, causes the processing system 1314 to perform the various functions described *supra* for any particular apparatus. The computer-readable medium / memory 1306 may also be used for storing data that is manipulated by the processor 1304 when executing software. The processing system 1314 further includes at least one of the components 1204, 1206, 1208, and 1210. The components may be software components running in the processor 1304, resident/stored in the computer readable medium / memory 1306, one or more hardware components coupled to the processor 1304, or some combination thereof. The processing system 1314 may be a component of the base station 310 and may include the memory 376

and/or at least one of the TX processor 316, the RX processor 370, and the controller/processor 375.

[0094] In one configuration, the apparatus 1202/1202' for wireless communication includes means for receiving a blackout indication from a UE, means for ceasing monitoring the impact BPLs, and means for communicating a confirmation message. The aforementioned means may be one or more of the aforementioned components of the apparatus 1202 and/or the processing system 1314 of the apparatus 1202' configured to perform the functions recited by the aforementioned means. As described *supra*, the processing system 1014 may include the TX Processor 316, the RX Processor 370, and the controller/processor 375. As such, in one configuration, the aforementioned means may be the TX Processor 316, the RX Processor 370, and the controller/processor 375 configured to perform the functions recited by the aforementioned means.

[0095] It is understood that the specific order or hierarchy of blocks in the processes / flowcharts disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes / flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0096] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term “some” refers to one or more. Combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” include any

combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word “means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.”

## CLAIMS

1. A method of wireless communication at a user equipment (UE), comprising:  
determining a blackout period associated with a beam failure (BF) event; and  
communicating a blackout indication to a base station, the blackout indication including the blackout period,  
wherein said determining of the blackout period comprises identifying at least one antenna panel that is impacted by the BF event and predicting the blackout period for at least one beam pair link (BPL) associated with the at least one antenna panel.
2. The method of claim 1, wherein said determining of the blackout period comprises identifying a configuration of UE receiving and transmitting components.
3. The method of claim 1, further comprising:  
receiving a confirmation message from the base station in response to the blackout indication.
4. The method of claim 3, further comprising:  
ceasing monitoring the BPL upon receiving the confirmation message from the base station.
5. The method of claim 4, wherein said ceasing of monitoring the BPL further comprises ceasing monitoring the BPL for an already scheduled downlink transmission during the blackout period.
6. The method of claim 1, wherein said communicating of the blackout indication comprises transmitting the blackout indication on a carrier frequency different from a current carrier frequency on the BPL or on another BPL.
7. The method of claim 1, wherein said communicating of the blackout indication comprises  
transmitting a schedule request (SR) to request an uplink transmission;  
receiving a downlink signaling message in response to the SR; and  
transmitting the blackout indication based on the received downlink signaling message.

8. The method of claim 1, wherein said communicating of the blackout indication comprises transmitting a detailed blackout report in an uplink message without first transmitting a SR.
9. The method of claim 1, wherein the blackout indication comprises one or more of:
  - a first time stamp indicating a start of the blackout period;
  - a second time stamp indicating an end of the blackout period;
  - an indication of an identifier of the BPL;
  - an identifier of a first antenna panel associated with the BPL with a deactivation time stamp; and
  - an identifier of a second antenna panel associated with the BPL with an activation time stamp.
10. The method of claim 1, wherein the blackout indication further comprises an indicator of whether or not the entire UE is impacted, and the indicator is set if the one antenna panel is a last antenna panel in service for the UE.
11. The method of claim 9, wherein the blackout period is implicitly indicated if the activation time stamp is greater than the deactivation time stamp.
12. The method of claim 9, wherein the identifier of the BPL is associated with a transmission configuration indicator (TCI) state, an ID of an antenna panel, an ID of an SRS resource, a RS resource, and/or an assigned target RS resource or wherein the identifier of the BPL is associated with a configuration of a RS.
13. The method of claim 12, wherein the configuration of the RS indicates spatial relationship information linking the SRS resource with the RS resource or an antenna panel ID.
14. A method of wireless communication at a base station in communication with a user equipment (UE), comprising:
  - receiving a blackout indication from the UE, reporting a beam failure event impacting at least one beam pair link (BPL); and

determining a blackout period from the received blackout indication, wherein the blackout indication comprises at least one or more of:

- a time stamp indicating a start of the blackout period;
- a time stamp indicating an end of the blackout period;
- an indication of an identifier of the BPL;
- an identifier of an antenna panel associated with the BPL with a deactivation time stamp; and
- an identifier of a second antenna panel associated with the BPL with an activation time stamp; and

wherein said determining of the blackout period comprises identifying at least one antenna panel that is impacted by the identified BF event and identifying the blackout period for at least one beam pair link (BPL) associated with the at least one antenna panel, based on the activation time stamp and the deactivation time stamp.

15. The method of claim 14, wherein the blackout period is implicitly indicated if the activation time stamp is after deactivation time stamp.

16. The method of claim 14, further comprising  
transmitting a confirmation message to the UE to request that the base station refrains from transmitting during the blackout period on the at least one impacted BPL.

17. The method of claim 14, further comprising  
ceasing monitoring the BPL upon receiving the blackout indication.

18. The method of claim 14, further comprising  
scheduling uplink and downlink transmissions based at least in part on the determined blackout period.

19. The method of claim 14, wherein said receiving of the blackout indication comprises:

- receiving a schedule request (SR) to request an uplink transmission;
- transmitting a downlink signaling message in response to the SR; and
- receiving an uplink report of the blackout period based on the received downlink signaling message.

20. The method of claim 14, wherein said receiving of the blackout indication further comprises receiving a detailed blackout report in an uplink message without first transmitting a SR.

21. The method of claim 14, wherein an indicator for the entire UE is set if the one antenna panel is a last antenna panel in service for the UE.

22. The method of claim 14, wherein the identifier of the BPL is associated with a transmission configuration indicator (TCI) state, an ID of an antenna panel, an ID of an SRS resource, a RS resource, and/or an assigned target RS resource or wherein the identifier of the BPL is associated with a configuration of a RS.

23. The method of claim 22, wherein the configuration of the RS indicates spatial relationship information linking the SRS resource with the RS resource or an antenna panel ID.

24. An apparatus for wireless communication by a user equipment (UE), comprising:

a transceiver;

a memory; and

at least one processor coupled to the memory and configured to:

determine a blackout period associated with a beam failure (BF) event; and

communicate a blackout indication to a base station, the blackout indication including the blackout period,

wherein said determining of the blackout period comprises identifying at least one antenna panel that is impacted by the BF event and predicting the blackout period for at least one beam pair link (BPL) associated with the at least one antenna panel.

25. The apparatus of claim 24, wherein said determining of the blackout period comprises identifying a configuration of UE receiving and transmitting components.

26. The apparatus of claim 24, wherein the at least one processor is further configured to receive a confirmation message from the base station in response to the blackout indication.

27. The apparatus of claim 26, wherein the at least one processor is further configured to cease monitoring the BPL upon receiving the confirmation message from the base station.
28. The apparatus of claim 27, wherein said ceasing of monitoring the BPL further comprises ceasing monitoring the BPL for an already scheduled downlink transmission during the blackout period.
29. The apparatus of claim 24, wherein said communicating of the blackout indication comprises transmitting the blackout indication on a carrier frequency different from a current carrier frequency on the BPL or on another BPL.
30. The apparatus of claim 24, wherein said communicating of the blackout indication comprises
- transmitting a schedule request (SR) to request an uplink transmission;
  - receiving a downlink signaling message in response to the SR; and
  - transmitting the blackout indication based on the received downlink signaling message.
31. The apparatus of claim 24, wherein said communicating of the blackout indication comprises transmitting a detailed blackout report in an uplink message without first transmitting a SR.
32. The apparatus of claim 24, wherein the blackout indication comprises one or more of:
- a first time stamp indicating a start of the blackout period;
  - a second time stamp indicating an end of the blackout period;
  - an indication of an identifier of the BPL;
  - an identifier of a first antenna panel associated with the BPL with a deactivation time stamp; and
  - an identifier of a second antenna panel associated with the BPL with an activation time stamp.
33. An apparatus for wireless communication by a user equipment (UE), comprising:

means for determining a blackout period associated with a beam failure (BF) event; and

means for communicating a blackout indication to a base station, the blackout indication including the blackout period,

wherein said means for determining of the blackout period comprises means for identifying at least one antenna panel that is impacted by the BF event and predicting the blackout period for at least one beam pair link (BPL) associated with the at least one antenna panel.

34. The apparatus of claim 33, wherein the means for determining the blackout period comprises means for identifying a configuration of UE receiving and transmitting components.

35. The apparatus of claim 33, wherein said means for communicating the blackout indication comprises

means for transmitting a schedule request (SR) to request an uplink transmission;

means for receiving a downlink signaling message in response to the SR; and

means for transmitting the blackout indication based on the received downlink signaling message.