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Power Backoff Mechanism for Intermodulation Distortion and Harmonic Distortion

Abstract:

This publication describes systems and techniques for power backoff to address intermodulation distortion and harmonic distortion. A wireless communication device, which engineers often refer to as user equipment (UE), includes power backoff logic and a transmit backoff table. In a dual-connectivity environment with operating conditions known to result in potential distortion, a processor of the UE looks up a power backoff level in the transmit backoff table and directs a transceiver to back off the transmit power to mitigate intermodulation distortion or harmonic distortion. The UE can use similar systems and techniques to address distortion issues in carrier aggregation or multi-connectivity environments.

Keywords:

Dual-connectivity, EN-DC, multi-connectivity, carrier aggregation (CA), 5G NR, 3GPP LTE, 6G, 4G LTE, power backoff, backoff table, intermodulation distortion (IMD), harmonic distortion (HD), maximum transmission power, power headroom, ping-pong mitigation, timer

Background:

A wireless communication device (*e.g.*, UE) can be engaged in dual-connectivity or multi-connectivity communication with multiple base stations. As an example, the UE can communicate using a first transceiver over a wireless connection with a master node (MN), which provides access to a first wireless network of a first type. The MN can be a base station providing access to a 3rd Generation Partnership Project Long-Term Evolution (3GPP LTE) wireless network.

Simultaneously, the UE can communicate using a second transceiver over another wireless connection with a secondary node (SN), which provides access to a second wireless network of a second type. The SN can be another base station giving access to a Fifth Generation New Radio (5G NR) wireless network. Although this example represents 5G non-standalone (NSA) with E-UTRAN New Radio - Dual Connectivity (EN-DC), other multi-connectivity implementations can involve other combinations of UE transceiver radios (*e.g.*, 5G and 6G; 5G mmWave and Wi-Fi mmWave; or 5G sub-6GHz, 5G mmWave, Wi-Fi sub-6GHz, and Wi-Fi mmWave).

Simultaneous transmissions during dual-connectivity or multi-connectivity communications can result in intermodulation products within the frequency spectrum of one or more of the UE receivers. The power level of the intermodulation products increases as the power of the transmitted signals increases, which Figure 1 illustrates below. For example, the power of the third-order intermodulation product increases 3 dB for each 1 dB increase in the power level of the transmit signal. When transmitters of a UE emit signals at certain power levels, one or more UE receivers may not be able to decode a received signal due to a high-level of intermodulation distortion. A similar phenomenon can occur during carrier aggregation.

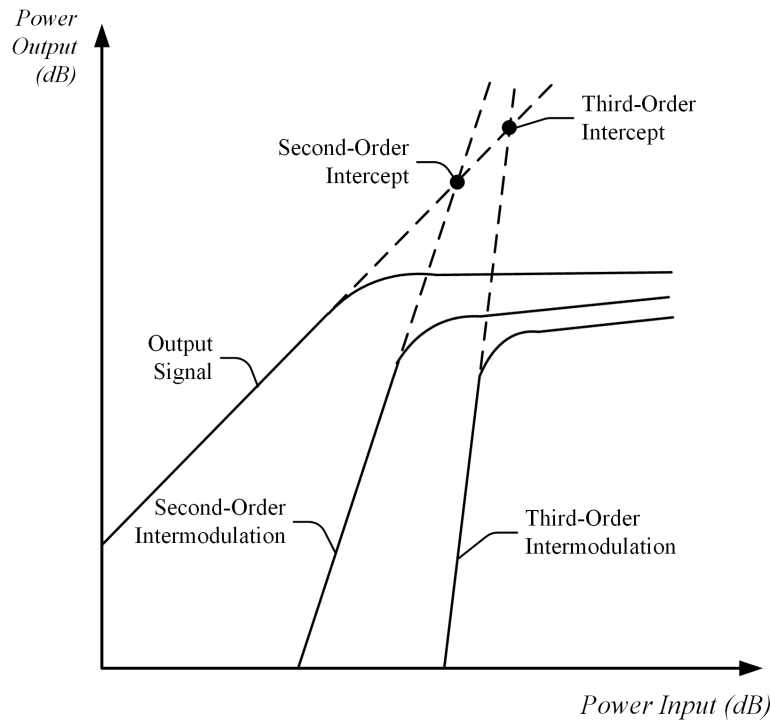


Figure 1

Similar receiver performance issues can occur due to harmonic distortion. Harmonic distortion arises when the harmonics of a transmitted signal occur within the frequency spectrum of a UE receiver. Unlike intermodulation distortion that occurs from simultaneous transmissions, the operation of a single UE transmitter can cause harmonic distortion.

Wireless communication protocols (*e.g.*, 3GPP LTE protocols, 5G NR protocols) currently do not contain provisions for the UE or a communication network to identify and address intermodulation distortion and harmonic distortion. As an example, a UE receiver may experience reduced sensitivity, but the UE generally cannot determine whether intermodulation distortion, harmonic distortion, and/or network interference is a cause. Because neither the communication network nor the UE can determine the underlying issue(s), neither side of the connection can take appropriate action. As a result, the UE may repeat the following steps: (1) determine a radio link failure due to desensitization on the receive path; (2) reestablish a connection over the 3GPP LTE

network with an MN; (3) report to an SN acceptable measurements for a 5G NR cell that can cause intermodulation distortion in some operating scenarios; (4) configure the UE for dual-connectivity or multi-connectivity over the 5G NR network with an SN and experience receiver desensitization due to intermodulation distortion; and (5) repeat steps (1) – (4).

It is desirable to develop systems and techniques for a UE to identify and address operating scenarios that can introduce intermodulation distortion and harmonic distortion.

Description:

This publication describes systems and techniques to back off the transmit power in wireless communication devices to address intermodulation distortion and harmonic distortion. The UE includes power backoff logic and a transmit backoff table. Under specific operating parameters for dual-connectivity (DC), multi-connectivity, or carrier aggregation (CA), a processor of the UE, using the power backoff logic, directs the UE to mitigate desensitization of one or more UE receivers.

Figure 2 illustrates an example dual-connectivity environment in which a UE receiver experiences degraded performance. In Figure 2, the UE is a smartphone, but other wireless communication devices (*e.g.*, tablets, laptop computers, wearable devices) can also support the described systems and techniques. The UE wirelessly connects to a MN of a master cell group (MCG) using a first transceiver, which supports an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) for 3GPP LTE wireless communications. The MCG includes one or more nodes (*e.g.*, base stations) that connect to a core network (*e.g.*, an Evolved Packet Core (EPC) network). An MN wireless link (MN LINK) wirelessly connects the UE to the MN of the MCG.

The MN LINK supports uplink transmissions from the UE to the MN and downlink transmissions from the MN to the UE.

The UE also wirelessly connects to a SN of a secondary cell group (SCG) using a second transceiver, which supports a Next-Generation Radio Access Network (NG-RAN) for 5G NR wireless communications. The SCG includes one or more nodes that connect to another core network (*e.g.*, a 5G Core (5GC) network). An SN wireless link (SN LINK) wirelessly connects the UE to the SN of the SCG. The SN LINK supports uplink transmissions from the UE to the SN and downlink transmissions from the SN to the UE. In general, the MN LINK and the SN LINK correspond to transmissions over air-interface resources (*e.g.*, resource blocks and resource elements spanning frequency and time domains) that can be allocated by the MN and the SN to the UE. While operating in this dual-connectivity state, the UE can experience intermodulation distortion or harmonic distortion that reduces the sensitivity of one or more of the receivers.

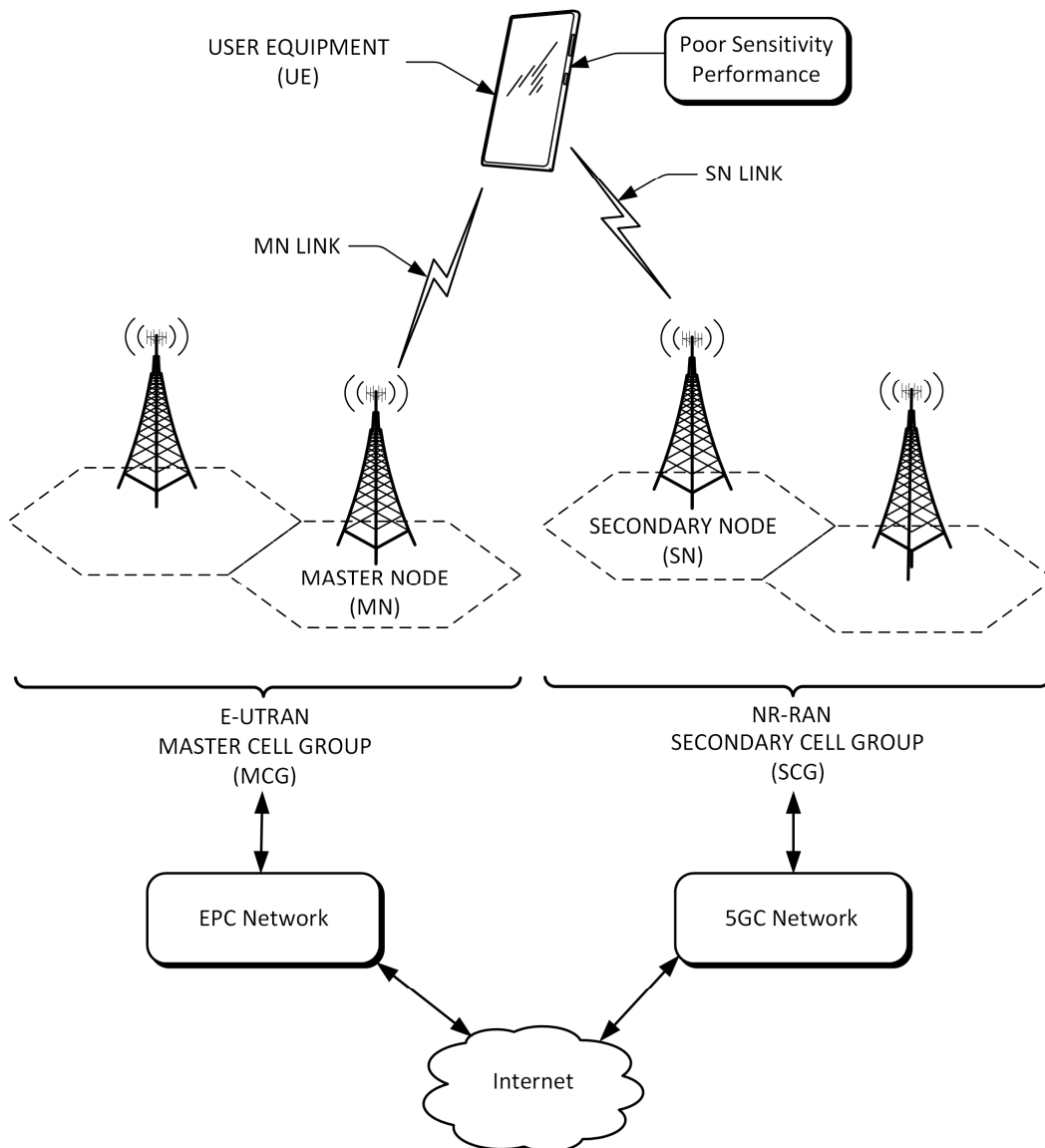


Figure 2

Figure 2 illustrates dual-connectivity with specific types of nodes associated with particular types of radio access networks (*e.g.*, E-UTRAN, NG-RAN). UEs, however, can use the described systems and techniques to address intermodulation distortions and harmonic distortions in other environments. For example, a node may correspond to a router or a “hotspot” provided by another UE. Different radio access networks include, for example, those associated with a wireless local access network (WLAN) and a global system for mobile communications (GSM) network. UEs

can also use the described systems and techniques to address distortions for carrier aggregation or multi-connectivity scenarios.

Figure 3 illustrates example components of a UE supporting power backoff to address intermodulation distortion and harmonic distortion. The UE includes multiple transceivers (*e.g.*, a 3GPP LTE transceiver and a 5G NR transceiver), a radio interface, one or more processors, and computer-readable media (CRM). The UE uses the transceivers and the radio interface for wireless communications. The CRM stores executable instructions of a transmit backoff table, a power backoff logic, and a radio interface layer (RIL) or cellular protocol stack. The power backoff logic, when executed by the one or more processors, causes the UE to identify and address intermodulation distortion or harmonic distortion.

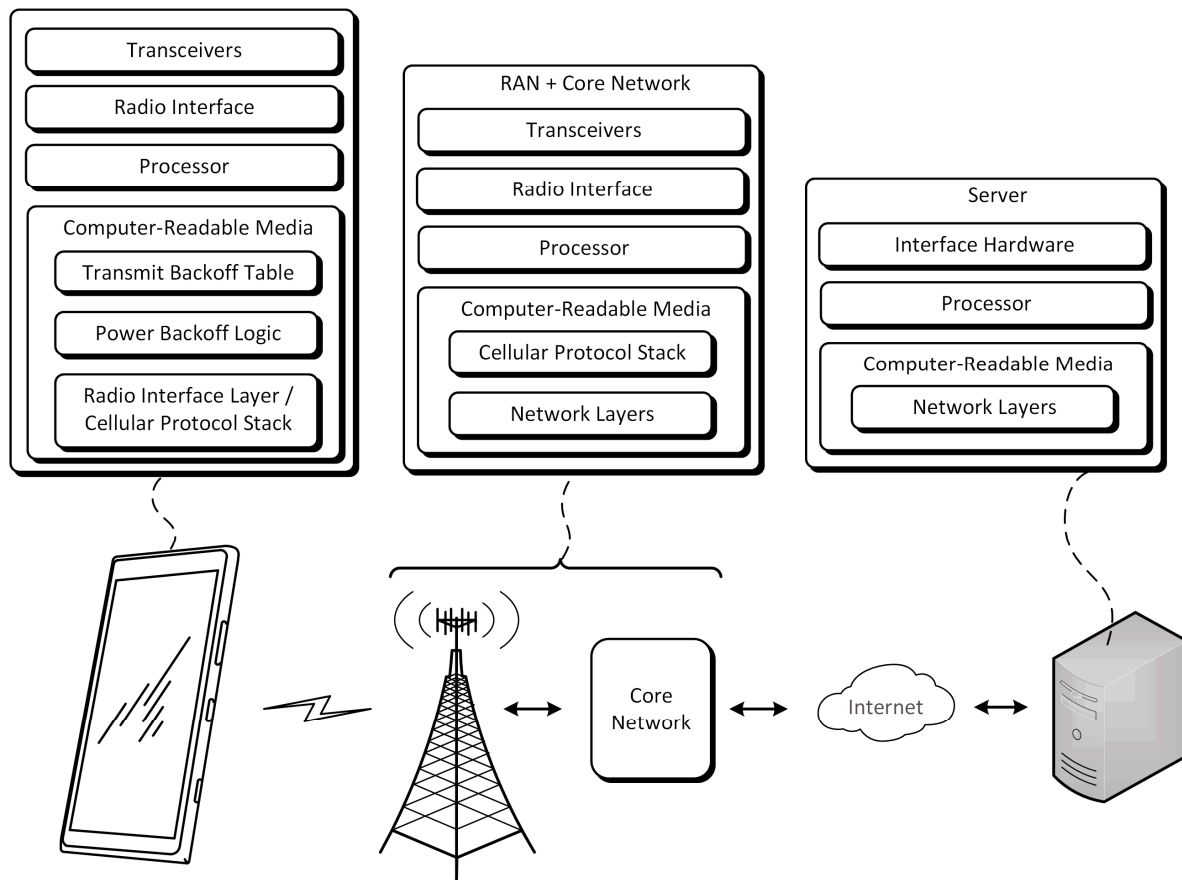


Figure 3

Figure 3 also illustrates a radio access network (RAN) as a base station and a core network (collectively, “the cellular network”). The RAN includes transceivers (*e.g.*, a combination of one or more 3GPP LTE transceivers or 5G NR transceivers) to wirelessly communicate with the UE via either the MN or the SN of Figure 2. The cellular network also includes inter-RAN node interface hardware for communicating with other base station(s), one or more processors, and CRM. The CRM stores executable instructions of a cellular protocol stack and network layers. The cellular protocol stack, when executed by the one or more processors, causes the RAN to communicate with the UE. The network layers, when executed by the one or more processors, cause the RAN to communicate with the one or more servers associated with the RAN, which include interface hardware, one or more processors, and CRM storing executable network layer instructions.

The transmit backoff table in the UE includes a list of dual-connectivity, multi-connectivity, and carrier aggregation operation parameters that can cause intermodulation distortion, harmonic distortion, or a combination thereof. For each set of problematic operation parameters, engineers prepopulate the transmit backoff table with the maximum transmit power of the secondary transceiver (*e.g.*, the 5G NR transceiver). This maximum power level indicates the transmission power at which distortion issues significantly degrade receiver performance when the primary transceiver (*e.g.*, the 3GPP LTE transceiver) is transmitting at maximum power. Engineers empirically determine the tabulated values using lab measurements for each combination of transceivers in a UE. As an example, lab testing can determine the maximum transmit power level of a 5G NR transceiver at which the 5G NR receiver can still decode signals when a 3GPP LTE transceiver transmits at maximum power.

Figure 4 illustrates example operations performed by the power backoff logic to address intermodulation distortion and harmonic distortion. In particular, the UE selects a lower maximum transmission power value between the value stored in the transmit backoff table and the one signaled by the RAN. Figure 4 illustrates the operations for the UE in an EN-DC environment. The UE, however, can use the same or similar processes for non-EN-DC dual-connectivity, multi-connectivity with more than two transmitters, and carrier aggregation.

In the EN-DC operation, the power backoff logic determines whether the UE has 5G NR headroom. If the UE has 5G NR headroom, the power backoff logic then looks up the EN-DC operating parameters in the transmit backoff table. If the operating parameters are in the transmit backoff table, the power backoff logic retrieves the maximum 5G NR transmit power level. The UE then reports its power headroom as the maximum of (i) zero or (ii) the backoff table value minus the current transmission power, which is the 5G NR transmission power in this example but could be the transmission power of other transmitters or groups of transmitters in other examples. If the current multi-connectivity operating parameters are not in the transmit backoff table, the UE reports its headroom as the relevant transceiver's maximum transmit power minus the current transmit power for that transceiver.

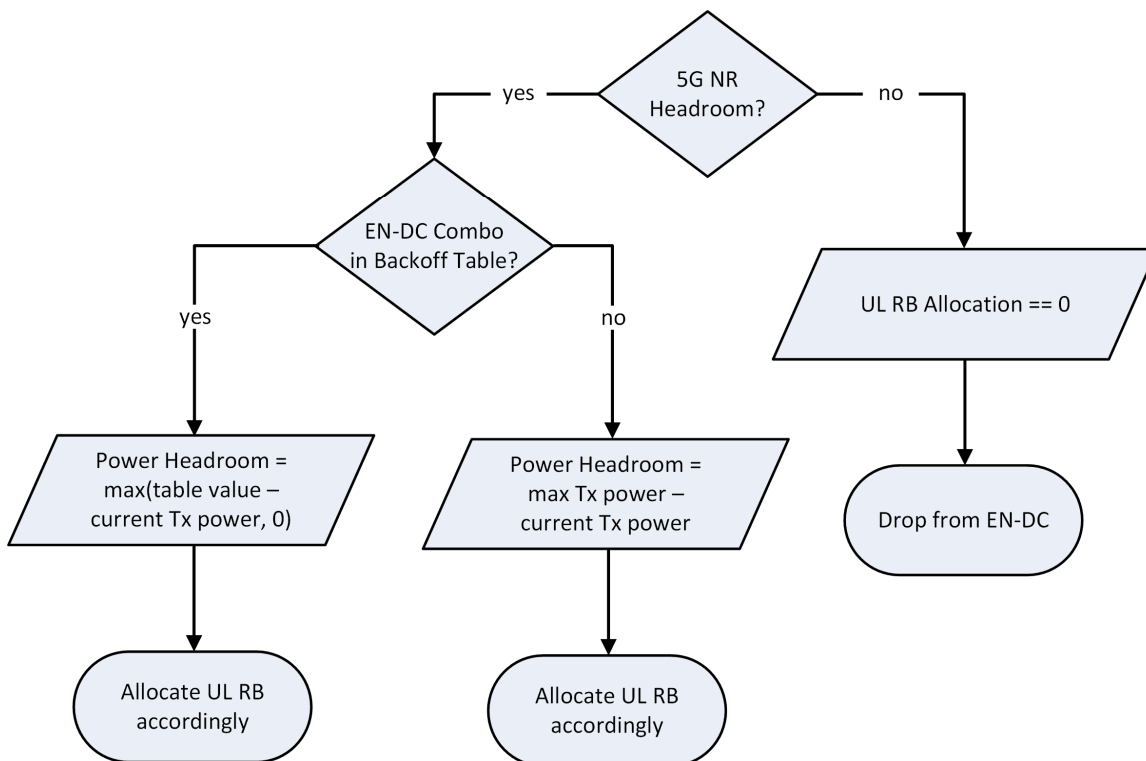


Figure 4

Consider a first example wherein the maximum 5G NR and 3GPP LTE transmit powers are each 20 dBm. When the 3GPP LTE transceiver transmits at its maximum power level, engineers have determined that the maximum 5G NR power at which the 5G NR receiver can still decode signals is 15 dBm. Thus, the transmit backoff table has an entry of “15 dBm” for a 5G NR transmitter when the UE is in EN-DC. Let us posit that the UE is in EN-DC and the 5G NR transmitter is currently transmitting at 13 dBm. Without the described systems and techniques, the UE reports a power headroom of 7 dBm (*e.g.*, 20 dBm (maximum 5G NR transmit power) – 13 dBm (current 5G NR transmit power)). In contrast, the power backoff logic causes the UE to report a power headroom of 2 dBm (*e.g.*, $\max(15 \text{ dBm (maximum 5G NR transmit power from the table)} - 13 \text{ dBm (current 5G NR transmit power)}, 0 \text{ dBm})$). The 5G NR RAN does not reduce the UL resource allocation for the UE 5G transmitter because the 5G NR transceiver has 2 dBm of power headroom.

In a second example, the 5G NR transmitter is now transmitting at 17 dBm while in EN-DC and the table values are the same. Without the described systems and techniques, the UE would report a power headroom of 3 dBm (*e.g.*, 20 dBm – 17 dBm). The power backoff logic, however, causes the UE to report a power headroom of 0 dBm (*e.g.*, max(15 dBm – 17 dBm, 0 dBm)). In this example, the 5G NR RAN reduces the UL resource allocation for the UE 5G NR transmitter because the 5G NR transceiver does not have power headroom available.

If the UE does not have 5G NR power headroom, the 5G RAN may reduce the UL resource block allocation for the UE to zero. The UE may be near the edge of a network cell, and it could be beneficial to drop from EN-DC to 3GPP LTE connectivity only.

When the UE does not have 5G NR power headroom or reports a lack of power headroom, the 5G NR RAN scheduler generally disables the 5G NR cell vis-à-vis the UE and causes the UE to switch to 3GPP LTE connectivity only. A potential issue in this scenario is that the default mechanism to enable EN-DC relies on cellular network (*e.g.*, SCG) measurements. Such measurements are based on received signal power or signal interference and do not account for intermodulation distortion or harmonic distortion at the UE. Shortly after disabling the 5G NR SCG, the cellular network may re-enable EN-DC, which can result in the UE experiencing alternating connections that bounce back and forth between 3GPP LTE and 5G EN-DC (which is sometimes referred to as “ping-ponging”).

To mitigate potential connectivity ping-ponging, the UE can utilize a timer. For example, if the UE detects a set amount of ping-pongs within a specified period, the UE can disable dual-connectivity (*e.g.*, EN-DC), multi-connectivity, and carrier aggregation. In an EN-DC scenario, the UE can disable the EN-DC by sending a capability update message via the Tracking Area Update/Re-attach procedure. After the timer expires, the UE can re-enable dual-connectivity,

multi-connectivity, and carrier aggregation (*e.g.*, by sending a UE capability update message via the Tracking Area Update/Re-attach procedure). The timer value can be set as several minutes to avoid excessive cellular network signaling.

The described systems and techniques provide a power backoff mechanism to address intermodulation distortion and harmonic distortion in dual-connectivity, multi-connectivity, and carrier aggregation environments.

References:

- [1] Patent Publication: US20190081657A1. Detection of Intermodulation Issues and Transmission Scheme Configuration to Remedy Intermodulation Issues. Priority Date: September 11, 2017.
- [2] Patent Publication: US20150195795A1. Power Headroom Reporting for In-Device Coexistence Interference Avoidance. Priority Date: August 3, 2012.
- [3] Patent Publication: US20200154442A1. Method and Apparatus for Coordinating Interference, Base Station and User Equipment. Priority Date: July 7, 2017.
- [4] Patent Publication: US20110158117A1. Power Headroom Report for Simultaneous Transmissions on Disparate Radio Access Technologies. Priority Date: June 29, 2009.
- [5] Patent Publication: US20160323832A1. Inter-Modulation Distortion Reduction in Multi-Mode Wireless Communication Terminal. Priority Date: January 13, 2011.
- [6] 3GPP TS 36.321 v.15.8.0 (2020-01).