

CONTROLLING TRANSMISSION POWER

TECHNICAL FIELD

The exemplary and non-limiting embodiments of the invention relate generally to wireless communication systems. Embodiments of the invention
5 relate especially to apparatuses and methods in wireless communication networks.

BACKGROUND

Power control of terminal devices in modern communication networks is an important aspect. The terminal devices must be able to communicate with the network with good signal quality. On the other hand, interference to other users in
10 the communication network and to environment should be low. Further, the battery life of mobile units is also an issue which should be kept in mind.

Typically, the maximum transmission power the terminal devices may use in communication is limited by legislation. The purpose is to ensure that interference is kept low. Also, the radiation the users of the terminal devices
15 experience is one factor limiting the maximum available power.

BRIEF DESCRIPTION

According to an aspect, there is provided the subject matter of the independent claims. Embodiments are defined in the dependent claims.

In an embodiment, there is provided an apparatus comprising: means
20 for determining uplink bandwidth allocated to a terminal device, means for determining total guard bandwidth as the shortest frequency distance between an edge of frequency range allocated to uplink signal of the terminal device and an edge of a frequency range to be protected from interference, means for selecting the additional maximum power reduction values for the terminal device
25 based on the determination.

In an embodiment, there is provided a method comprising: determining uplink bandwidth allocated to a terminal device; determining total guard bandwidth as the shortest frequency distance between an edge of frequency range allocated to uplink signal of the terminal device and an edge of a frequency range
30 to be protected from interference; and selecting the additional maximum power reduction values for the terminal device based on the determination.

In an embodiment, there is provided an apparatus further comprising means for selecting the additional maximum power reduction values for the terminal device based on mapping of the uplink bandwidth allocated to a terminal

device to a total guard bandwidth threshold below which a higher level of output power reduction is allowed.

In an embodiment, there is provided an apparatus further comprising means for selecting the additional maximum power reduction values for the terminal device when the uplink bandwidth allocated to the terminal device is inside a resource allocation regrowth region where spectral regrowth causes spurious emissions.

In an embodiment, there is provided an apparatus comprising at least one processor; and at least one memory including computer program code; the at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: determine uplink bandwidth allocated to a terminal device; determine total guard bandwidth as the shortest frequency distance between an edge of frequency range allocated to uplink signal of the terminal device and an edge of a frequency range to be protected from interference; and select the additional maximum power reduction values for the terminal device based on the determination.

In an embodiment, there is provided a non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the following: determining uplink bandwidth allocated to a terminal device; determining total guard bandwidth as the shortest frequency distance between an edge of frequency range allocated to uplink signal of the terminal device and an edge of a frequency range to be protected from interference; and selecting the additional maximum power reduction values for the terminal device based on the determination.

One or more examples of implementations are set forth in more detail in the accompanying drawings and the description below. Other features will be apparent from the description, drawings and the claims.

BRIEF DESCRIPTION OF DRAWINGS

In the following, embodiments will be described in greater detail with reference to the attached drawings, in which

Figure 1 illustrates an exemplified wireless communication system,

Figures 2A and 2B illustrate examples of uplink operating band and a protected frequency range,

Figure 3 illustrates an example of allocation regions,

Figures 4 and 5 illustrate output power back-off in regrowth region versus total guard bandwidth and allocation bandwidth,

Figure 6A and 6B are flowcharts illustrating some embodiments, and Figures 7A and 7B illustrate apparatus according to some embodiments.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

5 The following embodiments are only presented as examples. Although the specification may refer to “an”, “one”, or “some” embodiment(s) and/or example(s) in several locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s) or example(s), or that a particular feature only applies to a single embodiment and/or example. Single features of
10 different embodiments and/or examples may also be combined to provide other embodiments and/or examples.

 In the following, different exemplifying embodiments will be described using, as an example of an access architecture to which the embodiments may be applied, a radio access architecture based on long term evolution advanced (LTE
15 Advanced, LTE-A) or new radio (NR, 5G), without restricting the embodiments to such an architecture, however. It is obvious for a person skilled in the art that the embodiments may also be applied to other kinds of communications networks having suitable means by adjusting parameters and procedures appropriately. Some examples of other options for suitable systems are the universal mobile
20 telecommunications system (UMTS) radio access network (UTRAN or E-UTRAN), long term evolution (LTE, the same as E-UTRA), wireless local area network (WLAN or WiFi), worldwide interoperability for microwave access (WiMAX), Bluetooth®, personal communications services (PCS), ZigBee®, wideband code division multiple access (WCDMA), systems using ultra-wideband (UWB)
25 technology, sensor networks, mobile ad-hoc networks (MANETs) and Internet Protocol multimedia subsystems (IMS) or any combination thereof.

 Figure 1 depicts examples of simplified system architectures only showing some elements and functional entities, all being logical units, whose implementation may differ from what is shown. The connections shown in Figure
30 1 are logical connections; the actual physical connections may be different. It is apparent to a person skilled in the art that the system typically comprises also other functions and structures than those shown in Figure 1.

 The embodiments are not, however, restricted to the system given as an example but a person skilled in the art may apply the solution to other
35 communication systems provided with necessary properties.

The example of Figure 1 shows a part of an exemplifying radio access network.

Figure 1 shows user devices 100 and 102 configured to be in a wireless connection on one or more communication channels in a cell with an access node (such as (e/g)NodeB) 104 providing the cell. The physical link from a user device to a (e/g)NodeB is called uplink or reverse link and the physical link from the (e/g)NodeB to the user device is called downlink or forward link. It should be appreciated that (e/g)NodeBs or their functionalities may be implemented by using any node, host, server or access point etc. entity suitable for such a usage.

A communications system typically comprises more than one (e/g)NodeB in which case the (e/g)NodeBs may also be configured to communicate with one another over links, wired or wireless, designed for the purpose. These links may be used for signalling purposes. The (e/g)NodeB is a computing device configured to control the radio resources of communication system it is coupled to. The NodeB may also be referred to as a base station, an access point or any other type of interfacing device including a relay station capable of operating in a wireless environment. The (e/g)NodeB includes or is coupled to transceivers. From the transceivers of the (e/g)NodeB, a connection is provided to an antenna unit that establishes bi-directional radio links to user devices. The antenna unit may comprise a plurality of antennas or antenna elements. The (e/g)NodeB is further connected to core network 110 (CN or next generation core NGC). Depending on the system, the counterpart on the CN side can be a serving gateway (S-GW, routing and forwarding user data packets), packet data network gateway (P-GW), for providing connectivity of user devices (UEs) to external packet data networks, or mobile management entity (MME), etc.

The user device (also called UE, user equipment, user terminal, terminal device, etc.) illustrates one type of an apparatus to which resources on the air interface are allocated and assigned, and thus any feature described herein with a user device may be implemented with a corresponding apparatus, such as a relay node. An example of such a relay node is a layer 3 relay (self-backhauling relay) towards the base station.

The user device typically refers to a portable computing device that includes wireless mobile communication devices operating with or without a subscriber identification module (SIM), including, but not limited to, the following types of devices: a mobile station (mobile phone), smartphone, personal digital assistant (PDA), handset, device using a wireless modem (alarm or measurement

device, etc.), laptop and/or touch screen computer, tablet, game console, notebook, and multimedia device. It should be appreciated that a user device may also be a nearly exclusive uplink only device, of which an example is a camera or video camera loading images or video clips to a network. A user device may also be a device having capability to operate in Internet of Things (IoT) network which is a scenario in which objects are provided with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The user device (or in some embodiments a layer 3 relay node) is configured to perform one or more of user equipment functionalities. The user device may also be called a subscriber unit, mobile station, remote terminal, access terminal, user terminal or user equipment (UE) just to mention but a few names or apparatuses.

Various techniques described herein may also be applied to a cyber-physical system (CPS) (a system of collaborating computational elements controlling physical entities). CPS may enable the implementation and exploitation of massive amounts of interconnected ICT devices (sensors, actuators, processors microcontrollers, etc.) embedded in physical objects at different locations. Mobile cyber physical systems, in which the physical system in question has inherent mobility, are a subcategory of cyber-physical systems. Examples of mobile physical systems include mobile robotics and electronics transported by humans or animals.

It should be understood that, in Figure 1, user devices are depicted to include 2 antennas only for the sake of clarity. The number of reception and/or transmission antennas may naturally vary according to a current implementation.

Additionally, although the apparatuses have been depicted as single entities, different units, processors and/or memory units (not all shown in Figure 1) may be implemented.

5G enables using multiple input – multiple output (MIMO) antennas, many more base stations or nodes than the LTE (a so-called small cell concept), including macro sites operating in co-operation with smaller stations and employing a variety of radio technologies depending on service needs, use cases and/or spectrum available. 5G mobile communications supports a wide range of use cases and related applications including video streaming, augmented reality, different ways of data sharing and various forms of machine type applications, including vehicular safety, different sensors and real-time control. 5G is expected to have multiple radio interfaces, namely below 6GHz, cmWave and mmWave, and also being integratable with existing legacy radio access technologies, such as the

LTE. Integration with the LTE may be implemented, at least in the early phase, as a system, where macro coverage is provided by the LTE and 5G radio interface access comes from small cells by aggregation to the LTE. In other words, 5G is planned to support both inter-RAT operability (such as LTE-5G) and inter-RF operability (inter-radio interface operability, such as below 6GHz – cmWave, below 6GHz – cmWave – mmWave). One of the concepts considered to be used in 5G networks is network slicing in which multiple independent and dedicated virtual sub-networks (network instances) may be created within the same infrastructure to run services that have different requirements on latency, reliability, throughput and mobility.

10 The current architecture in LTE networks is fully distributed in the radio and fully centralized in the core network. The low latency applications and services in 5G require to bring the content close to the radio which leads to local break out and multi-access edge computing (MEC). 5G enables analytics and knowledge generation to occur at the source of the data. This approach requires
15 leveraging resources that may not be continuously connected to a network such as laptops, smartphones, tablets and sensors. MEC provides a distributed computing environment for application and service hosting. It also has the ability to store and process content in close proximity to cellular subscribers for faster response time. Edge computing covers a wide range of technologies such as wireless sensor
20 networks, mobile data acquisition, mobile signature analysis, cooperative distributed peer-to-peer ad hoc networking and processing also classifiable as local cloud/fog computing and grid/mesh computing, dew computing, mobile edge computing, cloudlet, distributed data storage and retrieval, autonomic self-healing networks, remote cloud services, augmented and virtual reality, data caching,
25 Internet of Things (massive connectivity and/or latency critical), critical communications (autonomous vehicles, traffic safety, real-time analytics, time-critical control, healthcare applications).

 The communication system is also able to communicate with other networks, such as a public switched telephone network or the Internet 112, or
30 utilise services provided by them. The communication network may also be able to support the usage of cloud services, for example at least part of core network operations may be carried out as a cloud service (this is depicted in Figure 1 by “cloud” 114). The communication system may also comprise a central control entity, or a like, providing facilities for networks of different operators to cooperate
35 for example in spectrum sharing.

Edge cloud may be brought into radio access network (RAN) by utilizing network function virtualization (NVF) and software defined networking (SDN). Using edge cloud may mean access node operations to be carried out, at least partly, in a server, host or node operationally coupled to a remote radio head or base station comprising radio parts. It is also possible that node operations will be distributed among a plurality of servers, nodes or hosts. Application of cloudRAN architecture enables RAN real time functions being carried out at the RAN side (in a distributed unit, DU 104) and non-real time functions being carried out in a centralized manner (in a centralized unit, CU 108).

It should also be understood that the distribution of labour between core network operations and base station operations may differ from that of the LTE or even be non-existent. Some other technology advancements probably to be used are Big Data and all-IP, which may change the way networks are being constructed and managed. 5G (or new radio, NR) networks are being designed to support multiple hierarchies, where MEC servers can be placed between the core and the base station or nodeB (gNB). It should be appreciated that MEC can be applied in 4G networks as well.

5G may also utilize satellite communication to enhance or complement the coverage of 5G service, for example by providing backhauling. Possible use cases are providing service continuity for machine-to-machine (M2M) or Internet of Things (IoT) devices or for passengers on board of vehicles, or ensuring service availability for critical communications, and future railway/maritime/aeronautical communications. Satellite communication may utilise geostationary earth orbit (GEO) satellite systems, but also low earth orbit (LEO) satellite systems, in particular mega-constellations (systems in which hundreds of (nano)satellites are deployed). Each satellite 106 in the mega-constellation may cover several satellite-enabled network entities that create on-ground cells. The on-ground cells may be created through an on-ground relay node 104 or by a gNB located on-ground or in a satellite.

It is obvious for a person skilled in the art that the depicted system is only an example of a part of a radio access system and in practice, the system may comprise a plurality of (e/g)NodeBs, the user device may have an access to a plurality of radio cells and the system may comprise also other apparatuses, such as physical layer relay nodes or other network elements, etc. At least one of the (e/g)NodeBs or may be a Home(e/g)nodeB. Additionally, in a geographical area of a radio communication system a plurality of different kinds of radio cells as well as

a plurality of radio cells may be provided. Radio cells may be macro cells (or umbrella cells) which are large cells, usually having a diameter of up to tens of kilometers, or smaller cells such as micro-, femto- or picocells. The (e/g)NodeBs of Figure 1 may provide any kind of these cells. A cellular radio system may be implemented as a multilayer network including several kinds of cells. Typically, in multilayer networks, one access node provides one kind of a cell or cells, and thus a plurality of (e/g)NodeBs are required to provide such a network structure.

For fulfilling the need for improving the deployment and performance of communication systems, the concept of “plug-and-play” (e/g)NodeBs has been introduced. Typically, a network which is able to use “plug-and-play” (e/g)NodeBs, includes, in addition to Home (e/g)NodeBs (H(e/g)nodeBs), a home node B gateway, or HNB-GW (not shown in Figure 1). A HNB Gateway (HNB-GW), which is typically installed within an operator’s network may aggregate traffic from a large number of HNBs back to a core network.

6G networks are expected to adopt flexible decentralized and/or distributed computing systems and architecture and ubiquitous computing, with local spectrum licensing, spectrum sharing, infrastructure sharing, and intelligent automated management underpinned by mobile edge computing, artificial intelligence, short-packet communication and blockchain technologies. Key features of 6G will include intelligent connected management and control functions, programmability, integrated sensing and communication, reduction of energy footprint, trustworthy infrastructure, scalability and affordability. In addition to these, 6G is also targeting new use cases covering the integration of localization and sensing capabilities into system definition to unifying user experience across physical and digital worlds.

Wireless communication systems it is customary to apply power control. The transmission power of terminal devices is controlled. For example, an open loop or a closed loop power control scheme may be used. The network element the terminal devices are connected to may transmit power control commands to the terminal devices. The purpose of power control is to reduce interference to the connections of other terminal devices, to external devices and reduce the power consumption of the terminal devices. However, the quality of the link between the terminal device and the network element is also taken into account. Power control may be used, for example, to cause a terminal device to adjust its transmission power on the uplink to enable the receiving network

element to achieve a minimum signal quality (such as, signal-to-interference plus noise ratio (SINR) for example) for the signals received from the terminal device.

The terminal device may have been given a maximum transmission power. The terminal device may be configured to determine its power headroom as a difference between its allowed maximum transmission power and its current transmission power. In some cases, the terminal device may report its current transmission power, power headroom, and/or maximum allowed transmission power to the network element. The terminal device may use a given transmission power, and the network element may measure signal quality (such as SINR, for example) of the received signal.

In an embodiment, the network element may transmit an uplink grant (or uplink resource allocation) that may comprise a transmit power control (TPC) command, which may be used to request the UE to increase or decrease its transmission power, for example, to meet a desired SINR. Power control may also be used to decrease radio interference with other wireless devices and/or to reduce power consumption by the UE. For example, in poor propagation conditions are poor, such as when multi-path fading is present, the network element may request the terminal device to increase its transmission power. Thus, for example, the terminal device may vary its transmission power within a range up to its maximum allowed transmission power, e.g., based on power control commands from the network element. However, if the terminal device is already transmitting at its maximum allowed transmission level, this means its power headroom is zero, and the terminal device is unable to further increase its transmission power.

A maximum power reduction (MPR), or a MPR value, may be a value or an amount that a terminal device reduces its maximum transmission power to meet certain unwanted emission limits. A terminal device may determine a MPR value, and then may adjust (decrease) its maximum transmission power by the MPR value, which also correspondingly decreases its power headroom. The terminal device may, for example, report to a network element it is connected to the current transmission power of the terminal device, the (MPR-adjusted) maximum transmission power of the terminal device, and/or the power headroom of the terminal device.

In cellular communication systems, such as LTE, 5G or NR, or 6G, the network allocates transmission resources to the terminal devices of the system. For example, a terminal device may receive from a network element it is connected to a resource block allocation for uplink transmission that may include one or more

resource blocks within a frequency channel, such as within a frequency channel assigned to the terminal device and/or the network element. Furthermore, one or more resource allocation regions (such as an inter-modulation or IMD3 region and/or regrowth region) may be indicated or determined for which a resource block allocation within the resource allocation region may require an additional maximum power reduction for the terminal device in order to reduce interference to a protected frequency range.

As mentioned, a maximum power reduction MPR may be applied to a terminal device for uplink transmissions. In addition, an additional (or further) maximum power reduction, A-MPR, may be applied for the terminal device transmission power. The A-MPR may be applied, for example, if the resource blocks allocated to the terminal device for uplink transmission are within the above-mentioned resource allocation region, or the used frequency channel has a frequency offset from an edge of a protected frequency band that is less than a given threshold frequency offset of the resource allocation region. For example, a frequency offset of the frequency channel may be measured from an edge of the protected frequency band to an edge of the frequency channel of the terminal device. Thus, for example, in some cases, no additional MPR (or less additional MPR) may be necessary to the terminal device in a case where the frequency channel assigned to the terminal device and network element for communication is a sufficient distance (e.g., at least a threshold frequency offset away) from the edge of the protected frequency band.

Figs. 2A and 2B illustrate examples of uplink operating band and a protected frequency range. Fig. 2A illustrates an example, where the protected frequency range 200, is below the uplink operating band 202. Fig. 2B illustrates an example, where the protected frequency range 200, is above the uplink operating band 202. The uplink operating band 202 comprises a frequency channel 204 assigned to the terminal device. The channel in turn comprises guard bands 206A, 206B, unallocated resource blocks 208A, 208B, 208C and I/Q image 210 and resource blocks 212 allocated to the terminal device. The bandwidth of the resource blocks 212 allocated to the terminal device may be denoted as BW_{alloc} .

In an embodiment, a total guard bandwidth 214 may be defined as the shortest frequency distance between an edge of frequency range 212 allocated to uplink signal of the terminal device and an edge of a frequency range 200 to be protected from interference.

In an embodiment, the total guard bandwidth 214 comprises the

frequency distance 216 between the protected frequency range 200 edge and the uplink operating band 202 edge.

In an embodiment, the total guard bandwidth 214 comprises the frequency distance 218 between the uplink operating band 202 edge and transmitting channel 204 edge.

In an embodiment, the total guard bandwidth comprises the guard band 206A within transmitting channel 204 bandwidth and frequency distance 220 between transmission bandwidth configuration edge and the edge of frequency range 212 allocated to uplink signal of the terminal device.

Currently, only one A-MPR value is defined for each power class of terminal devices modulation/waveform combination when certain conditions are fulfilled for the transmitting channel edge, the starting resource block index, and the allocation bandwidth (the number of contiguously allocated resource blocks of the resource block allocation, L_{CRB}) for the transmission.

The resource block allocation for the transmission that require A-MPR can be divided into the following regions (here the protected frequency range is below the UL operating band):

Edge region: narrow allocations at lower channel edge, with linear spectral regrowth hitting the additional spurious emissions; this region requires the largest A-MPR values.

Regrowth region: wide allocations at or near lower channel edge with spectral regrowth causing additional spurious emissions.

IMD3 region: narrow allocations near the lower channel edge with third order intermodulation distortion, IMD3, (of allocation and its image) causing the additional spurious emissions.

CIM3 region: narrow allocations near the upper channel edge with third order counter intermodulation, CIM3, causing additional spurious emissions.

Fig. 3 illustrates an example of allocation regions. On the x-axis is the RB start, or resource block index of lowest allocated resource block of resource block allocation within frequency channel. On the y-axis is L_{CRB} , or the number of contiguously allocated resource blocks of the resource block allocation. The figure shows regrowth region 300, IMD3 region 302, and CIM3 region 304. MPR 306 indicates the region where A-MPR is not applicable. The edge region is in this example too small to be visible in the figure.

It has been shown in literature, as Table 1 below illustrates, that the allowed A-MPR values required in each of the above regions for a Power Class 1,

PC1, terminal device in band n41 would be 11 dB if the current way of defining A-MPR for PC3, PC2 and PC1.5 terminal device where only one allowed MPR value is defined for each modulation/waveform is applied to a PC1 terminal device.

Modulation/Waveform		A-MPR (dB)			
		Edge region	IMD3 region	CIM3 region	Regrowth region
DFT-s-OFDM	Pi/2-BPSK	≤ 11	≤ 2	N/A	≤ 3.5
	QPSK	≤ 11	≤ 2	N/A	≤ 4.0
	16 QAM	≤ 11	≤ 2.5	≤ 2.0	≤ 4.0
	64 QAM	≤ 11	≤ 3	≤ 3.0	≤ 4.0
	256 QAM	≤ 11	N/A	N/A	N/A
CP-OFDM	QPSK	≤ 11	≤ 2.5	≤ 10.5	≤ 6.0
	16 QAM	≤ 11	≤ 3	≤ 10.5	≤ 6.0
	64 QAM	≤ 11	N/A	≤ 10.5	≤ 6.0
	256 QAM	≤ 11	N/A	≤ 11	N/A

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Table 1: Maximum A-MPR values for PC1

On the other hand, it has been shown in literature that there is a large proportion of transmit configurations (modulation, starting resource block, allocation bandwidth) that could require significantly lower A-MPR values in the regrowth region than those shown in the rightmost last column of Table 1 above. It has been noticed that more than 21% and 46% of transmit configurations do not require A-MPR in the regrowth region for modulation/waveform CP-OFDM and DFT-s-OFDM, respectively.

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Fig. 4 illustrates output power back-off, OBO [dB], in regrowth region versus total guard bandwidth TGBW [MHz] and allocation bandwidth BW_{alloc}[MHz] when QPSK/CP-OFDM is applied. It can be seen in that the required output power back-off in the regrowth region to meet the NS_04 additional spectrum emission mask limits vary with the allocation bandwidth and the total guard bandwidth for QPSK/CP-OFDM. It may be noted that the lines 400, 402, 404, 406, 408, 410 are the output power back-off contour lines in 1 dB step. Therefore, in this example there is a maximum of 6 dB difference for the required output power back-off for QPSK/CP-OFDM resource block allocation in the regrowth region. This can be explained by the rationale that a larger allocation bandwidth will lead to a larger regrowth region (requiring a higher output power back-off), while a higher transmit filter rejection can be achieved with a larger total guard bandwidth (requiring a lower output power back-off).

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Therefore, applying the prior art way of defining A-MPR for PC3, PC2 and PC1.5 UE to PC1 UE would allow 6 dB more output power back-off than

necessary in the regrowth region, which in turn would lead to 6 dB uplink coverage loss.

Fig. 5 is a top-down view of Fig. 4. It can be seen, that for each line 400, 402, 404, 406, 408, 410 which denotes a certain level (in 1 dB step) of the required output power back-off, a higher level of output power back-off is required when the total guard bandwidth is on the left-hand-side of the line each 400, 402, 404, 406, 408, 410. For example, >0 dB output power back-off is required with 10 MHz allocation bandwidth when total guard bandwidth is smaller than 5 MHz, and >1 dB output power back-off is required with 60 MHz allocation bandwidth when total guard bandwidth is smaller than 30 MHz.

In mathematical terms, each line 400, 402, 404, 406, 408, 410 in Figs. 4 and 5 can be represented as a function $G_A(BW_{alloc})$ mapping the allocation bandwidth (BW_{alloc}) to a minimum total guard bandwidth (TGBW) above which the corresponding level of output power back-off suffices.

Therefore, to keep A-MPR as small as possible, it is proposed to define the allowed A-MPR values for each modulation/waveform for PC1 UE in band n41 with NS_04 separately in each region (edge, regrowth, IMD3, and CIM3) and define the allowed A-MPR values in the edge, IMD3 and CIM3 regions as functions of the starting resource block and the allocation bandwidth.

In an embodiment, uplink bandwidth allocated to a terminal device is determined, total guard bandwidth is determined as the shortest frequency distance between an edge of frequency range allocated to uplink signal of the terminal device and an edge of a frequency range to be protected from interference, and the additional maximum power reduction values for the terminal device are selected based on the determination.

In an embodiment, the additional maximum power reduction values for the terminal device are selected based on mapping or functions mapping the uplink bandwidth allocated to a terminal device to a total guard bandwidth threshold below which a higher level of output power reduction is allowed.

In an embodiment, the allowed A-MPR values in the regrowth region can be defined as illustrated in Table 2:

TGBW range	A-MPR (dB)
$G_{0dB}(BW_{alloc}) \leq TGBW$	0
$G_{1dB}(BW_{alloc}) \leq TGBW < G_{0dB}(BW_{alloc})$	1
$G_{2dB}(BW_{alloc}) \leq TGBW < G_{1dB}(BW_{alloc})$	2
$G_{3dB}(BW_{alloc}) \leq TGBW < G_{2dB}(BW_{alloc})$	3

$G_{4dB}(BW_{alloc}) \leq TGBW < G_{3dB}(BW_{alloc})$	4
$G_{5dB}(BW_{alloc}) \leq TGBW < G_{4dB}(BW_{alloc})$	5
$TGBW < G_{5dB}(BW_{alloc})$	6

Table 2

In an embodiment, Table 2 can be expressed as an if-then-else statement:

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5      If TGBW >= G0dB(BWalloc)
      then A-MPR = 0 dB,
      else, if TGBW >= G1dB(BWalloc)
      then A-MPR = 1 dB,
      else, if TGBW >= G2dB(BWalloc)
10     then A-MPR = 2 dB,
      else, if TGBW >= G3dB(BWalloc)
      then A-MPR = 3 dB,
      else, if TGBW >= G4dB(BWalloc)
      then A-MPR = 4 dB,
15     else, if TGBW >= G5dB(BWalloc)
      then A-MPR = 5 dB,
      else, A-MPR = 6 dB.

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In an embodiment, Table 2 can be expressed as a Nested-if-then-else statement to minimize the count of function evaluations:

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20     If TGBW >= G3dB(BWalloc),
      then
        if TGBW >= G1dB(BWalloc),
          then
            if TGBW >= G0dB(BWalloc),
25             then A-MPR = 0 dB,
            else, A-MPR = 1 dB,
          else,
            if TGBW >= G2dB(BWalloc),
30             then A-MPR = 2 dB,
            else, A-MPR = 3 dB,
        else,
          if TGBW >= G5dB(BWalloc),
          then
            if TGBW >= G4dB(BWalloc),
35             then A-MPR = 4 dB,
            else, A-MPR = 5 dB,
          else, A-MPR = 6 dB.

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Above, $G_A(BW_{\text{alloc}})$ is the required total guard bandwidth TGBW for A-MPR value A, and BW_{alloc} is the bandwidth of resource blocks allocated to a terminal device.

Furthermore, the invention can also be applied to UE of other PCs or in other LTE or NR bands or to 6G. Note that the specific 1 dB steps in the embodiments are for example only, and other steps like 0.5 dB may be defined. A more general form may be expressed as

if $TGBW \geq G_{(0)\text{dB}}(BW_{\text{alloc}})$
 then A-MPR = 0 dB,
 10 else, if $TGBW \geq G_{(i)\text{dB}}(BW_{\text{alloc}})$
 then A-MPR = i dB,
 else, if $TGBW \geq G_{(2i)\text{dB}}(BW_{\text{alloc}})$
 then A-MPR = 2i dB,
 else, if $TGBW \geq G_{(3i)\text{dB}}(BW_{\text{alloc}})$
 15 then A-MPR = 3i dB,
 else, if $TGBW \geq G_{(4i)\text{dB}}(BW_{\text{alloc}})$
 then A-MPR = 4i dB,
 else, if $TGBW \geq G_{(5i)\text{dB}}(BW_{\text{alloc}})$
 then A-MPR = 5i dB,
 20 else, A-MPR = 6i dB
 where

$G_i(BW_{\text{alloc}})$ is the required total guard bandwidth TGBW for A-MPR value i, i being a positive integer or fractional number and BW_{alloc} is the bandwidth of resource blocks allocated to a terminal device.

25 In an embodiment, for NS_04, A-MPR is not added to MPR. Also, when NS_04 is signalled, MPR may be set to zero in the P_{CMAX} equations to avoid double counting MPR.

For Power Class 3, allowed maximum power reduction is defined as A-MPR = max(MPR, A-MPR'),
 30 Note that A-MPR' = 0 dB means only MPR is applied, where A-MPR' is defined as

if $RB_{\text{start}} \leq f_{\text{start,max,IMD3}} / (12 \cdot \text{SCS})$ and $L_{\text{CRB}} \leq AW_{\text{max,IMD3}} / (12 \cdot \text{SCS})$ and $F_c - BW_{\text{Channel}}/2 < F_{\text{UL_low}} + \text{offset}_{\text{IMD3}}$,
 then
 35 the A-MPR' is defined according to Table 6.2.3.2-2
 PC3_A2 relative to 23 dBm for power class 3, PC2_A4
 relative to 26 dBm for power class 2, and PC1.5_A6
 relative to 29 dBm for power class 1.5,

else,
 if $RB_{start} \leq L_{CRB}/2 + \Delta_{start} / (12 \cdot SCS)$ and $L_{CRB} \leq AW_{max, regrowth} / (12 \cdot SCS)$ and $F_C - BW_{Channel}/2 < F_{UL_low} + offset_{regrowth}$,
 then
 5 the A-MPR' is defined according to Table 6.2.3.2-2
 PC3_A1 relative to 23 dBm for power class 3, PC2_A3
 relative to 26 dBm for power class 2, , and PC1.5_A5
 relative to 29 dBm for power class 1.5,
 else
 10 A-MPR' = 0 dB and apply MPR.

The parameters above are defined in Table 3 (corresponding to Table 6.2.3.2-1 of 3GPP TS 38.101-1).

Parameter	Symbol	Value		Related condition
		CP-OFDM	DFT-s-OFDM	
Max allocation start in IMD3 region	$f_{start,max,IMD3}$	0.33 $BW_{Channel}$		$RB_{start} \leq f_{start,max,IMD3} / (12SCS)$
Max allocation BW in IMD3 region	$AW_{max,IMD3}$	4 MHz		$L_{CRB} \leq AW_{max,IMD3} / (12SCS)$
Freq. offset required to avoid A-MPR in IMD3 region	$offset_{IMD3}$	$BW_{Channel} - 6$ MHz		$F_C - BW_{Channel}/2 \geq F_{UL_low} + offset_{IMD3}$
Right edge of regrowth region	Δ_{start}	0.08 $BW_{Channel}$		$RB_{start} \leq L_{CRB}/2 + \Delta_{start} / (12SCS)$
Max allocation BW in regrowth region	$AW_{max,regrowth}$	100 MHz		$L_{CRB} \leq \min(L_{CRB,Max}, AW_{max,regrowth} / (12SCS))$
Freq. offset required to avoid A-MPR in regrowth region	$offset_{regrowth}$	Max (10 MHz, 0.25* $BW_{Channel}$ MHz)	Max (10 MHz, 0.45* $BW_{Channel}$ MHz)	$F_C - BW_{Channel}/2 \geq F_{UL_low} + offset_{regrowth}$

Table 3

15 In an embodiment, for PC1, NS_04 the value for A-MPR may be defined as A-MPR = max(MPR, A-MPR_{regrowth}, A-MPR_{IMD3}, A-MPR_{CIM3}, A-MPR_{edge}).

In an embodiment, the value for A-MPR_{regrowth} may be obtained from above Table 2 in terms of the total guard bandwidth, TGBW. As mentioned, the TGBW may be defined as the frequency distance between the resource block
 20 allocation and additional spurious emission limit, and may also be expressed as

$$TGBW = f_{alloc,low} - 2496 \text{ MHz},$$

where

$$f_{alloc,low} = F_C - \frac{BW_{Channel}}{2} + BW_{GB} + RB_{start} \cdot 12 \text{ SCS} \quad \text{Eq.1)}$$

25

is the lower edge frequency of the resource block allocation. F_C is the channel centre frequency, $BW_{Channel}$ is the channel bandwidth and BW_{GB} is the

minimum guard bandwidth defined in Table 5.3.3.-1 of 3GPP TS 38.101-1, as follows in Table 4. SCS is subcarrier spacing.

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	35 MHz	40 MHz	45 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
15	242.5	312.5	382.5	452.5	522.5	592.5	572.5	552.5	712.5	692.5	N/A	N/A	N/A	N/A	N/A
30	505	665	645	805	785	945	925	905	1065	1045	825	965	925	885	845
60	N/A	1010	990	1330	1310	1290	1630	1610	1590	1570	1530	1490	1450	1410	1370

Table 4

In Table 2, each function $G_A(BW_{alloc})$ defines the required total guard bandwidth for A-MPR value A. In an embodiment, G_A may be defined utilising a second order polynomial function of the uplink bandwidth. As an example, G_A may be defined as

$$G_A(BW_{alloc}) = \max(0, C_2 \left(\frac{BW_{alloc}}{100\text{MHz}}\right)^2 + C_1 \frac{BW_{alloc}}{100\text{MHz}} + C_0), \quad \text{Eq.2}$$

where $BW_{alloc} = L_{CRB} \cdot 12 \text{ SCS}$ is the allocation bandwidth, L_{CRB} is the number of contiguously allocated resource blocks of the resource block allocation, and C_2 , C_1 , and C_0 . C_2 , C_1 , and C_0 are constants defined for combinations of waveform, modulation, and total guard bandwidth threshold values. They may be obtained from Table 5 below, for example, for each combination of waveform, modulation, and total guard bandwidth threshold value A. Table 5 below illustrates polynomial coefficients for determining the required total guard bandwidth for each value of A-MPR_{regrowth}.

In an embodiment, for both OFDM and DFT-S-OFDM,

$$A\text{-MPR}_{\text{IMD3}} = \max\left(0, \min\left(3, 4 - 2.77 \frac{BW_{alloc}}{1 \text{ MHz}}\right)\right) \text{ dB},$$

if $3f_{alloc,low} - 2f_{CL} \leq 2490.5 \text{ MHz}$; otherwise, $A\text{-MPR}_{\text{IMD3}} = 0 \text{ dB}$.

Here, f_{CL} is the carrier frequency (which may differ from the center frequency of the channel or bandwidth part).

In an embodiment, for OFDM,

$$A\text{-MPR}_{\text{CIM3}} = \max\left(0, \min\left(11, 12 - 2 \frac{BW_{alloc}}{1 \text{ MHz}}\right)\right) \text{ dB},$$

if $4f_{CL} - 3f_{alloc,high} \leq 2490.5 \text{ MHz}$; otherwise, $A\text{-MPR}_{\text{CIM3}} = 0$.

In an embodiment, for DFT-S-OFDM,

$$A\text{-MPR}_{\text{CIM3}} = 3 \text{ dB},$$

if $BW_{alloc} \leq 1.08 \text{ MHz}$ and $4f_{CL} - 3f_{alloc,high} \leq 2490.5 \text{ MHz}$; otherwise, $A\text{-MPR}_{\text{CIM3}} = 0$.

Here, $f_{alloc,high} = f_{alloc,low} + BW_{alloc}$ are defined as the upper edge frequency of the RB allocation.

In an embodiment, for both OFDM and DFT-S-OFDM,

of the terminal device and an edge of a frequency range to be protected from interference.

In step 602, one or more total guard bandwidth threshold values are determined using a second order polynomial function where the uplink bandwidth
5 allocated to a terminal device is used as a parameter.

In step 604, the one or more total guard bandwidth are compared to the one or more total guard bandwidth threshold value.

In step 606 the additional maximum power reduction values for the terminal device are selected based on the comparison.

10 In an embodiment, the additional maximum power reduction values for the terminal device are selected based on mapping of the uplink bandwidth allocated to a terminal device to a total guard bandwidth threshold below which a higher level of output power reduction is allowed.

Fig. 6B is a flowchart illustrating an embodiment. It illustrates the operation of an apparatus applying an embodiment. It may be noted that any
15 numerical values below are only non-limiting examples of possible values.

As mentioned above, in step 602 a set of total guard bandwidth threshold values G_i are selected.

20 In an embodiment, each threshold value being associated with an additional maximum power reduction value of a set of additional maximum power reduction values of different sizes, where the value of threshold increases as the value of the additional maximum power reduction value increases.

In an embodiment, threshold values are calculated utilizing Equation 2 and Table 3.

25 In the example of Table 3, there are additional maximum power reduction values of 0, 1, 2, 3, 4, 5 and 6 dB, thus there are values G_i , where i goes from 0 to 5.

30 In an embodiment, the total guard bandwidth is compared to a threshold value being associated with the smallest additional maximum power reduction value of the set.

Thus, in step 610 index i is set to an initial value of 0.

In step 612, the total guard bandwidth TGBW is first compared to a threshold value G_0 .

35 If the threshold is smaller than GBW, then the corresponding A-MPR value is selected in step 614.

If the threshold is not smaller than GBW, then i is increased with one in

step 616.

In step 618 it may be checked whether i has exceeded its maximum value. In this example 5. In such a case the maximum value for A-MPR is selected in step 614. If not, the process continues in step 612, where the next threshold value
5 being associated with the next largest additional maximum power reduction value is compared to the TGBW.

In an embodiment, the additional maximum power reduction values for the terminal device are selected when the uplink bandwidth allocated to the terminal device is inside a resource allocation regrowth region where spectral
10 regrowth causes spurious emissions.

The blocks, related functions, and information exchanges (messages) described above by means of Figure 6A and 6B are in no absolute chronological order, and some of them may be performed simultaneously or in an order differing from the given one. Other functions can also be executed between them or within
15 them, and other information may be sent, and/or other rules applied. Some of the blocks or part of the blocks or one or more pieces of information can also be left out or replaced by a corresponding block or part of the block or one or more pieces of information.

Fig. 7A illustrates an embodiment. The figure illustrates a simplified example of an apparatus applying embodiments of the disclosure. In some embodiments, the apparatus is a network element or node. In some embodiments, the apparatus may be an (e/g)NodeB, or a part of a (e/g)NodeB of a communication system. In an embodiment, the apparatus is a network apparatus separate from an (e/g)NodeB.
20

It should be understood that the apparatus is depicted herein as an example illustrating some embodiments. It is apparent to a person skilled in the art that the apparatus may also comprise other functions and/or structures and not all described functions and structures are required. Although the apparatus has been depicted as one entity, different modules and memory may be implemented in one
25 or more physical or logical entities.

The apparatus of the example includes a control circuitry 700 configured to control at least part of the operation of the network element.

The network element may comprise a memory 702 for storing data. Furthermore, the memory may store software 704 executable by the control
35 circuitry 700. The memory may be integrated in the control circuitry.

The network element may comprise one or more interface circuitries 706, 708. The interface circuitries are operationally connected to the control circuitry 700. An interface circuitry 706 may be a set of transceivers configured to communicate with terminal devices of a wireless communication network. The interface circuitry may be connected to an antenna arrangement (not shown). The network element may also comprise a connection to a transmitter instead of a transceiver.

An interface circuitry 708 may connect the apparatus to other network elements in a wired or wireless manner, for example to network elements of the communication system. The network elements may be network elements responsible for OAM, NWDAF or MDAF in the system, for example.

In an embodiment, the software 704 may comprise a computer program comprising program code means configured to cause the control circuitry 700 of the network element to realize at least some of the embodiments described above.

In an embodiment, as shown in Fig. 7B, at least some of the functionalities of the apparatus of Fig. 7A may be shared between two physically separate devices, forming one operational entity. Therefore, the apparatus may be seen to depict the operational entity comprising one or more physically separate devices for executing at least some of the described processes. Thus, the apparatus of Fig. 7B, utilizing such shared architecture, may comprise a remote control unit RCU 720, such as a host computer or a server computer, operatively coupled (e.g. via a wireless or wired network) to a remote distributed unit RDU 722 located in the base station. In an embodiment, at least some of the described processes may be performed by the RCU 720. In an embodiment, the execution of at least some of the described processes may be shared among the RDU 722 and the RCU 720.

In an embodiment, the RCU 720 may generate a virtual network through which the RCU 720 communicates with the RDU 722. In general, virtual networking may involve a process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization may involve platform virtualization, often combined with resource virtualization. Network virtualization may be categorized as external virtual networking which combines many networks, or parts of networks, into the server computer or the host computer (e.g. to the RCU). External network virtualization is targeted to optimized network sharing. Another category is internal virtual networking

which provides network-like functionality to the software containers on a single system. Virtual networking may also be used for testing the terminal device.

In an embodiment, the virtual network may provide flexible distribution of operations between the RDU and the RCU. In practice, any digital
5 signal processing task may be performed in either the RDU or the RCU and the boundary where the responsibility is shifted between the RDU and the RCU may be selected according to implementation.

As used in this application, the term 'circuitry' may refer to one or more or all of the following: (a) hardware-only circuit implementations, such as
10 implementations in only analog and/or digital circuitry, and (b) combinations of hardware circuits and software (and/or firmware), such as (as applicable): (i) a combination of analog and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software, including digital
15 signal processor(s), software, and memory(ies) that work together to cause an apparatus, such as a terminal device or an access node, to perform various functions, and (c) hardware circuit(s) and processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g. firmware) for operation, but the software may not be present when it is not needed
20 for operation. This definition of 'circuitry' applies to all uses of this term in this application, including any claims. As a further example, as used in this application, the term 'circuitry' also covers an implementation of merely a hardware circuit or processor (or multiple processors) or a portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term 'circuitry' also covers, for example and if applicable to the particular claim element, a baseband
25 integrated circuit for an access node or a terminal device or other computing or network device.

Embodiments as described may also be carried out in the form of a computer process defined by a computer program or portions thereof. Embodiments of the methods described in connection with Figures 2 to 6 may be
30 carried out by executing at least one portion of a computer program comprising corresponding instructions. The computer program may be provided as a computer readable medium comprising program instructions stored thereon or as a non-transitory computer readable medium comprising program instructions stored thereon. The computer program may be in source code form, object code
35 form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. For example,

the computer program may be stored on a computer program distribution medium readable by a computer or a processor. The computer program medium may be, for example but not limited to, a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. The computer program medium may be a non-transitory medium. Coding of software for carrying out the embodiments as shown and described is well within the scope of a person of ordinary skill in the art.

Even though the embodiments have been described above with reference to examples according to the accompanying drawings, it is clear that the embodiments are not restricted thereto but can be modified in several ways within the scope of the appended claims. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Further, it is clear to a person skilled in the art that the described embodiments may, but are not required to, be combined with other embodiments in various ways.

CLAIMS

1. An apparatus comprising:
means for determining total guard bandwidth as the shortest frequency distance between an edge of an uplink bandwidth allocated to uplink signal of a terminal device and an edge of a frequency range to be protected from interference;
5 means for determining one or more total guard bandwidth threshold values using a second order polynomial function where the uplink bandwidth is used as a parameter;
means for comparing the total guard bandwidth to the one or more total
10 guard bandwidth threshold values;
means for selecting the additional maximum power reduction value for the terminal device based on the comparison.
2. The apparatus of claim 1, further comprising:
15 means for determining a set of total guard bandwidth threshold values, each threshold value being associated with an additional maximum power reduction value of a set of additional maximum power reduction values of different sizes, where the value of threshold decreases as the value of the additional maximum power reduction value increases.
- 20 3. The apparatus of claim 2, further comprising:
means for comparing the the total guard bandwidth to a threshold value being associated with the smallest additional maximum power reduction value of the set, and
25 if the threshold value is smaller, then selecting the smallest additional maximum power reduction value as the additional maximum power reduction value for the terminal device;
and if the threshold value is not smaller, then performing the comparison of the total guard bandwidth to a threshold value being associated with
30 the next largest additional maximum power reduction value of the set, until a smaller threshold value is found and selecting the corresponding additional maximum power reduction value as the additional maximum power reduction value for the terminal device, or all values in the set of thresholds have been compared and selecting the largest additional maximum power reduction value as
35 the additional maximum power reduction value for the terminal device.

4. The apparatus of any preceding claim, further comprising:
 means for selecting the additional maximum power reduction value for
 the terminal device when the uplink bandwidth allocated to the terminal device is
 inside a resource allocation regrowth region where spectral regrowth causes
 5 spurious emissions.

5. The apparatus of any preceding claim, wherein the total guard
 bandwidth comprises
 the frequency distance between the protected frequency range edge
 10 and the uplink operating band edge, the frequency distance between the uplink
 operating band edge and transmitting channel edge, the guard band within
 transmitting channel bandwidth and frequency distance between transmission
 bandwidth configuration edge and the edge of frequency range allocated to uplink
 signal of the terminal device.

15 6. The apparatus of any preceding claim, further comprising:
 determining one or more total guard bandwidth threshold values using
 a function $G_A(BW_{alloc}) = \max(0, C_2 \left(\frac{BW_{alloc}}{100\text{MHz}}\right)^2 + C_1 \frac{BW_{alloc}}{100\text{MHz}} + C_0)$, where BW_{alloc} is
 the uplink bandwidth and C_0 , C_1 and C_2 are constants defined for combinations of
 20 waveform, modulation, and total guard bandwidth threshold values.

7. The apparatus of any preceding claim, further comprising:
 means for transmitting to the terminal device a Network Signalling
 value for which the selected additional maximum power reduction value can be
 25 applied.

8. The apparatus of any preceding claim, further comprising:
 means for selecting the additional maximum power reduction value A-
 MPR in regrowth region for the terminal device based on
 30 if $TGBW \geq G_{(0)\text{dB}}(BW_{alloc})$
 then A-MPR = 0 dB,
 else, if $TGBW \geq G_{(1)\text{dB}}(BW_{alloc})$
 then A-MPR = 1 dB,
 else, if $TGBW \geq G_{(2i)\text{dB}}(BW_{alloc})$
 35 then A-MPR = 2i dB,
 else, if $TGBW \geq G_{(3i)\text{dB}}(BW_{alloc})$

then A-MPR = 3i dB,
 else, if $TGBW \geq G_{(4i)dB}(BW_{alloc})$
 then A-MPR = 4i dB,
 else, if $TGBW \geq G_{(5i)dB}(BW_{alloc})$
 5 then A-MPR = 5i dB,
 else, A-MPR = 6i dB
 where
 $G_i(BW_{alloc})$ is the total guard bandwidth threshold value for A-MPR value
 i, i being a positive integer or fractional number and BW_{alloc} is the uplink
 10 bandwidth.

9. The apparatus of any preceding claim, wherein means comprise at least one processor and at least one memory including computer program code.

15 10. A method comprising:
 determining total guard bandwidth as the shortest frequency distance between an edge of an uplink bandwidth allocated to uplink signal of the terminal device and an edge of a frequency range to be protected from interference;
 determining one or more total guard bandwidth threshold values using
 20 a second order polynomial function where the uplink bandwidth is used as a parameter;
 comparing the one or more total guard bandwidth to the one or more total guard bandwidth threshold value;
 selecting the additional maximum power reduction value for the
 25 terminal device based on the comparison.

11. The method of claim 10, further comprising:
 determining a set of total guard bandwidth threshold values, each threshold value being associated with an additional maximum power reduction value of a set of additional maximum power reduction values of different sizes,
 30 where the value of threshold increases as the value of the additional maximum power reduction value increases.

12. The method of claim 11, further comprising:
 35 comparing the the total guard bandwidth to a threshold value being associated with the smallest additional maximum power reduction value of the set,

and

if the threshold value is smaller, then selecting the smallest additional maximum power reduction value as the additional maximum power reduction value for the terminal device;

- 5 and if the threshold value is not smaller, then performing the comparison of the total guard bandwidth to a threshold value being associated with the next largest additional maximum power reduction value of the set, until a smaller threshold value is found and selecting the corresponding additional maximum power reduction value as the additional maximum power reduction value for the terminal device, or all values in the set of thresholds have been compared and selecting the largest additional maximum power reduction value as the additional maximum power reduction value for the terminal device.

13. The method of claim 10, further comprising:

- 15 selecting the additional maximum power reduction values for the terminal device when the uplink bandwidth allocated to the terminal device is inside a resource allocation regrowth region where spectral regrowth causes spurious emissions.

14. The method of any preceding claim 10 to 13, wherein the total guard bandwidth comprises the frequency distance between the protected frequency range edge and the uplink operating band edge,

- the frequency distance between the uplink operating band edge and transmitting channel edge, the guard band within transmitting channel bandwidth and frequency distance between transmission bandwidth configuration edge and the edge of frequency range allocated to uplink signal of the terminal device.

15. The method of any preceding claim 10 to 14, further comprising:

- determining one or more total guard bandwidth threshold values using a function $G_A(BW_{alloc}) = \max(0, C_2 \left(\frac{BW_{alloc}}{100\text{MHz}}\right)^2 + C_1 \frac{BW_{alloc}}{100\text{MHz}} + C_0)$, where BW_{alloc} is the uplink bandwidth and C_0 , C_1 and C_2 are constants defined for combinations of waveform, modulation, and total guard bandwidth threshold values.

16. The method of any preceding claim 10 to 15, further comprising:

- transmitting to the terminal device a Network Signalling value for which the selected additional maximum power reduction value can be applied.

17. The method of any preceding claim 10 to 16, further comprising:
 selecting the additional maximum power reduction value A-MPR in
 regrowth region for the terminal device based on

5 if $TGBW \geq G_{(0)dB}(BW_{alloc})$
 then A-MPR = 0 dB,
 else, if $TGBW \geq G_{(i)dB}(BW_{alloc})$
 then A-MPR = i dB,
 else, if $TGBW \geq G_{(2i)dB}(BW_{alloc})$
 10 then A-MPR = 2i dB,
 else, if $TGBW \geq G_{(3i)dB}(BW_{alloc})$
 then A-MPR = 3i dB,
 else, if $TGBW \geq G_{(4i)dB}(BW_{alloc})$
 then A-MPR = 4i dB,
 15 else, if $TGBW \geq G_{(5i)dB}(BW_{alloc})$
 then A-MPR = 5i dB,
 else, A-MPR = 6i dB
 where
 $G_i(BW_{alloc})$ is the total guard bandwidth threshold value for A-MPR value
 20 i, i being a positive integer or fractional number and BW_{alloc} is the uplink
 bandwidth.

18. A non-transitory computer readable medium comprising program
 instructions for causing an apparatus to perform at least the following:

25 determining total guard bandwidth as the shortest frequency distance
 between an edge of an uplink bandwidth allocated to uplink signal of the terminal
 device and an edge of a frequency range to be protected from interference;
 determining one or more total guard bandwidth threshold values using
 a second order polynomial function where the uplink bandwidth is used as a
 30 parameter;
 comparing the one or more total guard bandwidth to the one or more
 total guard bandwidth threshold value;
 selecting the additional maximum power reduction value for the
 terminal device based on the comparison.

35