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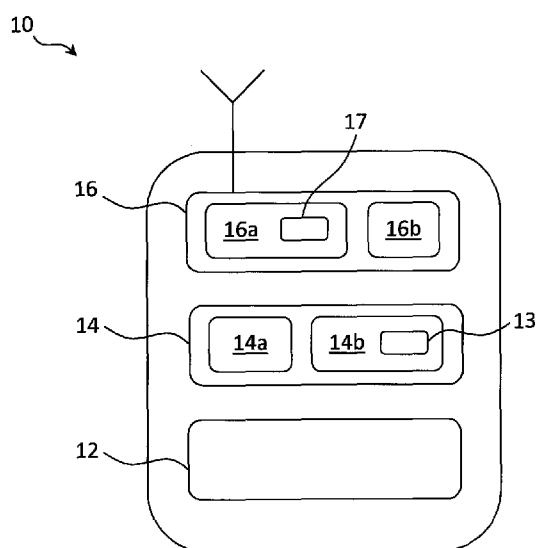
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(54) Title: DEVICE FOR A RADIO COMMUNICATIONS SYSTEM AND METHOD OF OPERATING SUCH DEVICE

Fig. 1



(57) Abstract: The invention relates to a device (10) for a radio communications system (1000), the device comprising: - a processing unit (12); - a memory unit (14); and - a transceiver (16) comprising a transmitter (16a) provided with a power amplifier (17); wherein said device (10) is configurable to: - send (210) a request to a base station (100) of said communications system (1000) for permission of transmission of one or more data symbols, the one or more data symbols being amplified with the power amplifier in an overdrive regime; - receive (212) a grant for such transmission; - amplify (214) the one or more data symbols with the power amplifier of the transmitter in the overdrive regime; and - transmit (216) the one or more data symbols to the base station.

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- 5 **Title: Device for a Radio Communications System and
 Method of Operating such Device**

Specification

10 **Field of the invention**

The present invention relates to a device for a radio communications system, and to a method of operating such device.

The invention further relates to a base station for a radio communications system, and to a method of operating such
15 base station.

Background

One of the key upcoming service trends for communications systems, particularly cellular communications systems, such
20 as e.g. fourth generation, 4G, or fifth generation, 5G, systems, is mission critical communication (MCC). Such kind of services (e.g. for industrial automation or remote controlling of objects) require a very high reliability and typically also low latencies. In conjunction with mobility
25 support, this high reliability requires a good coverage.

Also, these trends and the resulting requirements are not limited to cellular communications systems, but also applicable to e.g. peer-to-peer communications systems, systems supporting ad-hoc communications, and the like.

30 Coverage limitations in conventional systems typically occur in the uplink, e.g. during data transmissions from a device to a base station. Conventional systems try to exploit various sources of diversity to address this issue. Time diversity (e.g., by using HARQ, hybrid-ARQ (automated
35 repeat request)) is often not possible because of latency constraints. Frequency diversity depends on the nature of the radio channel. Spatial diversity depends on the number

5 of available antennas and the decorrelation of their radio channels.

US 2013/044621 A1 discloses self-interference handling in a wireless communication terminal.

Summary

10 In view of this, it is an object of the present invention to provide an improved device and method of operating such device which enable good coverage and high reliability particularly for transmissions to a base station, e.g. for uplink transmissions.

15 Further, it is an object of the present invention to provide an improved base station and method of operating such base station.

Regarding the abovementioned device, according to a first aspect, said object is achieved by said device comprising a
20 processing unit, a memory unit, and a transceiver comprising a transmitter provided with a power amplifier, wherein said device is configurable to: send a request to a base station of said communications system for permission of transmission of one or more data symbols, the one or
25 more data symbols being amplified with the power amplifier in an overdrive regime; receive a grant for such transmission; amplify the one or more data symbols with the power amplifier of the transmitter in the overdrive regime; and transmit the one or more data symbols to the base
30 station.

This advantageously enables to transmit data symbols in uplink data transmissions with increased transmission power as compared to conventional devices due to overdriving said power amplifier. Moreover, as such transmissions are
35 (preferably only) performed if granted by the base station, a coordinated manner of overdriving the power amplifier of the device is provided.

- 5 Also, according to an embodiment, mission critical communication (MCC) services and ultra-reliable low latency communication (URLLC) services, e.g. according to 3GPP standardization, may be provided with good coverage and high reliability.
- 10 According to further embodiments, it is also possible for the device to amplify the one or more data symbols with the power amplifier of the transmitter in the overdrive regime without requesting a permission as mentioned above.
- According to a further embodiment, said one or more data
- 15 symbols are part of a subframe, wherein said device is configurable to transmit the subframe comprising the one or more data symbols to the base station without exceeding a predetermined maximum average device output power per subframe (e.g., +23dBm for an LTE system), where "average"
- 20 refers to temporal averaging of the signal (e.g., for an interval of 1 ms). Thus, the criterion related to said predetermined maximum device output power per subframe is not violated.
- According to a further embodiment, said device is
- 25 configurable to overdrive the power amplifier of the transmitter for amplification of the one or more data symbols within the subframe and to mute transmission of remaining symbols within the subframe. Thus, comparatively important data symbols may profit from the overdriving
- 30 according to the embodiments, and the chances for a reliable uplink data transmission are further increased, while reducing the risk of violating a predetermined admissible maximum average device output power per subframe due to muting said remaining symbols.
- 35 According to a further embodiment, the device is further configurable to send to the base station a priority indication related to the one or more data symbols, whereby

- 5 the base station may be notified on the respective priority and may thus adapt its resource scheduling for related uplink transmissions, particularly also the granting mechanism for data symbols to be sent using the overdrive regime.
- 10 According to a further embodiment, the device is configurable to obey an in-band spectrum emission mask of said communications system for a transmission of data symbols to the base station which are amplified not using said overdrive regime for the power amplifier. And
- 15 additionally, the device is configurable to obey a further spectrum emission mask of the communication system, the further spectrum emission mask being different than the in-band spectrum emission mask for a transmission of data symbols to the base station which are amplified using said
- 20 overdrive regime. In other words, in an operating mode where no overdriving of the power amplifier is used, the device keeps to a predetermined in-band spectrum emission mask (SEM) of said communications system thus not producing any interference due to mask violations of said SEM.
- 25 However, in a different operating mode, which may use the overdrive regime according to the embodiments, the device obeys a further spectrum emission mask. As an example, for such different operating mode, a more relaxed SEM may be provided.
- 30 According to a further embodiment, the further SEM may be defined by standardization and/or instructed to the device by the base station in response to its request for applying the overdrive regime.
- According to an embodiment, the device may be a device for
- 35 a cellular communications network, e.g. a terminal for a cellular communications network.

5 According to a further embodiment, the device may be a terminal compatible with the Long Term Evolution, LTE, or LTE Advanced, LTE-A, standard. Hence, the device may be configured to operate according to the LTE standard (3GPP, Third Generation Partnership Project, standardization
10 Releases 8, 9) or LTE-A standard (3GPP standardization Releases 10, 11, 12 and above), with the exception of the application of the principle according to the embodiments. Likewise, according to an embodiment, the base station may be a base station for said cellular communications network,
15 e.g. according to the LTE or LTE-A standard, and may correspondingly be compatible with the LTE or LTE-A standard, again with the exception of the application of the principle according to the embodiments.

Examples of standardization documents related to the LTE
20 standard and the LTE-A standard as well as further systems as referred to herein are the following documents:

[1] 3GPP TS 36.211 V12.6.0, June 2015; Technical Specification Group Radio Access Network; Evolved Universal
25 Terrestrial Radio Access (E-UTRA); Physical channels and modulation,

[2] 3GPP TS 36.300 V12.7.0, September 2015; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal
30 Terrestrial Radio Access Network (E-UTRAN); Overall description,

[3] 3GPP TS 36.331 V12.7.0, September 2015; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control
35 (RRC),

[4] 3GPP TS 36.213 V12.6.0, June 2015; Technical Specification Group Radio Access Network; Evolved Universal

5 Terrestrial Radio Access (E-UTRA); Physical layer procedures,

[5] 3GPP TS 23.203 V12.11.0, December 2015; Technical Specification Service Architecture; Policy and charging control architecture,

10 [6] Recommendation ITU-R M.2083: IMT Vision - "Framework and overall objectives of the future development of IMT for 2020 and beyond".

A technical summary of 5G systems as referred to herein is provided by "Understanding 5G: Perspectives on future
15 technological advancements in mobile", Analysis, December 2014; available in the World Wide Web at <https://gsmaintelligence.com/research/?file=141208-5g.pdf&download> from GSMA Intelligence.

It is noted that the principle according to the embodiments
20 is also applicable to more recent (and also future) versions of these documents and standards, respectively.

It is noted that the principle according to the embodiments is also applicable to other system architectures and radio communications systems than cellular communications
25 systems, where a base station can receive the mentioned request and issue a corresponding grant, respectively.

In addition to its compatibility with the LTE or LTE-A standard in accordance with the aforementioned embodiment, the device according to the embodiments is configurable
30 and/or configured to perform the method according to the embodiments thus enhancing the conventional system by the functionality according to the embodiments, i.e. using the overdrive regime for amplifying said one or more data symbols.

35 In the context of the present application, the expression "configurable" defines that the device may include at least

5 one operating mode in which the device is acting according to at least one aspect of the embodiments. I.e., according to some embodiments, the device may also comprise further operating mode(s) wherein no functionality in the sense of the embodiments, is provided. This also applies to the base
10 station according to the embodiments.

Particularly, the expression "configurable" also includes a device which is, for example in a static configuration, configured to perform aspects of the embodiments. In addition, the expression "configurable" also includes a
15 device which can be configured (e.g., by a further device such as a base station or other control mechanism, which may e.g. be implemented remotely or locally to the device) to perform aspects of the embodiments, but which comprises at least one operating mode in which it does not perform
20 aspects of the embodiments.

As an example, according to an embodiment, a device may be provided which in a first operating mode acts as a conventional LTE- (or LTE-A- or 5G-) compatible terminal, but which, in a second operating mode, implements aspects
25 according to the embodiments, e.g. employing the overdrive regime for uplink transmission of data symbols, wherein local or remote configuration may control whether the terminal assumes its first or second operation mode.

As an example, when considering a radio communications
30 network using multi-carrier modulated signals, the one or more data symbols may comprise one or more multi-carrier modulated data symbols such as OFDM symbols or the like.

As a further example, in the context of an LTE system, the maximum admissible average signal power for the
35 transmission of data symbols of a subframe is specified to +23dBm, and when applying the principle according to the

5 embodiments, at least some data symbols may be transmitted using a signal power that is greater than +23dBm.

According to a further preferred embodiment, the device is configurable to use said overdrive regime for amplification depending on priority information which characterizes a
10 priority of information associated with said one or more data symbols. According to an embodiment, specific priority information may be associated with a specific service handled by the device.

According to a further embodiment, said device is
15 configurable to perform at least one of the following actions, preferably in order to alter a transmission power for uplink transmissions or in combination with altering said transmission power: modifying a power backoff parameter, modifying a clipping threshold of an RF pre-
20 processing process performed by the transceiver, modifying waveform parameters characterizing at least one signal waveform to be used for said uplink transmissions.

According to a further aspect, the device according to the embodiments may e.g. comprise or constitute at least one of
25 the following: end user equipment, LTE UE (user equipment), M2M (machine-to-machine) device, Smartphone, Mobile terminal, sensor with radio transceiver, 5G transceiver, 5G radio terminal with device-to-device communication support.

According to an aspect, one or more devices according to
30 the embodiments may be present in a radio cell of a cellular communications network, together with one or more conventional, e.g. LTE or LTE-A capable, devices or terminals, respectively. Advantageously, the conventional devices or terminals are not required to be modified in any
35 way to enable the principle according to the embodiments to be applied to the cellular communications network.

5 Further embodiments feature a method of operating a device within a communication system, the method comprising: - sending, via a transmitter of the device, a request to a base station of said communications system for permission of transmission of one or more data symbols, the one or
10 more data symbols being amplified with a power amplifier of the transmitter in an overdrive regime; - receiving a grant for such transmission; - amplifying the one or more data symbols with the power amplifier of the transmitter in the overdrive regime; and - transmitting the one or more data
15 symbols.

According to an embodiment, said one or more data symbols are part of a subframe, e.g. an OFDM subframe in case of a communications system using OFDM subframes, and the subframe comprising the one or more data symbols is
20 transmitted to the base station without exceeding a predetermined maximum average device output power per subframe.

According to a further embodiment, the power amplifier of the transmitter is overdriven to amplify the one or more
25 data symbols within the subframe, wherein the remaining symbols within the subframe are muted.

According to a further embodiment, said method may further comprise sending to the base station a priority indication related to the one or more data symbols.

30 Further embodiments feature a base station for a radio communications system, wherein said base station comprises: - a processing unit; - a memory unit; and - a transceiver; wherein said base station is configurable to: - receive a request from a device for permission of transmission of one
35 or more data symbols while overdriving a power amplifier of a transmitter of the device; - verify if such permission can be granted; and - if such permission can be granted,

5 transmit an indication to the device that the transmission of the one or more data symbols while overdriving a power amplifier of a transmitter of the device is allowed.

According to an embodiment, said base station is further configurable to receive a priority indication related to
10 the requested transmission of the one or more data symbols, wherein verifying if such permission can be granted is, at least partially, based on said priority indication.

According to an embodiment, said base station is further configurable to - schedule frequency resources for the one
15 or more data symbols by at least one of selecting frequency resources that have a non-vanishing predetermined minimum frequency spacing from a carrier band edge and scheduling frequency resources for uplink transmissions such that at least one guard carrier is provided adjacent to the
20 frequency resources scheduled for the one or more data symbols; and - sending information regarding the frequency resources scheduled for the one or more data symbols to the device.

Further embodiments feature a method of operating a base
25 station within a communication system, the method comprising: - receiving a request from a device for permission of transmission of one or more data symbols while overdriving a power amplifier of a transmitter of the device; - verifying if such permission can be granted; and
30 - if such permission can be granted, transmitting an indication to the device that the transmission of the one or more data symbols while overdriving a power amplifier of a transmitter of the device is allowed.

According to an embodiment, said method further comprises
35 receiving a priority indication related to the requested transmission of the one or more data symbols, wherein said

5 verifying if such permission can be granted is, at least partially, based on said priority indication.

According to a further embodiment, said method further comprises: - scheduling, for the one or more data symbols, frequency resources that have a non-vanishing predetermined
10 minimum frequency spacing from a carrier band edge; and - sending information regarding the scheduled frequency resources to the device. This way, violation of spectral masks provided by a respective communications standard the communications system is adhering to may be prevented.

15 According to a further embodiment, said method further comprises: - scheduling frequency resources for uplink transmissions such that at least one guard carrier is provided adjacent to the frequency resources scheduled for the one or more data symbols, and - sending information
20 regarding the frequency resources scheduled for the one or more data symbols to the device. By providing the guard carrier(s), it is ensured that no further frequency resources, which are adjacent to the scheduled frequency resources for the device according to the embodiments, will
25 be scheduled, because these further frequency resources could possibly be affected by interference resulting from the use of an "excessive" signal power resulting from overdriving the amplifier according to the embodiments.

According to further embodiments, the functionality of the
30 embodiments explained above with reference to a base station may also at least partly be located within (further) network equipment of a radio communications system.

Brief description of the figures

35 Further features, aspects and advantages of the present invention are given in the following detailed description with reference to the drawings in which:

- 5 Figure 1 schematically depicts a device for a radio
 communications system according to an embodiment,
Figure 2 schematically depicts a radio communications
 system with a device according to an embodiment,
Figure 3A schematically depicts a simplified flow-chart of
10 a method of operating a device according
 to an embodiment,
Figure 3B schematically depicts a simplified flow-chart of
 a method of operating a device according
 to a further embodiment,
15 Figure 4 schematically depicts a base station for a radio
 communications system according to an embodiment,
Figure 5 schematically depicts a simplified flow-chart of
 a method of operating a base station according
 to an embodiment,
20 Figure 6 schematically depicts components of a transmitter
 of a device according to an embodiment, and
Figure 7 schematically depicts a gain of a power amplifier
 over an input power according to an embodiment.

Description of the embodiments

- 25 Figure 1 schematically depicts a device 10 for a radio
communications system according to an embodiment. The
device 10 comprises a processing unit 12 configured to
execute a computer program 13, a memory unit 14, and a
transceiver 16.
- 30 According to an embodiment, the processing unit 12
comprises a digital signal processor (DSP) or general
purpose microprocessor or correspondingly configured field
programmable gate array (FPGA) or an ASIC (application
specific integrated circuit) or the like.

5 According to a further embodiment, the memory unit 14 comprises a RAM (random access memory) 14a and/or ROM (read only memory) 14b and/or other forms of volatile and/or non-volatile memory devices. In one or more memory devices of the memory unit 14, a computer program 13 for executing the
10 steps according to one or more of the present embodiments may be provided.

The transceiver 16 comprises a transmitter 16a and a receiver 16b for data transmission with a further device such as e.g. a base station of a radio communications
15 system. The transmitter 16a comprises a power amplifier 17 for amplifying signals to be transmitted.

Figure 2 schematically depicts a radio communications system 1000 with a device 10 according to an embodiment. The communications system 1000 further comprises a base
20 station 100 serving device 10 and optionally also further devices 10'.

Although the principle according to the embodiments is not limited to cellular radio communications systems, for the further exemplary description it is assumed that the radio
25 communications system 1000 of Fig. 2 is a cellular communications system such as e.g. defined by the LTE or LTE-A standard. Insofar, for the further description, it is assumed that the base station 100 and the devices 10, 10' are compatible with the LTE or LTE-A standard, the devices
30 10, 10' e.g. representing terminals 10, 10' (also denoted as "UE") of the system 1000. Correspondingly, the base station 100 may exchange data with the UEs 10, 10' by means of downlink and/or uplink data transmissions in a per se known manner.

35 In contrast to the further UEs 10', which, according to some embodiments, may be conventional LTE- or LTE-A compatible devices, the device 10, according to an

5 embodiment, is enhanced regarding its functionality with respect to the current LTE- or LTE-A standards to improve reliability for uplink data transmissions from the device 10 to the base station 100.

According to a first aspect, the device 10 is configurable
10 and/or configured to send a request to the base station 100 of said communications system 1000 for permission of transmission of one or more data symbols ds1, ds2, the one or more data symbols being amplified with the power 17
amplifier (Fig. 1) in an overdrive regime, receive a grant
15 for such transmission from the base station 100, amplify the one or more data symbols ds1, ds2 with the power amplifier 17 of the transmitter 16a in the overdrive regime, and transmit the one or more data symbols ds1, ds2 to the base station 100.

20 This advantageously enables to transmit specific data symbols ds1, ds2 with an increased transmission power - as compared to conventional systems - so that the chances for proper signal reception at the base station 100 are increased for said specific data symbols ds1, ds2. This
25 mechanism may e.g. be used for specific services handled by the device 10, for example particularly important services such as MCC or URLLC services.

For other data symbols, the overdrive regime is not required to be used. For these data symbols, a conventional
30 transmission power may be used according to further embodiments.

Advantageously, said overdrive regime is preferably only used by the device 10 if granted by the base station 100 upon said request of the device 10. This way, the base
35 station 100 is notified on a planned transmission with increased transmission power and may take this into consideration in resource scheduling processes.

5 Figure 3A schematically depicts a simplified flow-chart of a method of operating the device 10 according to an embodiment. In a first step 210, the device 10 (Fig. 2) sends a request to a base station 100 for permission of transmission of one or more data symbols, the one or more
10 data symbols being amplified with the power amplifier in an overdrive regime. In step 212, the device 10 receives a grant for such transmission. In step 214, the device 10 amplifies the one or more data symbols with the power amplifier 17 (Fig. 1) of the transmitter 16a in the
15 overdrive regime, and in step 216 the device 10 transmits the one or more data symbols to the base station 100.

According to a further embodiment, said one or more data symbols ds1, ds2 (Fig. 2) are part of a subframe, e.g. an OFDM subframe, and said device 10 is configurable to
20 transmit the subframe comprising the one or more data symbols ds1, ds2 to the base station 100 without exceeding a predetermined maximum average device output power per subframe.

According to a further embodiment, this may e.g. be
25 attained by overdriving the power amplifier 17 (Fig. 1) of the transmitter 16a for amplification of the one or more data symbols ds1, ds2 within the subframe and by muting transmission of remaining data symbols within the subframe. As an example, muting a transmission of remaining symbols
30 may comprise setting to zero the amplitude of a signal corresponding with said remaining symbols. This embodiment is further illustrated by the flow-chart of Fig. 3B. In step 220, the one or more data symbols ds1, ds2 within the subframe are amplified with the power amplifier 17 of the
35 transmitter 16a in the overdrive regime, and in step 222, the transmission of remaining data symbols within the (same) subframe is muted.

5 Figure 7 schematically depicts a gain in dBm of the power amplifier 17 (Fig. 1) over an input power according to an embodiment. As can be seen from Fig. 7, the gain curve C is basically flat for input power values of up to about -13 dBm. Hence, with conventional devices, the first operating point P1 may be chosen for amplification of a signal associated with data symbols to be transmitted to the base station in an uplink direction. Said first operating point P1 is characterized by a specific first backoff value indicated by arrow a1 from the second operating point P2, which indicates the 1dB expansion point. A gain difference is symbolized by arrow a2.

For the overdrive regime as proposed according to the principle of the embodiments, a smaller backoff value - as seen from the second 1dB expansion point P2 - may be chosen, which e.g. leads to the third operating point P3.

In other words, according to a further embodiment, said device 10 (Fig. 2) is configurable to modify a power backoff parameter, e.g. the backoff value a1 as explained above, to implement the overdrive mode.

25 Embodiments of the invention are not limited to power amplifiers with a gain curve comprising an expansion point. It will be understood that a similar scenario may be described for power amplifiers with a compression point instead of an expansion point, i.e. power amplifiers with merely a monotonic decrease of power amplifier gain.

According to an embodiment, modifying the power backoff parameter may comprise reducing its power backoff value in the power amplifier 17 of the transmitter 16a (Fig. 1) by several dB, cf. point P3 of Fig. 7. In this context, Fig. 6 schematically depicts some components of the transmitter 16a, inter alia the power backoff parameter 16a'.

5 While in some embodiments this modification of the power backoff value may increase nonlinearities and error vector magnitude (EVM) and may yield worse spectral properties (e.g. regarding spectral mask fulfillment behavior), this variant is particularly beneficial in that it enables the
10 device 10 (Fig. 2) to efficiently modify its transmission power to attain the overdrive operation in the sense of the embodiments. Also, for transmissions of data symbols e.g. related to services that do not require a particularly high reliability, for example, the device 10 may change back its
15 power backoff value, e.g. by increasing by several dB, for example assuming the first operating point P1 of Fig. 7.

According to further embodiments, the device 10 may also perform at least one of the following actions, preferably in order to alter a transmission power for uplink
20 transmissions or in combination with altering said transmission power for uplink transmissions: modifying a clipping threshold of an RF pre-processing process performed by the transceiver 16 (Fig. 1), modifying waveform parameters characterizing at least one signal
25 waveform to be used for said uplink transmissions.

According to a further embodiment, a clipping threshold of a radio frequency (RF) digital pre-processing stage 16a'' (Fig. 6) of said transmitter 16a of the device 10 (Fig. 1) may be adjusted such that more clipping noise is tolerated.

30 According to a further embodiment, waveform parameters 16a''' (Fig. 6) may be adjusted in order to take into account or at least partly compensate worse signal properties that may result from e.g. modifying the backoff value as mentioned above. According to an embodiment, when
35 a power amplifier (PA) 17 of the transmitter 16a is impairing spectral properties of the signal anyway, windowing or filtering may be skipped at the device 10,

5 increasing a multi-path protection budget and reducing complexity.

Figure 4 schematically depicts a base station 100 for a radio communications system 1000 according to an embodiment. For example, the base station 100 of figure 2
10 may comprise the structure depicted by figure 4. The base station 100 comprises a processing unit 112, a memory unit 114, and a transceiver 116.

Similar to the structure of the device 10 depicted by figure 1, according to an embodiment, the processing unit
15 112 (Fig. 4) of the base station 100 comprises a DSP or general purpose microprocessor or correspondingly configured FPGA or an ASIC or the like.

According to a further embodiment, the memory unit 114 of the base station 10 comprises a RAM 114a and/or ROM 114b
20 and/or other forms of volatile and/or non-volatile memory devices. In one or more memory devices of the memory unit 114, a computer program (not depicted) for executing the steps according to one or more of the present embodiments may be provided.

25 The base station 100 further comprises a transceiver 116 having a transmitter 116a and a receiver 116b for data transmission with a further device 10, 10'.

In the following, a method of operating the base station 100 is explained with reference to the flow-chart of Fig.
30 5. According to an embodiment, in a first step 230, the base station 100 (Fig. 2) receives a request from a device 10 for permission of transmission of one or more data symbols ds1, ds2 while overdriving a power amplifier 17 (Fig. 1) of a transmitter 16a of the device 10. In step 232
35 (Fig. 5) the base station 100 verifies if such permission can be granted (e.g., depending on a cell load and/or interference situation and/or further operational

5 parameters of the base station 100 and/or devices 10, 10' served by said base station 100), and, if such permission can be granted, in step 234 the base station 100 transmits an indication to the device 10 that the transmission of the one or more data symbols ds1, ds2 while overdriving the
10 power amplifier 17 of the transmitter 16a of the device 10 is allowed. In this case, the device 10 may control its PA 17 (Fig. 1) to employ the third operating point P3 (Fig. 7) for the overdrive mode intended to be used for transmission of said one or more data symbols ds1, ds2 to the base
15 station 100.

In some embodiments, the base station indicates that the device 10 is allowed to transmit the one or more data symbols ds1, ds2 while overdriving the power amplifier 17 with time constraints. For example, the base station 100
20 may indicate that overdriving is only allowed for a predetermined period of time and/or at predetermined times. The predetermined period of time may be controlled by means of a timer. Such timer may be configured to run in a processor of the device 10, e.g. processing unit 12, and/or
25 in a processor of the base station 100, e.g. processing unit 112.

According to an embodiment, the base station is further configurable to receive a priority indication related to the requested transmission of the one or more data symbols
30 ds1, ds2, wherein verifying if such permission can be granted is, at least partially, based on said priority indication. Thus, the base station 100 may take into consideration the priority for verifying if such permission can be granted. This may be particularly beneficial if the
35 base station receives different requests of this type from a plurality of devices 10, 10' (Fig. 2).

According to a further embodiment, the base station 100 is further configurable to: - schedule frequency resources for

5 the one or more data symbols ds1, ds2 (Fig. 2) by at least one of selecting frequency resources that have a non-vanishing predetermined minimum frequency spacing from a carrier band edge and scheduling frequency resources for uplink transmissions such that at least one guard carrier
10 is provided adjacent to the frequency resources scheduled for the one or more data symbols; and - sending information regarding the frequency resources scheduled for the one or more data symbols to the device 10. This way, it is ensured that spectral mask requirements are not violated although
15 using the overdrive regime for the amplifier 17 for said one or more data symbols ds1, ds2.

According to further embodiments, for example, if more than one device 10 of the system 1000 according to figure 2 operates in accordance with the embodiments, the base
20 station 100 may perform an optimization process which is e.g. directed to determining which one(s) of a plurality of requesting devices 10 may be allowed to operate its (their) PA 17 in the overdrive regime.

In the following, various aspects and embodiments are
25 disclosed in further detail.

The principle according to the embodiments provides a possibility for deliberately overdriving the power amplifier 17 of the transmitter 16a of the device 10. According to a preferred embodiment, this is done in a
30 managed, signaled and controlled way, and also preferably for a limited time. The control and management of such overdriving may e.g. be performed by the base station 100 as explained above with reference to figure 5.

According to a further embodiment, service-related
35 information may be used to label a device 10, e.g. a UE, as eligible for PA overdriving. E.g., according to an embodiment, the UE 10 (Fig. 2) sends an indicating

5 signaling information to the base station 100 in order to
signal that the current uplink traffic (waiting for uplink
transmission) is of very high priority, which can e.g. be
confirmed by the base station 100.

The base station 100 then can indicate to the UE
10 (preferably in conjunction with a scheduling grant, which
is transmitted in a per se known manner to the UE 10)
whether it is allowed to overdrive its PA - and optionally
also - under which kind of conditions it is allowed to do
so.

15 According to an embodiment, conditions under which
overdriving the PA 17 or using a usually inadmissibly high
transmit power level may be granted may e.g. occur if the
maximum admissible transmit power the device 10 is
originally designed for is expected to be not sufficient
20 for the upcoming transmission to be successful. According
to some embodiments, such determination may be made by the
device 10 and/or the base station 100, preferably depending
on a history of previous uplink data transmissions.

According to a preferred embodiment, the base station 100
25 may schedule the UE 10 not directly at the carrier band
edge in order to prevent violating spectral masks. Instead,
guard frequency band(s) or guard subcarriers may be
provided.

According to a further embodiment, the base station 100 may
30 also leave guard subcarriers to the frequency resources
scheduled for other devices 10' (Fig. 2) to mitigate inter-
carrier interference that may result from non-linearities
effected by PA overdriving according to some embodiments.

According to a further embodiment, the device 10 may apply
35 less complex modulation and coding schemes (e.g. binary
phase shift keying, BPSK), especially for such data
symbols, which may be associated with comparatively

5 important services, which further increases the chances for its uplink transmissions to be successful.

According to a further embodiment, overdriving the PA may be restricted to specific time intervals in order not to impact on overall cell spectral efficiency for too long.

10 Such time intervals may be provided by the device 10 and/or the base station 100.

Also, according to further embodiments, the base station 100 may decide to disallow the PA overdriving, e.g. only allowing it for a limited amount of time for a few high
15 priority UEs 10, but not for other UEs 10'.

A further aspect of the embodiments relates to shifting distortions that may arise from the PA 17 being overdriven (i.e., using a higher average transmission power) into frequency portions of the carrier not being used by a
20 current transmission. In other words, high priority transmissions related to e.g. mission-critical communications services may be enabled at the cost of at least temporarily affecting or even prohibiting other UL transmissions, which are related to services with lower
25 priority.

According to a further embodiment, techniques for shaping a clipping noise such as e.g. content-aware clipping may be applied by the device 10. By doing so, clipping noise, which may be increased by PA overdriving, may at least
30 partly be shifted to frequency ranges or subbands, respectively, with lower priority services. Those subbands may be indicated by the base station 100 via downlink control signaling to the devices 10, 10'.

According to a further embodiment, a device such as the UE
35 10 (Fig. 2) may employ the principle according to the embodiments in order to increase a reliability for its uplink data transmissions to the base station 100. For

5 example, if the UE 10, which may be a mobile terminal, moves to an edge of a radio cell of the system 1000, where the radio coverage conditions usually are worse than in a cell center region, it may use the principle according to the embodiments for transmitting data symbols e.g. associated with high priority services.

According to a particularly preferred embodiment, the UE 10 may use the overdrive regime for only some symbols of a specific subframe, whereas for other symbols of said same subframe no overdriving may be used. According to further
15 embodiments, it is also possible to use a further reduced transmission power (or even zero transmission power, i.e. muting) for some data symbols of a subframe which comprise reduced priority in contrast to those data symbols, which comprise high priority.

20 As an example, in 3GPP TS 36.101 it is defined, that a maximum UE output power is measured at least over one subframe (1ms). If the UE moves to the edge of a cell and the radio conditions become bad, according to the principle of the embodiments, the PA 17 of the transmitter 16a of the
25 UE 10 (Fig. 2) may be operated in an overdrive mode to increase the output power by another few dBs within a very short time range, wherein said short time range is preferably smaller than 1ms. This is especially suitable for URLLC use cases. In other words, according to some
30 embodiments, the device 10 is able to boost all the (admissible) energy of one subframe into only several symbols of said subframe, and the remaining symbols in this subframe are muted (e.g., set to 0), in order not to violate the above-mentioned maximum average output power
35 requirement. This embodiment advantageously enables to employ the principle according to the embodiments, while at the same time not violating maximum average output power

5 requirements as standardized for the respective communications system 1000.

According to some aspects of the embodiments, especially during a PA overdrive operation, where selected data symbols ds2 (Fig. 2) associated with a particularly
10 important service are transmitted with a comparatively high average transmission power, the power amplifier 17 of the transmitter 16a (Fig. 1) will potentially be more strongly operated in a nonlinear region, which may result in more distortions of an amplified transmission signal. Regarding
15 this hardware aspect, according to further embodiments, different strategies are proposed in the following, said strategies inter alia enabling to perform optimization processes.

According to one aspect, reducing a peak to average power ratio (PAPR) is possible. According to one embodiment, a
20 reduction of PAPR is possible by changing a modulation scheme from higher order QAM to QPSK or even BPSK.

According to further embodiments, one can further optimize a waveform used for signal transmission for low PAPR
25 purpose, e.g. by adjusting a subcarrier spacing such that less carriers are used in parallel, whereby PAPR is reduced.

According to further embodiments, a waveform used for signal transmission may even be switched to single carrier
30 (SC) transmission with even less PAPR.

According to further embodiments, one can also use clipping algorithms to reduce the PAPR, and a clipping threshold value may e.g. depend on the PA characteristics, channel conditions, and so on.

35 According to applicant's analysis, clipping algorithms may take into account an adjusted PA operation point P3 (Fig. 7) in the following way: a) a clipping threshold may be

5 reduced b) since it is expected that in the overdriven mode
a PA generates more out of band distortions, one approach
according to a further embodiment is to optimize a clipping
noise filter of the transmitter 16a in such a manner that
some of the clipping noise energy does not fall in a signal
10 band, but out of the signal band, which will be overlapped
by PA nonlinear effects. In this way, the in-band
distortion caused by clipping algorithm can be reduced and
hence a lower bit error rate (BER) at receiver side will be
achieved. c) As mentioned above an active shaping of the
15 clipping noise can be carried out using content-aware
clipping (cf. e.g. EP2485477) accumulating all clipping
noise outside of the subbands of high priority users or
devices 10 which have to transmit data symbols ds_2
associated with services having high priority,
20 respectively. According to a further embodiment, an
information indicating which frequency bands may be used to
dump clipping noise to may be broadcasted by the base
station 100.

According to further embodiments, a protection overhead for
25 reducing inter-symbol interference (ISI) may be removed.

According to some embodiments, the device 10 may only boost
(i.e., use the higher, potentially inadmissible, average
transmission power) every n-th data symbol in a
transmission time interval (TTI), with e.g. $n=2$ or $n=3$,
30 while not transmitting anything on the remaining symbols of
the same TTI. This has the effect that no two successive
symbols of said TTI are both "turned on" (e.g., have a non-
vanishing amplitude), so that ISI may be avoided and the
cyclic prefix can e.g. be removed from the signal given
35 that a CP-OFDM receiver is aware of the absence of the CP
through e.g. signaling information.

So, according to a further embodiment, a receiver 116b
(Fig. 4) of the base station 100 may treat a received

5 uplink signal as described above as a ZP (zero prefix)-OFDM (orthogonal frequency division multiplex) signal and use appropriate receiver techniques. Consequently, the pure data signal would have more power.

According to a further embodiment, in case the waveform
10 used by the device 10 for uplink transmissions is UF (universal filtered)-OFDM (e.g., a combination of zero postfix and sub-band filter), as a shift in a PA operation point anyway worsens a spectral localization of the signal, a filter may be set to a unit amplitude spike, so is in
15 fact turned off, which will save computational effort.

In this case, no prior signaling is needed to the receiver side, and this measure concentrates the signal in time and allows for even higher instantaneous signal amplitudes for the same average power within 1 ms (millisecond).

20 The principle according to the embodiments advantageously enables to increase the transmission reliability for the uplink direction.

The principle according to the embodiments is particularly beneficial for mission critical use cases preventing the
25 loss of coverage.

The principle according to the embodiments enables to attain the ultra-high reliability targets of upcoming 5G systems, e.g. 3GPP New Radio.

According to a further embodiment, the device 10 (Fig. 1)
30 is further configurable to obey an in-band spectrum emission mask of said communications system 1000 (Fig. 2) for a transmission of data symbols to the base station 100 which are amplified not using said overdrive regime for the PA 17 (Fig. 1). Additionally, the device 10 may be further
35 configurable to a further spectrum emission mask of said communications system 1000 for a transmission of data symbols ds1, ds2 to the base station 100 which are

5 amplified using said overdrive regime. In other words, in
an operating mode where no overdriving of the power
amplifier is used, the device 10 keeps to a predetermined
in-band spectrum emission mask (SEM) of said communications
system thus not producing any interference due to mask
10 violations of said SEM. In a different operating mode,
which may use the overdrive regime according to the
embodiments, the device 10 obeys the further SEM of the
communication system 1000 being different than the in-band
SEM.

15 As an example, for the operating mode using the overdrive
regime, the further SEM may be a more relaxed SEM i.e. some
interference may be allowed in regions for which
interference is disallowed in view of the in-band SEM. In
other words, in such scenario transmission of the one or
20 more data symbols ds1, ds2 is performed while violating the
in-band SEM, but not violating the further SEM.

The further SEM may be defined by standardization and/or
instructed to the device 10 by the base station 100 in
response to its request for applying the overdrive regime.

25 In some embodiments, use of the further SEM is, explicitly
or implicitly, granted by the base station 100 in response
to a device request to operate in the overdrive mode.
Preferably usage of the further SEM is limited, e.g. by the
base station 100, to a predetermined number of devices
30 and/or for a limited amount of time.

The description and drawings merely illustrate the
principles of the invention. It will thus be appreciated
that those skilled in the art will be able to devise
various arrangements that, although not explicitly
35 described or shown herein, embody the principles of the
invention and are included within its spirit and scope.
Furthermore, all examples recited herein are principally

5 intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples
10 and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

It should be appreciated by those skilled in the art that
15 any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be
20 substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

A person of skill in the art would readily recognize that steps of various above-described methods can be performed
25 by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform
30 some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also
35 intended to cover computers programmed to perform said steps of the above-described methods.

The functions of the various elements shown in the FIGs., including any functional blocks labeled as "processors",

5 may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a
10 plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal
15 processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage. Other hardware, conventional and/or custom, may also be
20 included. Similarly, any switches shown in the FIGS. are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being
25 selectable by the implementer as more specifically understood from the context.

It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the
30 invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such
35 computer or processor is explicitly shown.

At least parts of the above described radio communications network including base stations could be implemented using network functions virtualization (NFV). NFV is a network

5 architecture that makes use of technologies of computer
virtualization. Entire network equipment like base stations
or parts thereof or part of their functions can be
virtualized using software building blocks that may
connect, or interact, to create communication services. A
10 virtualized network function of e.g. a base station may
include at least one virtual machine running different
software and processes, on top of standard high-volume
servers, switches and storage, or a cloud computing
infrastructure, instead of having customized hardware
15 appliances for each network function. As such a base
station function may be implemented using a computer
program product embodied on a non-transitory computer
readable medium for performing operations, wherein the
computer program product comprises instructions, that when
20 executed by a processor, perform the operations of the
specific base station function.

5

Claims

1. Device (10) for a radio communications system (1000),
the device comprising:
10 - a processing unit (12);
 - a memory unit (14); and
 - a transceiver (16) comprising a transmitter (16a)
 provided with a power amplifier (17);
 wherein said device (10) is configurable to:
15 - send (210) a request to a base station (100) of said
 communications system (1000) for permission of
 transmission of one or more data symbols, the one or
 more data symbols being amplified with the power
 amplifier in an overdrive regime;
20 - receive (212) a grant for such transmission;
 - amplify (214) the one or more data symbols with the
 power amplifier of the transmitter in the overdrive
 regime; and
 - transmit (216) the one or more data symbols to the
25 base station.
2. Device (10) according to claim 1, wherein said one or
more data symbols are part of a subframe, and wherein
said device (10) is configurable to transmit the
30 subframe comprising the one or more data symbols to
 the base station (100) without exceeding a
 predetermined maximum average device output power per
 subframe.
- 35 3. Device (10) according to claim 2, wherein said device
 is configurable to overdrive the power amplifier (17)
 of the transmitter (16a) for amplification of the one
 or more data symbols within the subframe and to mute
 transmission of remaining symbols within the subframe.

- 5
4. Device (10) according to any one of the preceding claims, wherein the device (10) is further configurable to obey an in-band spectrum emission mask of said communications system (1000) for a
- 10 transmission of data symbols to the base station (100) which are amplified not using said overdrive regime for the power amplifier (17), and wherein said device (10) is further configurable to obey a further spectrum emission mask of said communications system
- 15 (1000) different from the in-band spectrum emission mask for a transmission of data symbols to the base station (100) which are amplified using said overdrive regime.
- 20 5. Method of operating a device (10) within a communication system (1000), the method comprising:
- sending (210), via a transmitter of the device (10), a request to a base station (100) of said communications system (1000) for permission of
- 25 transmission of one or more data symbols, the one or more data symbols being amplified with a power amplifier of the transmitter in an overdrive regime;
- receiving (212) a grant for such transmission;
 - amplifying (214) the one or more data symbols with
- 30 the power amplifier of the transmitter in the overdrive regime; and
- transmitting (216) the one or more data symbols.
6. Method according to claim 5, wherein said one or more
- 35 data symbols are part of a subframe, and wherein the subframe comprising the one or more data symbols is transmitted to the base station without exceeding a predetermined maximum device output power per subframe.

- 5
7. Method according to claim 6, wherein the power amplifier of the transmitter is overdriven to amplify the one or more data symbols within the subframe and wherein the remaining symbols within the subframe are muted.
- 10
8. Method according to any one of claims 5-7, further comprising sending to the base station a priority indication related to the one or more data symbols.
- 15
9. Base station (100) for a radio communications system (1000), wherein said base station (100) comprises:
- a processing unit (112);
 - a memory unit (114); and
 - 20 - a transceiver (116);
- wherein said base station (100) is configurable to:
- receive (230) a request from a device (10) for permission of transmission of one or more data symbols while overdriving a power amplifier of a transmitter of the device;
 - 25 - verify (232) if such permission can be granted; and
 - if such permission can be granted, transmit (234) an indication to the device (10) that the transmission of the one or more data symbols while overdriving a power amplifier of a transmitter of the device is allowed.
 - 30
10. Base station (100) according to claim 9, further configurable to receive a priority indication related to the requested transmission of the one or more data symbols, and wherein verifying if such permission can be granted is, at least partially, based on said priority indication.
- 35

- 5 11. Base station (100) according to claim 9 or 10, further configurable to:
- schedule frequency resources for the one or more data symbols by at least one of selecting frequency resources that have a non-vanishing predetermined
 - 10 minimum frequency spacing from a carrier band edge and scheduling frequency resources for uplink transmissions such that at least one guard carrier is provided adjacent to the frequency resources scheduled for the one or more data symbols; and
 - 15 - sending information regarding the frequency resources scheduled for the one or more data symbols to the device (10).
- 20 12. Method of operating a base station (100) within a communication system (1000), the method comprising:
- receiving a request from a device (10) for permission of transmission of one or more data symbols while overdriving a power amplifier of a transmitter of the device;
 - 25 - verifying if such permission can be granted; and
 - if such permission can be granted, transmitting an indication to the device (10) that the transmission of the one or more data symbols while overdriving a power amplifier of a transmitter of the device is allowed.
 - 30
13. Method according to claim 12, further comprising receiving a priority indication related to the requested transmission of the one or more data symbols, and wherein said verifying if such permission
- 35 can be granted is, at least partially, based on said priority indication.
14. Method according to claim 12 or 13, further comprising:

5 - scheduling, for the one or more data symbols,
frequency resources that have a non-vanishing
predetermined minimum frequency spacing from a carrier
band edge; and
10 - sending information regarding the scheduled
frequency resources to the device (10).

15. Method according to any one of claims 12-14, further
comprising: - scheduling frequency resources for
uplink transmissions such that at least one guard
15 carrier is provided adjacent to the frequency
resources scheduled for the one or more data symbols,
and - sending information regarding the frequency
resources scheduled for the one or more data symbols
to the device (10).

20

Fig. 1

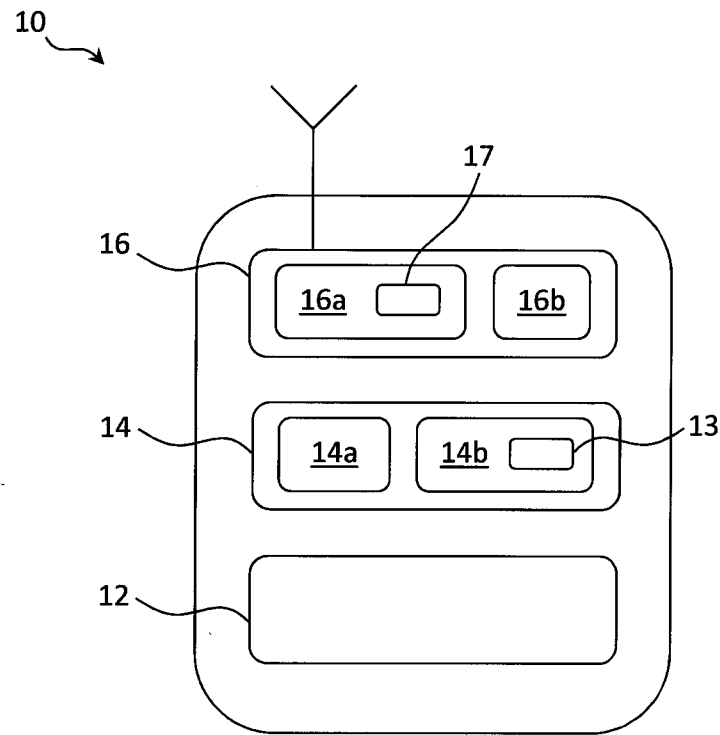


Fig. 2

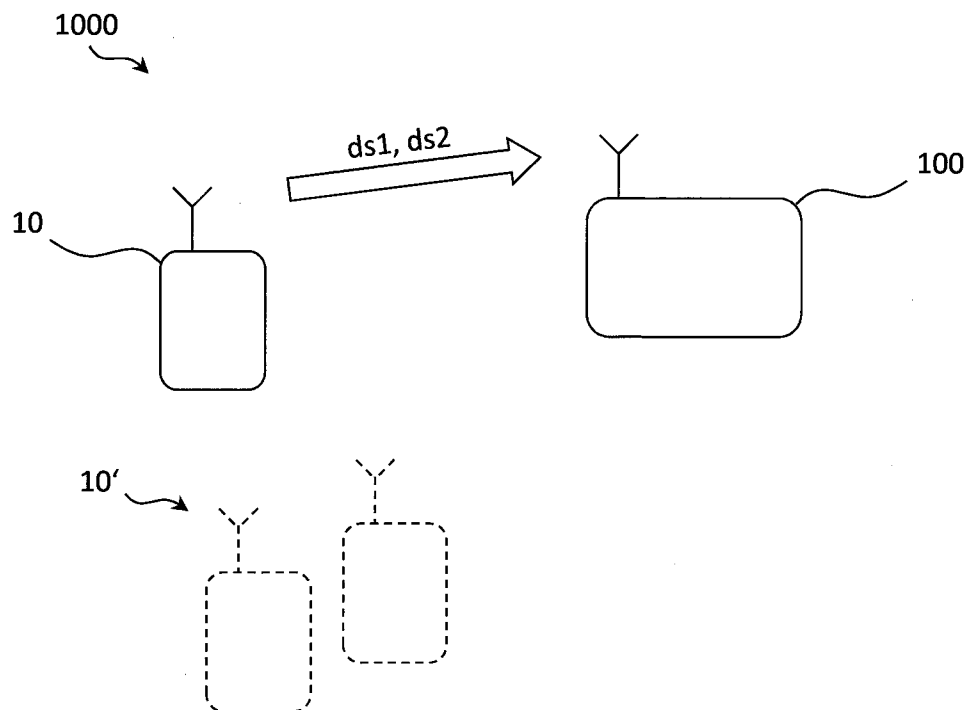


Fig. 3A

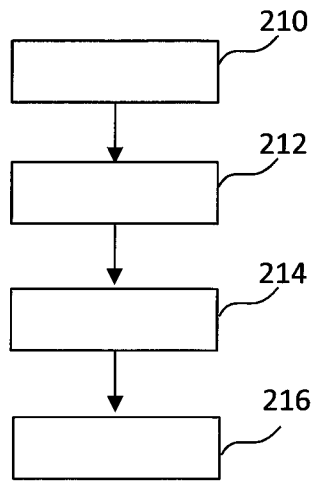


Fig. 3B

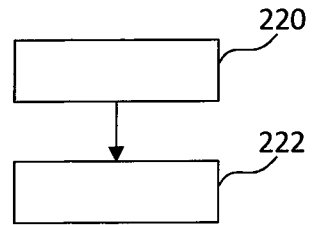


Fig. 4

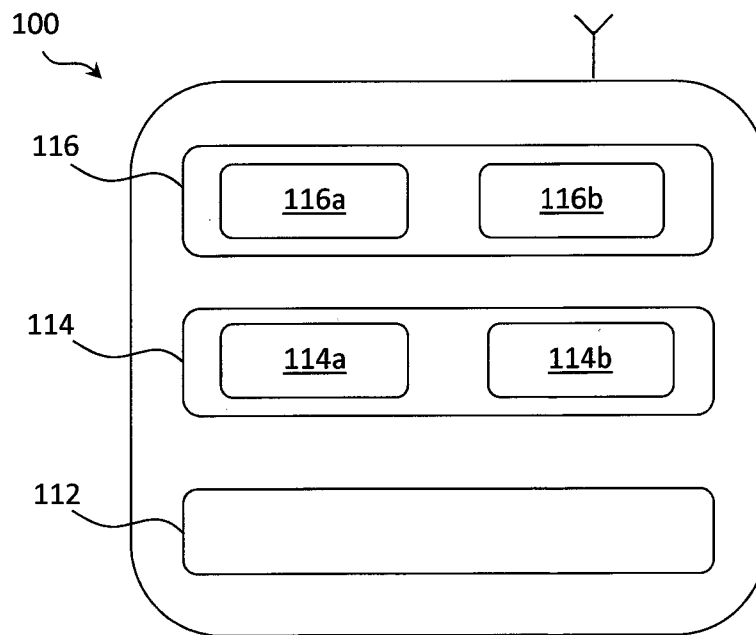
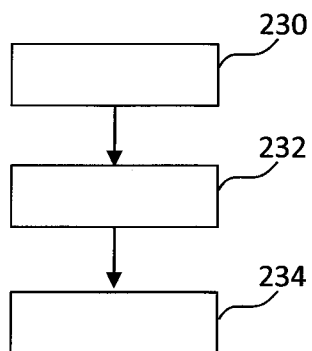
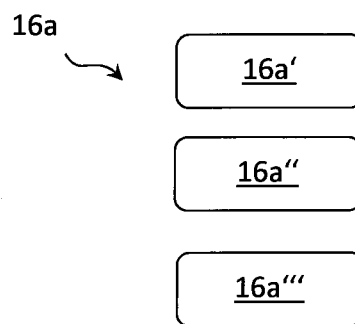
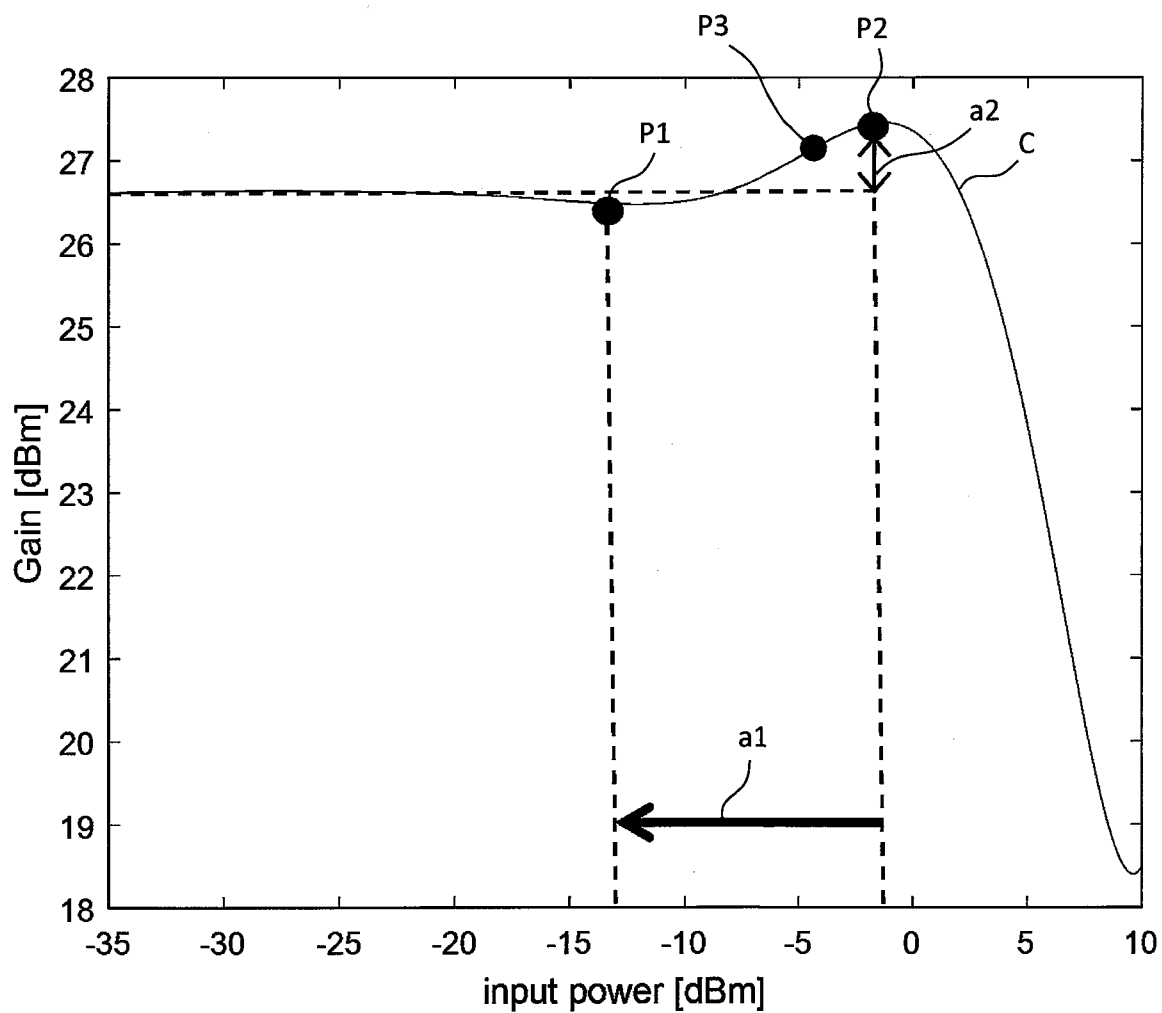


Fig. 5**Fig. 6****Fig. 7**

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/080935

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W52/34 H04W52/28 H04W52/36
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/044621 A1 (JUNG HYEJUNG [US] ET AL) 21 February 2013 (2013-02-21) paragraph [0031] paragraph [0033] paragraph [0069] paragraph [0072] - paragraph [0075] paragraph [0089] - paragraph [0090] paragraph [0094] - paragraph [0095] paragraph [0113] - paragraph [0114] -----	1-15
A	US 2013/142098 A1 (KWON KI BUM [KR] ET AL) 6 June 2013 (2013-06-06) abstract paragraph [0080] paragraph [0086] paragraph [0110] paragraph [0115] paragraph [0128] ----- -/-	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

"&" document member of the same patent family

Date of the actual completion of the international search

5 February 2018

Date of mailing of the international search report

12/02/2018

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/080935

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/080935

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