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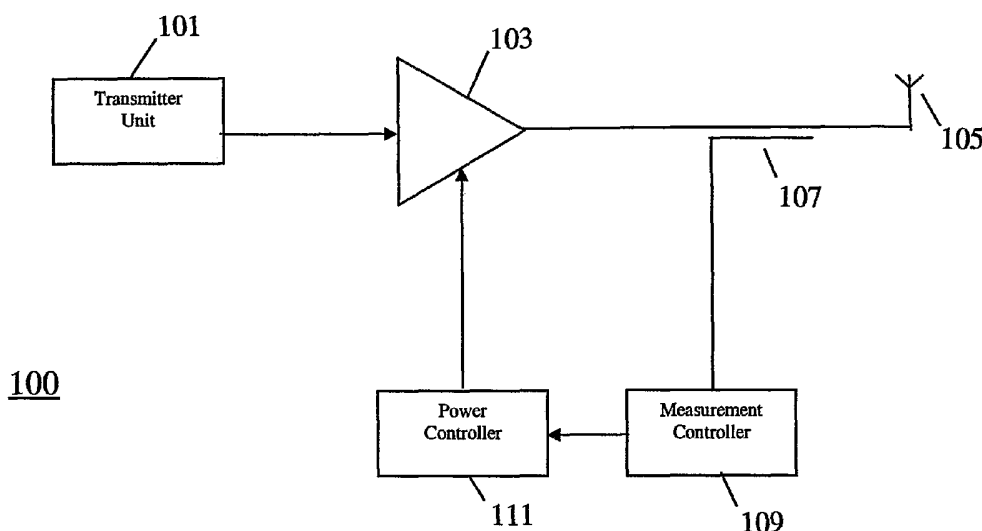
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(54) Title: A TRANSMITTER, A TRANSCEIVER AND A METHOD OF CONTROLLING A TRANSMIT POWER THEREFOR



(57) Abstract: A transmitter (100) for transmitting a radio signal comprises a power amplifier (103) for generating an amplified radio frequency signal. A coupling element (107) couples the signal to a measurement controller (109) which determines a non-linearity indication of the power amplifier (103) from the amplified signal. The measurement controller (109) may for example measure a signal level of an out of band frequency interval. The measurement controller (109) is coupled to a power controller (111) which controls an output power of the power amplifier (103) in response to the non-linearity indication. The power controller (111) may specifically deactivate the power amplifier (103) if the non-linearity indication exceeds a given threshold. The invention may in particular allow for a delayed switch-off of a power amplifier (103) during battery backup operation.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

**A TRANSMITTER, A TRANSCEIVER AND A METHOD OF CONTROLLING
A TRANSMIT POWER THEREFOR**

5 Field of the invention

The invention relates to a transmitter, a transceiver and a method of controlling a transmit power therefor and in particular, but not exclusively, to control of a transmit
10 power in a cellular communication system.

Background of the Invention

15 In a cellular communication system, a geographical region is divided into a number of cells each of which is served by a base station. The base stations are interconnected by a fixed network which can communicate data between the base stations. A mobile station is served via a radio
20 communication link by the base station of the cell within which the mobile station is situated. Communication from a mobile station to a base station is known as uplink, and communication from a base station to a mobile station is known as downlink.

25

Currently, the most ubiquitous cellular communication system is the 2nd generation communication system known as the Global System for Mobile communication (GSM). GSM uses a technology known as Time Division Multiple Access
30 (TDMA) wherein user separation is achieved by dividing frequency carriers into 8 discrete time slots, which individually can be allocated to a user. A base station may be allocated a single carrier or a multiple of

carriers. One carrier is used for a pilot signal which further contains broadcast information. This carrier is used by mobile stations for measuring of the signal level of transmissions from different base stations, and the
5 obtained information is used for determining a suitable serving cell during initial access or handovers. Further description of the GSM TDMA communication system can be found in 'The GSM System for Mobile Communications' by Michel Mouly and Marie Bernadette Pautet, Bay Foreign
10 Language Books, 1992, ISBN 2950719007.

Currently, 3rd generation systems are being rolled out to further enhance the communication services provided to mobile users. The most widely adopted 3rd generation
15 communication systems are based on Code Division Multiple Access (CDMA) wherein user separation is obtained by allocating different spreading and scrambling codes to different users on the same carrier frequency. An example of a communication system using this principle is the
20 Universal Mobile Telecommunication System (UMTS), which is currently being deployed. Further description of CDMA and specifically of the Wideband CDMA (WCDMA) mode of UMTS can be found in 'WCDMA for UMTS', Harri Holma (editor), Antti Toskala (Editor), Wiley & Sons, 2001,
25 ISBN 0471486876.

In cellular communication systems, it is important to control and minimize interference in order to maximise the capacity of the system. Accordingly, it is very
30 important to reduce the out of band interference caused by a transmitter in a cellular communication system and the technical specifications for a cellular communication system provide stringent requirements for the spectral

density of the transmitter signals. Accordingly, the transmitters in a cellular communication system are designed to meet these requirements and in particular this requires that the power amplifiers of the
5 transmitters are predominantly operated in the linear region.

However, the linearity of radio signal power amplifiers is dependent on the supply voltage of the power
10 amplifier, and in order to meet the requirements the supply voltage must be sufficiently high. For a base station, this is achieved during normal operation by controlling the supply voltage to always be above the required value. However, the power supply to the base
15 station may interrupted and in order to maintain operation in such cases, most base stations switch to a local battery back up supply. This minimises disruptions to the users and down time of the base station.

20 If the power supply to the base station is restored sufficiently quickly, the power supply interruption may not result in any degradation of the performance of the base station and may not be detectable by mobile stations. However, if the power supply is not restored in
25 time, the batteries will be discharged to a level where they cannot provide a sufficiently high voltage to ensure that the supply voltage to the power amplifier is sufficient to provide the required linearity.

30 It is therefore customary to switch off the base station (or at least the power amplifier) before the base station violates the technical requirements for the system. Typically, a power amplifier is characterised during

design/development and a battery voltage at which the power amplifier becomes unacceptably non-linear for a given dynamic range is determined. The base station is then hard wired to switch off the power amplifier before
5 the battery voltage reaches this level.

However, such an approach inherently relies on a worst case assumption. Firstly, the threshold for switching off the power amplifier must be set at a level where the
10 power amplifier is guaranteed to be within the requirements for all temperatures, maximum drift values, voltage measurement error etc. Thus, the power amplifier will typically be switched off long before the output signal violates the requirements. This results in a
15 significantly reduced battery backup time and may significantly increase the down time of base stations caused by power supply disruptions.

Similarly, for a mobile station, the power amplifier will
20 become increasingly non-linear when the supply voltage drops as a function of the batteries being discharged. A similar approach of pre-characterising the transmitter at manufacturing and hardwiring a worst case threshold for switching off the power amplifier is typically used.
25 However, this results in the power amplifier typically being switched off significantly before it is necessary and thus reduces the battery life of the mobile station.

Hence, an improved system for controlling an output power
30 of a transmitter would be advantageous and in particular a system allowing increased flexibility, performance, reduced interference, improved insensitivity to power

supply disruptions and/or increased battery operation time would be advantageous.

5 Summary of the Invention

Accordingly, the Invention seeks to preferably mitigate, alleviate or eliminate one or more of the above mentioned disadvantages singly or in any combination.

10

According to a first aspect of the invention there is provided a transmitter for transmitting a radio signal, the transmitter comprising: a power amplifier for generating an amplified radio frequency signal;

15 determining means for determining a non-linearity indication of the power amplifier from the amplified signal; and control means for controlling an output power of the power amplifier in response to the non-linearity indication.

20

The invention may allow a dynamic control of the output power of a power amplifier in response to an actual non-linearity indication for the power amplifier. Thus, the output power of a transmitter may be controlled to ensure
25 that it performs within specified requirements without requiring a predetermined switching off point for the power amplifier which is based on a worst case assumption.

30 The invention may provide for improved battery life, reduced out of band interference, improved availability and/or reduced sensitivity to power supply disruptions. The invention may in many embodiments provide improved

quality of service to a user and/or an improved performance of the communication system in which the transmitter is used as a whole.

- 5 The determining means may in particular determine the non-linearity indication of the power amplifier by measurement of a characteristic of the amplified radio frequency signal.
- 10 According to an optional feature of the invention, the control means is operable to reduce the output power for an increasing non-linearity indication. An increasing non-linearity of the power amplifier may typically result in performance which approaches or exceeds the
- 15 requirements and this may in many embodiments be mitigated by reducing the transmit power. For example, an increasing non-linearity may result in increased out of band power and reducing the transmit power may counteract this trend. The reduction may partly be due to a
- 20 decreased power of the amplified power signal but is also achieved by operating the power amplifier in a more linear operating range. Hence, an improvement which exceeds that of a proportional reduction of out of band power in line with the reduction of in-band power is
- 25 achieved.

- The reduction of the output power may be a monotonic function of the increasing non-linearity indication but may also be e.g. a step wise function. For example,
- 30 intervals of values of the non-linearity indication may be mapped to discrete relative or absolute transmit power levels.

According to an optional feature of the invention, the control means is operable to deactivate the power amplifier in response to the non-linearity indication.

- 5 The invention may allow for a deactivation of the power amplifier to be performed in response to current operating characteristics. Rather than relying on a predetermined worst case assumption for when to deactivate a power amplifier, this may be performed in
10 response to actual current and measured values. This may allow improved battery life and may for example allow that a battery back up may provide for continued operation in a much longer time interval. An increased insensitivity of the transmitter to supply power
15 disruptions may be achieved resulting in increased quality of service, increased reliability and/or improved performance of the communication system in which the transmitter is used.
- 20 The deactivation may switch the power amplifier off or may enter it into a stand by mode wherein there is substantially no output signal from the power amplifier. The power amplifier may for example be deactivated by the supply power to the power amplifier being disconnected or
25 by not providing an input signal to power amplifier. In some embodiments, the whole transmitter may be deactivated in response to the non-linearity indication.

According to an optional feature of the invention, the
30 control means is operable to deactivate the power amplifier if the non-linearity indication exceeds a threshold. This may provide for a low complexity and efficient implementation providing reliable performance.

The threshold may be variable or fixed. In the variable case it may e.g. be based on interference measurements made by loop back circuitry, or a table predetermined by
5 an operator.

According to an optional feature of the invention, the control means is further operable to control the output power in response to a power supply characteristic.

10

The power supply characteristic may for example be a power supply source, a power supply type or an operational power supply state. For example, the control means may control the output power in response to whether
15 the power supply is provided from the standard power supply (e.g. a mains power supply) or is from a battery backup. The control means may in particular deactivate the power amplifier in response to the power supply characteristic, for example by only deactivating the
20 power amplifier if the power supply is from a backup battery.

According to an optional feature of the invention, the determining means is operable to determine the non-
25 linearity indication in response to a frequency domain characteristic of the amplified signal. This may provide for a low complexity and efficient implementation providing reliable performance.

30 According to an optional feature of the invention, the determining means is operable to determine the non-linearity indication in response to a signal power of the

amplified signal in at least one out of band frequency interval.

This may provide an accurate indication of the non-
5 linearity of the power amplifier and may allow a practical and low complexity implementation.

The signal power may be determined from a signal output of a filter having a center frequency outside the channel
10 frequency band of the radio signal. The determining means may apply a frequency mask to the amplified signal and determine the resulting signal level. The frequency mask may attenuate on channel frequencies more than at least one out of band frequency interval.

15

According to an optional feature of the invention, the determining means is operable to determine the non-linearity indication in response to a signal power of at least one out of band spurious of the amplified signal.
20 This may provide a particularly accurate indication of the non-linearity of the power amplifier and may allow a practical and low complexity implementation.

According to an optional feature of the invention, the
25 transmitter further comprises means for detecting an error condition of the power amplifier in response to the non-linearity indication.

The invention may further allow a fault to be detected in
30 response to the actual, current characteristics of a transmitted signal. Hence, the functionality for determining a non-linearity indication may be used for multiple purposes and this may for example achieve an

improved availability of the communication system. E.g. a power amplifier may be deactivated when it fails to meet defined operating requirements.

- 5 In many embodiments, some faults of a power amplifier may result in an increased non-linearity while still allow a high power output signal to be generated. This may result in a failure to meet the requirements for the transmitted signal and may cause unacceptable interference. Such a
10 situation may be detected and thus improved fault performance may be achieved.

According to an optional feature of the invention, the transmitter further comprises means for detecting a
15 parameter drift of the power amplifier in response to the non-linearity indication.

The drift may for example be a drift due to temperature variations, component variations or ageing. The feature
20 may allow drift to be detected in response to the actual, current characteristics of a transmitted signal. Hence, the functionality for determining a non-linearity indication may be used for multiple purposes and this may for example achieve an improved reliability of the
25 communication system comprising the transmitter. For example, if excessive drift is detected, an alarm may be set indicating that a recalibration is required or a power amplifier may e.g. be deactivated when it fails to meet defined operating requirements due to excessive
30 parameter drift.

According to an optional feature of the invention, a transceiver comprises the transmitter and further

comprises: a receiver for receiving signals from a remote transmitter, the receiver being operable to generate a received signal level indication; and coupling means for coupling the amplified signal to the receiver; and the
5 determining means is operable to determine the non-linearity indication in response to the received signal level indication when the amplified signal is coupled to the receiver.

10 This may allow a very efficient implementation and may in particular provide for a minimal complexity increase as the circuitry of the receiver may be reused for the purpose of controlling the output power of the transmitter.

15

According to an optional feature of the invention, the coupling means comprises means for converting between a transmit frequency of the transceiver and a receive frequency of the transceiver. This may provide an
20 advantageous implementation of e.g. a Frequency Division Duplex (FDD) transceiver.

According to an optional feature of the invention, the receiver has an associated receiver channel bandwidth,
25 and the transceiver comprises means for measuring a frequency band having a larger bandwidth than the receiver channel bandwidth by varying a conversion frequency of the coupling means.

30 This may provide increased accuracy of the non-linearity indication while maintaining a low complexity,

For example, the transceiver may be designed for a given radio channel bandwidth and a larger frequency interval than this bandwidth may be measured using the existing circuitry (and receive filters) by varying the conversion
5 frequency.

According to an optional feature of the invention, the transceiver may be comprised in a base station for a cellular communication system. The base station may for
10 example be a base station of a GSM communication system or a Node B of a 3rd Generation cellular communication system, such as UMTS.

According to an optional feature of the invention, the
15 control means is further operable to deactivate the power amplifier in response to an operating characteristic of a cell supported by the base station.

This may provide improved performance. For example, the
20 operating characteristic may be an interference characteristic and the power amplifier may be deactivated in response to the current interference situation in the cell supported by the base station. E.g. the power amplifier may only be deactivated if the current
25 interference conditions are such that the additional interference caused by an increased non-linearity of the power amplifier is significant or critical.

According to an optional feature of the invention, the
30 control means is further operable to deactivate the power amplifier in response to an operating characteristic of a neighbour cell of the base station.

This may provide improved performance. For example, the operating characteristic may be an interference characteristic and the power amplifier may be deactivated in response to the current interference situation in the
5 neighbour cell. E.g. the power amplifier may only be deactivated if the current interference conditions are such that the additional interference caused by an increased non-linearity of the power amplifier is significant or critical.

10

According to an optional feature of the invention, the transceiver may be comprised in a user equipment of a cellular communication system.

15 The invention may provide improved performance of a user equipment and may in particular provide an increased battery life.

According to another aspect of the invention, there is
20 provided a method of controlling a transmit power of a transmitter comprising a power amplifier for generating an amplified radio frequency signal, the method comprising the steps of: determining a non-linearity indication of the power amplifier from the amplified
25 signal; and controlling an output power of the power amplifier in response to the non-linearity indication.

These and other aspects, features and advantages of the invention will be apparent from and elucidated with
30 reference to the embodiment(s) described hereinafter.

Brief Description of the Drawings

Embodiments of the invention will be described, by way of example only, with reference to the drawings, in which

5 FIG. 1 illustrates a transmitter for a base station of a GSM cellular communication system in accordance with some embodiments of the invention;

FIG. 2 illustrates exemplary amplifier characteristics
10 for two different supply voltages;

FIG. 3 illustrates a simplified spectral density of a power amplifier output signal operating partly in a non-linear region;

15

FIG. 4 illustrates a transceiver for a base station of a GSM cellular communication system in accordance with some embodiments of the invention; and

20 FIG. 5 illustrates a flow chart for a method of controlling a transmit power of a transmitter in accordance with some embodiments of the invention.

25 Detailed Description of Embodiments of the Invention

The following description focuses on embodiments of the invention applicable to a transmitter for a cellular communication system and in particular to a transmitter
30 for a GSM cellular communication system. However, it will be appreciated that the invention is not limited to this application but may be applied to many other communication systems.

The following description furthermore focuses on an application to base station but the invention is equally applicable to for example a user equipment such as a mobile station or a remote terminal.

FIG. 1 illustrates a transmitter 100 for a base station of a GSM cellular communication system in accordance with some embodiments of the invention.

10

The transmitter 100 comprises a transmitter unit 101 which generates a radio frequency signal by modulating and up-converting etc a data signal to be transmitted as will be familiar to the person skilled in the art. The transmitter unit 101 is coupled to a power amplifier 103 which amplifies the RF signal to an output power level of the transmitter 100. The power amplifier 103 is coupled to an antenna 105 from which the amplified RF signal is transmitted to user equipments.

20

A power amplifier 103 is characterised by an amplifier characteristic indicative of the amplification of the power amplifier 103 for different input levels. FIG. 2 illustrates exemplary amplifier characteristics for two different supply voltages. A first characteristic 201 may specifically indicate the amplifier characteristic for a nominal supply voltage to the power amplifier 103. During normal operation, the base station will provide this nominal supply voltage to the power amplifier 103 which accordingly operates in accordance with the first characteristic.

A second characteristic 203 indicates the amplifier characteristic for a reduced supply voltage to the power amplifier 103. If the power amplifier 103 for some reason is only provided with this reduced supply voltage, it will operate in accordance with the second characteristic 203 and consequently will have a reduced linear region.

As illustrated, the characteristic has a substantially linear section up to a given input signal level after which the characteristic becomes highly non-linear. This non-linearity will cause distortion of the signal and will typically result in increased spurious and out of band distortion signal components. Thus, in order to ensure that the transmitter operates within the specified requirements for a GSM cellular communication system, the power amplifier 103 is normally backed off from the non-linear region and is operated within the linear region. However, in order to provide a sufficiently high dynamic range and efficiency, most of the linear region is preferably exploited by the base station.

In some cases, the base station may not be able to provide the nominal voltage. For example, during a power disruption to the base station, a local battery power source may be used as a power backup. However, as the batteries are discharged, the battery voltage decreases and therefore the supply voltage to the power amplifier 103 may also decrease. This results in the power amplifier 103 characteristic changing and in particular results in the linear region reducing. Thus, as the batteries are discharged, the effective back-off from the non-linear region will reduce and at some point, the power amplifier 103 will begin to operate in the non-

linear region resulting in increased distortion of the output signal.

FIG. 3 illustrates a simplified spectral density of a power amplifier output signal operating partly in a non-linear region. As illustrated, the output signal has a main lobe 301 within the channel bandwidth of the transmitted signal. However, due to the distortion of the non-linear region, an increasing out-of band signal is generated. In particular, in the illustrated example, two spuri 303, 305 have appeared at out of band frequencies.

Thus, in order to ensure that the base station meets the requirements of the GSM cellular communication system, and in particular that it meets the required transmission spectral mask, it is necessary to control the power amplifier such that the non-linearity does not cause unacceptable performance.

It will be appreciated that the exact characteristic of a power amplifier for a given supply voltage will depend on many factors including the design of the power amplifier, component variations, ageing and the operating temperature. Accordingly, the power amplifier is typically characterised at manufacturing and circuitry is calibrated to switch off the power amplifier when the power supply voltage falls below a given threshold. However, as dynamic variations, component drift etc. also affects the power amplifier characteristic, this supply voltage threshold must be set at a relatively high value in order to ensure that the power amplifier meets the requirements in all situations. Thus, a worst case assumption must be used resulting in for example the

available battery back duration being significantly reduced, resulting in an increased sensitivity to power disruptions and an increased downtime.

5 In the example of FIG. 1, the base station comprises functionality for controlling the output power of the base station in response to a non-linearity indication of the power amplifier 103 which is derived from the actual amplified signal.

10

For this purpose, the transmitter 100 comprises a coupling element 107 which couples the amplified signal to a measurement controller 109. The coupling element 107 typically couples only a small energy of the signal to
15 the measurement controller thereby ensuring that the measurement controller 109 may be implemented using low power designs.

In some embodiments, the coupling element 107 may be a
20 PCB (Printed Circuit Board) wire running next to an output wire from the power amplifier for a suitable length. The output of the amplified power amplifier may in this way be capacitively, resistively and/or inductively coupled to the measurement controller 109.

25

The measurement controller 109 determines a non-linearity indication of the power amplifier 103 in response to the amplified signal. Thus, from the signal coupled from the output of the power amplifier 103, the measurement
30 controller 109 determines an indication of how non-linear the operation of the power amplifier 103 currently is.

In some embodiments, the measurement controller 109 may for example directly measure a non-linearity in the time domain by comparing an input signal of the power amplifier 103 to the signal from the output of the power
5 amplifier 103.

However, in most embodiments such an approach may be impractical and in many embodiments the determination of the non-linearity indication is performed by evaluation
10 of frequency domain characteristics of the amplified signal.

For example, in a low complexity implementation, the measurement controller 109 may comprise a filter which is
15 tuned to an out of band frequency interval. The amplified signal may be coupled to the input of the filter and the signal value at the output of the filter may be used as an indication of the non-linearity of the power amplifier. Hence, if the power amplifier 103 is
20 increasingly operated in the non-linear region, the amplified signal will be increasingly distorted and the out of band spectral density of the amplified signal will increase.

25 The bandwidth and central frequency of the filter may be selected to suit the current embodiment and may in particular be selected to provide a reliable indication for the current power amplifier design and signal characteristics.

30

Typically, increasing non-linearity will result in the emergence (or increasing energy) of spurious signal components. For example, if a power amplifier is

increasingly operated in a non-linear region, spurious signal components at specific frequencies will typically arise. Thus for a given input signal, it is in many embodiments possible to predict at which frequencies the distortion signal components will appear (or increase). Thus, the measurement controller 109 may specifically detect that such spurious signal components increase. For example, the center frequency and bandwidth of the filter may be selected to particularly filter an expected spurious signal component.

In some embodiments, the measurement controller 109 may apply a frequency mask to the coupled amplified signal and may use the resulting signal power as the non-linearity indication. The frequency mask may for example be a complex frequency mask selecting all expected spurious and attenuating all other frequencies or may for example be a simple wide bandwidth notch filter that attenuates only the channel band of the transmitted signal.

20

In some embodiments, such a frequency mask is applied directly in the frequency domain. For example, the amplified signal may be digitised and a Discrete Fourier Transform (DFT) may be applied to the digitised samples. The individual frequency samples may then be weighted by a suitable weight (determined by the frequency mask) and the resulting signal values may be summed. The result may then be used as the non-linearity indication.

The measurement controller 109 is coupled to a power controller 111 which controls the output power of the power amplifier in response to the non-linearity indication received from the measurement controller 109.

The output power may be controlled in any suitable manner but preferably the gain of the power amplifier 103 is controlled to ensure that the dynamic range of the
5 amplified signal stays within the linear region of the power amplifier 103. For example, a gain of one of the initial amplification stages of the power amplifier 103 may be adjusted such that the non-linearity indication is kept under a given value. Thus, a feedback control system
10 may be implemented wherein the gain of the power amplifier 103 is reduced if the non-linearity indication increases above a given level thus ensuring that the power amplifier 103 is operated within the requirements for the transmitter.

15
In some embodiments, the control means is arranged to deactivate the power amplifier in response to the non-linearity indication. For example, the base station may suffer a power disruption and may switch to a battery
20 backup power source. As the batteries discharge, the supply voltage to the power amplifier 103 drops. When the battery voltage drops below a voltage where the power amplifier 103 can provide the required dynamic range, the power amplifier 103 is increasingly operated in the non-
25 linear region thus resulting in increased out of band interference being generated.

This increased interference is measured and at a given point the power controller 111 determines that operation
30 can no longer be supported within the defined requirements and the power amplifier 103 is deactivated. The deactivation may for example be by switching the power amplifier 103 off, by removing the power supply to

all or parts of the power amplifier 103 or by substantially fully attenuating the input signal level.

Thus, if the non-linearity indication, such as the signal
5 power at the output of an out of band filter of the measurement controller 109, exceeds a threshold, the power amplifier 103 is entered into a deactivation state wherein substantially no output power is obtained from the power amplifier 103. The threshold may for example be
10 set to correspond to the specified requirements for out of band interference thereby allowing the battery backup operation to continue until the point when the performance becomes unacceptable.

15 It will be appreciated that in some embodiments, the power controller 111 may gradually reduce the output power as the battery voltage reduces. Thus a gradual shut down may be applied where support of user equipments that have sufficiently advantageous radio conditions to allow
20 them to be supported by a reduced dynamic power range is maintained, while ensuring that the interference requirements for the base station are met.

In some embodiments, the output power may also be
25 controlled in response to a power supply characteristic. For example, the operation may depend on the type of the power supply source. As a specific example, the power amplifier 103 may be deactivated if the current power supply is a battery backup power source. However if the
30 power supply from the normal (e.g. mains driven) power source, the power amplifier 103 is not deactivated but the power supply is switched to the battery backup power supply source.

In some embodiments, the transmitter may be part of a transceiver comprising a receiver. This receiver may in some embodiments be used to determine the non-linearity indication. For example, the GSM receiver of the GSM base station may be used to measure out of band signal levels thereby providing a non-linearity indication.

FIG. 4 illustrates a transceiver 400 for a base station of a GSM cellular communication system in accordance with some embodiments of the invention. The transmitter of the transceiver corresponds to the transmitter 100 of FIG. 1 and the same elements are referenced by the same reference numbers and will for brevity not be described further.

In the example, the transceiver 400 comprises a receiver 401 which is a GSM receiver arranged to receive signals from remote user equipments. In the example, the receiver 401 and the power amplifier 103 are coupled to the antenna 105 through a duplexer 403 which isolates the transmitter 100 from the receiver 401.

In FIG. 4, the coupling element 107 is coupled to a frequency converter 405 which converts between a transmit frequency and a receive frequency of the transceiver. Thus, in the example of an FDD transceiver, the frequency converter 405 converts the signal from the transmit frequency band to the receive frequency band such that it can be processed by the receiver 401. The frequency converter 405 may further perform level adaptation, typically attenuation, such that the signal being input

to the receiver has a suitable level for the existing circuitry.

The receiver 401 is not only capable of receiving GSM
5 signals but may also generate a received signal level indication. For example, the receiver 401 may generate an indication of the received signal level within the receiver channel bandwidth (which is 200 kHz for a GSM receiver).

10

In accordance with the example, the frequency converter 405 may perform a frequency conversion such that an out of band frequency of the transmit band is converted to a frequency in the receive band to which the receiver is
15 tuned. Thus, the existing circuitry of the receiver 401 is used to perform a measurement of the signal level at an out of band transmit frequency. The received signal level may be used as a non-linearity indication and may be fed to the power controller 111. Thus, a low
20 complexity implementation may be achieved wherein the same circuitry may be used for dual purposes. This may reduce cost of the transceiver and thus the base station.

The receiver channel bandwidth is typically relatively
25 narrow (for example 200 kHz for a GSM receiver) and it may in many embodiments be advantageous to determine the out of band transmit signal energy in a frequency interval which exceeds that of the receiver bandwidth. In such examples, the frequency converter 405 may comprise
30 functionality for varying the conversion frequency such that different transmit frequencies may be coupled to the receiver. The non-linearity indication may in such

examples be determined by summing the signal levels from the different transmit frequencies.

As a specific example, a 1 MHz out of band transmit
5 frequency bandwidth may be measured by the frequency
converter 405 stepping through five conversion
frequencies offset by 200 kHz. For each conversion
frequency, a signal measurement is made by the receiver
401 using the 200 kHz receiver bandwidth. The non-
10 linearity indication is determined by adding the five
measurements together.

Conversely for wide band system such as UMTS a narrow
band measurement may be made by digitally signal
15 processing a wideband channel

In some embodiments, the non-linearity indication may
also be used to detect a fault condition or a drift of
the power amplifier 103. For example, a component fault
20 may allow the power amplifier to continue to operate
generating a high power output signal. However, this
signal may be significantly distorted which may give rise
to large out of band interference. This interference may
be detected by the measurement controller 109 and if the
25 nominal supply voltage is applied to the power amplifier
103, the measurement controller 109 may determine that
the power amplifier 103 has developed a fault.
Accordingly, it may deactivate the power amplifier 103.

30 The fault condition may for example be due to ageing or
temperature drift of components resulting in the power
amplifier 103 becoming increasingly non-linear.

In some embodiments, the power controller 111 may deactivate the power amplifier in response to an operating characteristic of a cell supported by the base station. For example, the non-linearity indication may
5 indicate that the power amplifier 103 is increasingly being operated in the non-linear region and thus may generate increased interference. However, if the loading of the cell is very low, the total transmitted power, and thus interference, may be low and an increased
10 interference due to non-linearity of the power amplifier 103 may be acceptable. However, if the loading of the cell is very high, the total transmitted power, and thus interference, may be high and an increased interference due to non-linearity of the power amplifier 103 may be
15 unacceptable. For example, it may introduce interference to other cells or to other operator frequency bands.

In some embodiments, the power controller 111 may deactivate the power amplifier in response to an
20 operating characteristic of a neighbour cell of the base station. For example, if the loading of the neighbour cell is low and/or the interference level in the neighbour cell is low, an increased interference due to an increasingly non-linear power amplifier 103 may be
25 acceptable whereas if the loading of the neighbour cell is high and/or the interference level in the neighbour cell is high, an increased interference due to an increasingly non-linear power amplifier 103 may not be acceptable.

30

FIG. 5 illustrates a flow chart for a method of controlling a transmit power of a transmitter in accordance with some embodiments of the invention. The

transmitter may specifically be the transmitter of FIG. 1.

The method initiates in step 501 wherein a non-linearity
5 indication of the power amplifier of the transmitter is determined. As described previously, the non-linearity indication may be a signal level of an out of band frequency interval.

Step 501 is followed by step 503 wherein the output power
10 of the power amplifier is controlled in response to the non-linearity indication. The output power may be controlled by reducing the power amplifier output for increasing out of band signal level as previously described.

15

Although the description has focussed on an application for a base station of a cellular communication system, the invention is equally applicable to many other transmitters. For example, a transmitter of a user
20 equipment may be operated at reducing battery voltages until this provides unacceptable performance. Hence, the battery life of the user equipment may be increased as operation can be continued until the actual conditions become unacceptable. The user equipment may for example
25 be a communication unit, a 3rd Generation User Equipment (UE), a subscriber unit, a mobile station, a communication terminal, a personal digital assistant, a laptop computer, an embedded communication processor or any physical, functional or logical communication element
30 which is capable of communicating over the air interface of the cellular communication system.

It will be appreciated that the above description for clarity has described embodiments of the invention with reference to different functional units and processors. However, it will be apparent that any suitable
5 distribution of functionality between different functional units or processors may be used without detracting from the invention. For example, functionality illustrated to be performed by separate processors or controllers may be performed by the same
10 processor or controllers. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality rather than indicative of a strict logical or physical structure or organization.

15

The invention can be implemented in any suitable form including hardware, software, firmware or any combination of these. The invention may optionally be implemented partly as computer software running on one or more data
20 processors and/or digital signal processors. The elements and components of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed the functionality may be implemented in a single unit, in a plurality of units or as part of
25 other functional units. As such, the invention may be implemented in a single unit or may be physically and functionally distributed between different units and processors.

30 Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the

accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be
5 combined in accordance with the invention. In the claims, the term comprising does not exclude the presence of other elements or steps.

Furthermore, although individually listed, a plurality of
10 means, elements or method steps may be implemented by e.g. a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a
15 combination of features is not feasible and/or advantageous. Also the inclusion of a feature in one category of claims does not imply a limitation to this category but rather indicates that the feature is equally applicable to other claim categories as appropriate.
20 Furthermore, the order of features in the claims do not imply any specific order in which the features must be worked and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be
25 performed in any suitable order. In addition, singular references do not exclude a plurality. Thus references to "a", "an", "first", "second" etc do not preclude a plurality.

CLAIMS

1. A transmitter for transmitting a radio signal, the transmitter comprising:
 - 5 a power amplifier for generating an amplified radio frequency signal;
determining means for determining a non-linearity indication of the power amplifier from the amplified signal; and
 - 10 control means for controlling an output power of the power amplifier in response to the non-linearity indication.
2. The transmitter claimed in claim 1 wherein the
15 control means is operable to deactivate the power amplifier if the non-linearity indication exceeds a threshold.
3. The transmitter claimed in claim 1 wherein the
20 determining means is operable to determine the non-linearity indication in response to at least one of the group of; a frequency domain characteristic of the amplified signal, a signal power of the amplified signal in at least one out of band frequency interval, and a
25 signal power of at least one out of band spurious of the amplified signal.
4. The transmitter claimed in claim 1 wherein the transmitter further comprises means for detecting a
30 parameter drift of the power amplifier in response to the non-linearity indication.

5. The transmitter claimed in claim 1 and further comprising:

a receiver for receiving signals from a remote
5 transmitter, the receiver being operable to generate a received signal level indication; and

coupling means for coupling the amplified signal to the receiver;

and wherein the determining means is operable to
10 determine the non-linearity indication in response to the received signal level indication when the amplified signal is coupled to the receiver.

6. The transmitter claimed in claim 5 wherein the
15 coupling means comprises means for converting between a transmit frequency of the transceiver and a receive frequency of the transceiver.

7. The transmitter claimed in claim 5 wherein the
20 receiver has an associated receiver channel bandwidth, and the transceiver comprises means for measuring a frequency band having a larger bandwidth than the receiver channel bandwidth by varying a conversion frequency of the coupling means.

25

8. The transmitter claimed in claim 7 further comprising a base station, wherein the control means is further operable to deactivate the power amplifier in response to an operating characteristic of a cell
30 supported by the base station.

9. The transmitter claimed in claim 7 wherein the control means is further operable to deactivate the power amplifier in response to an operating characteristic of a neighbour cell of the base station.

5

10. A method of controlling a transmit power of a transmitter comprising a power amplifier for generating an amplified radio frequency signal, the method comprising the steps of:

- 10 determining a non-linearity indication of the power amplifier from the amplified signal; and
 controlling an output power of the power amplifier in response to the non-linearity indication.

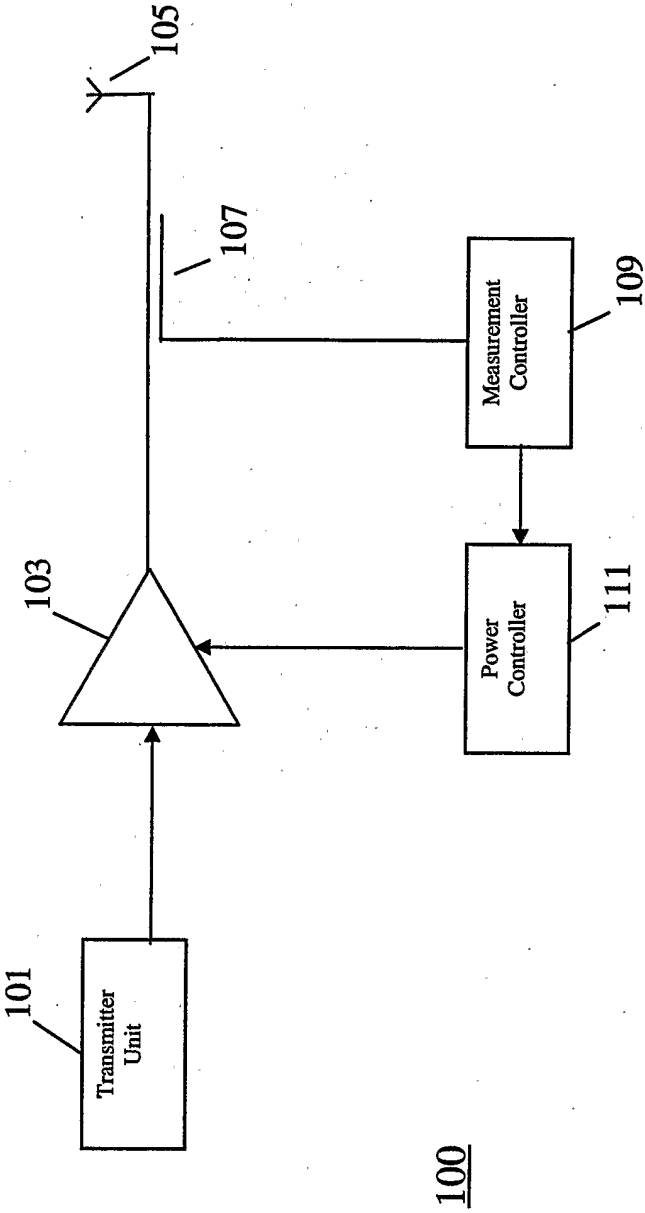


FIG. 1

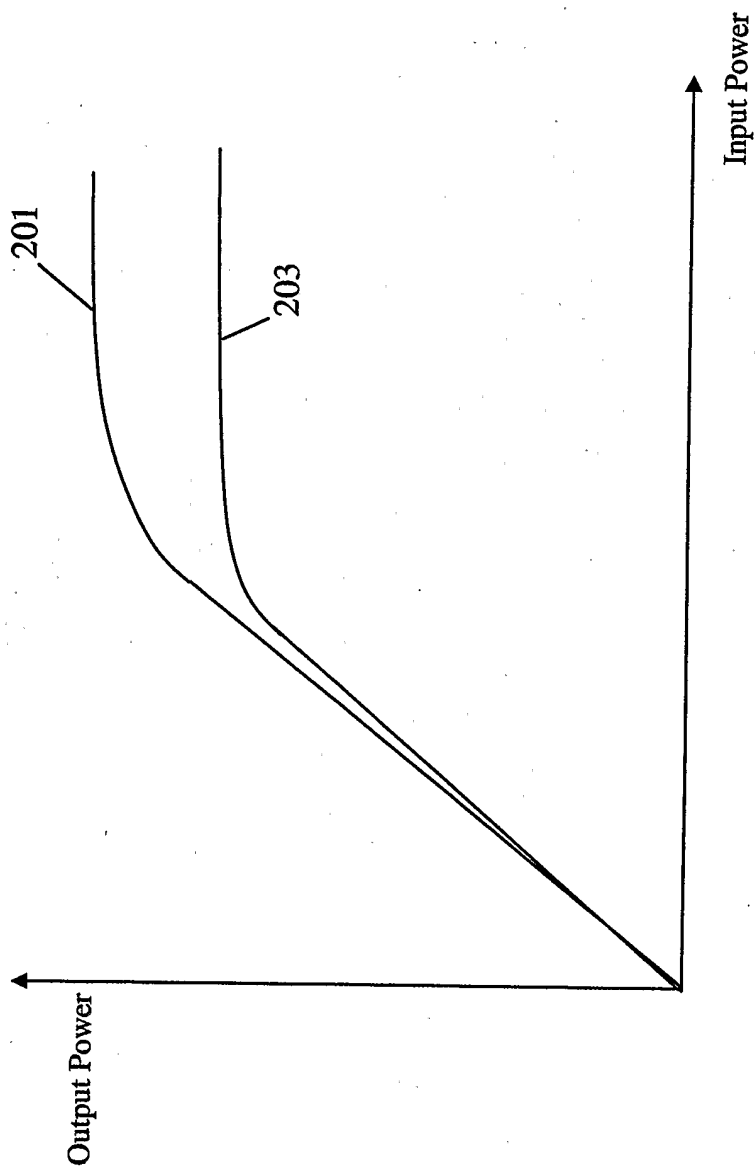


FIG. 2

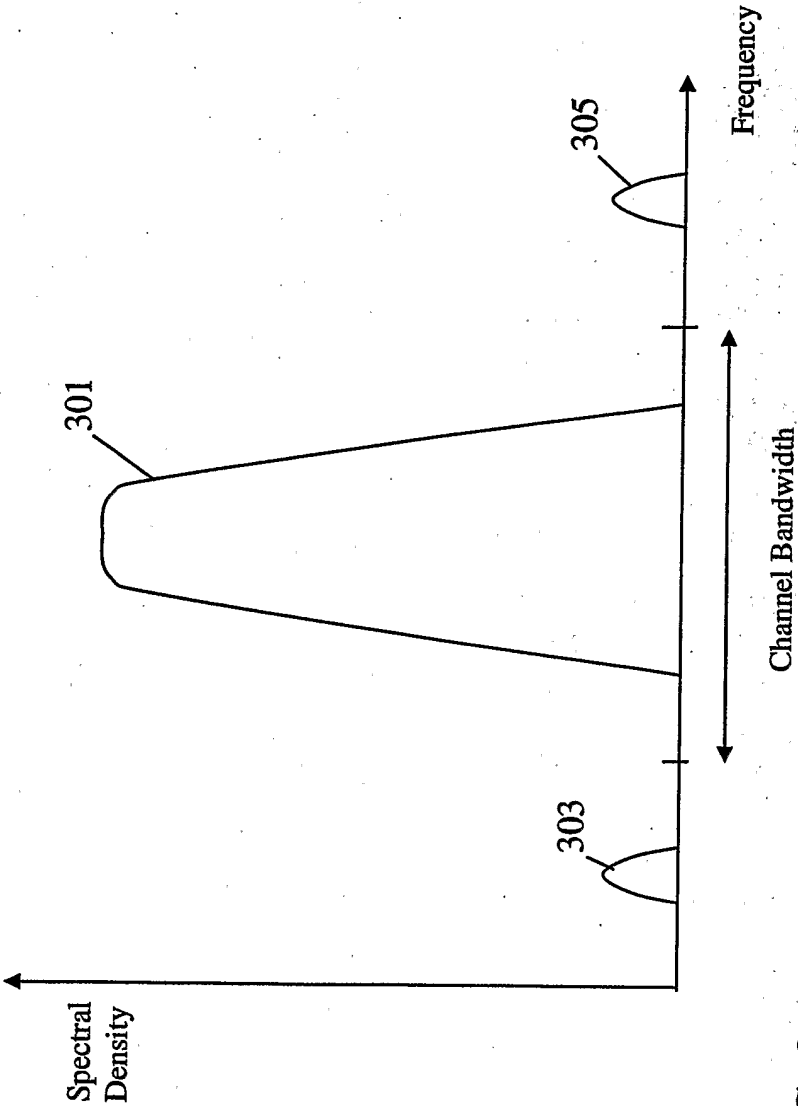


FIG. 3

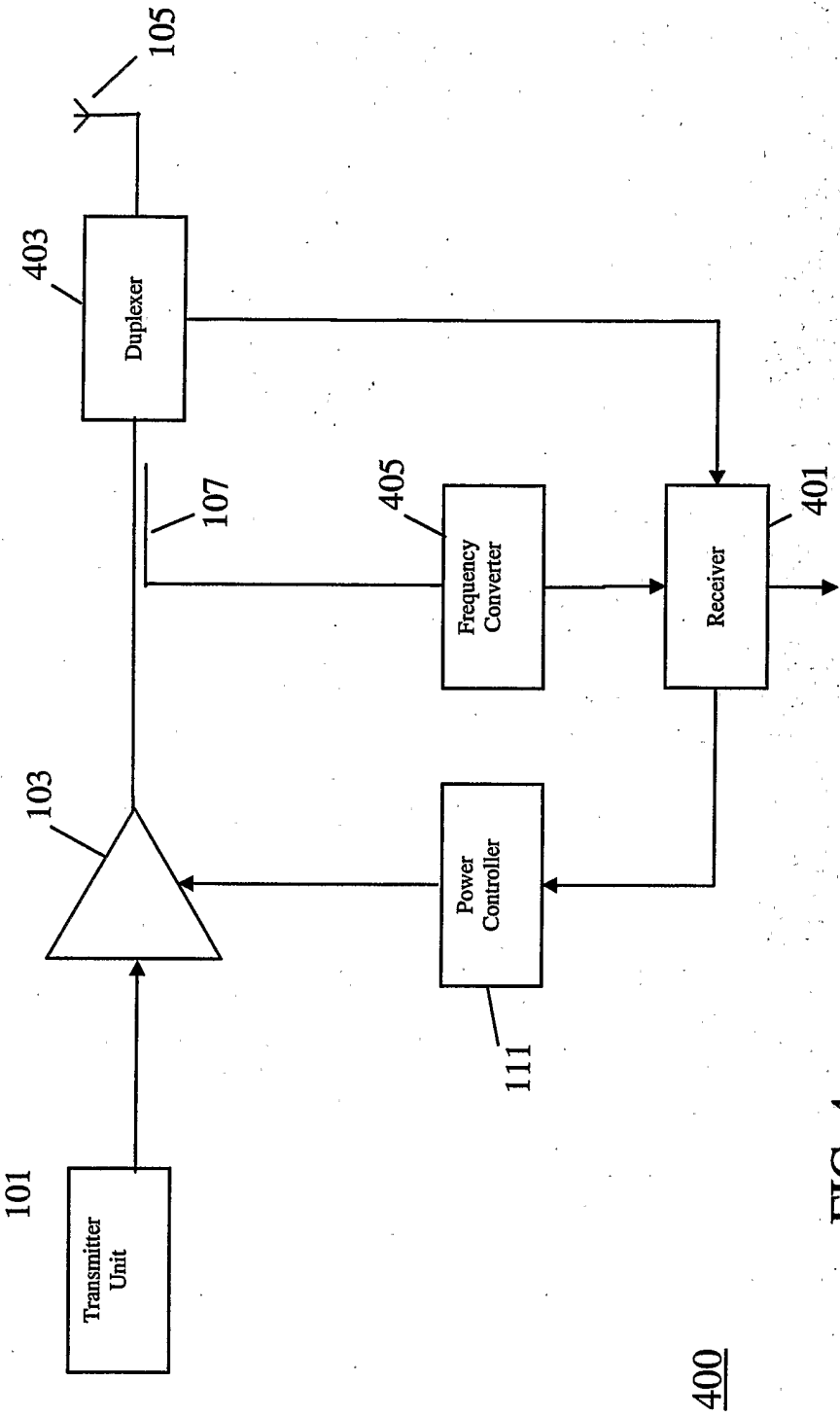
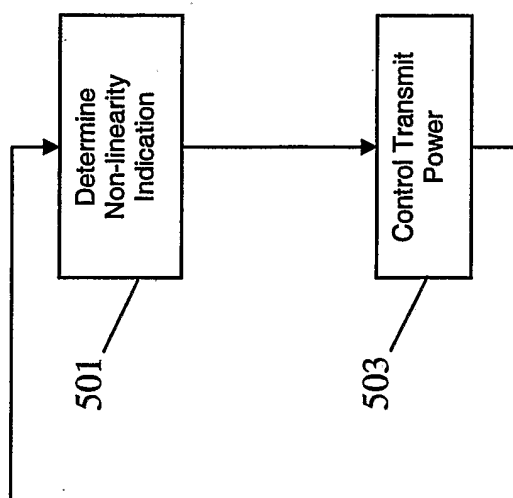


FIG. 4

FIG. 5



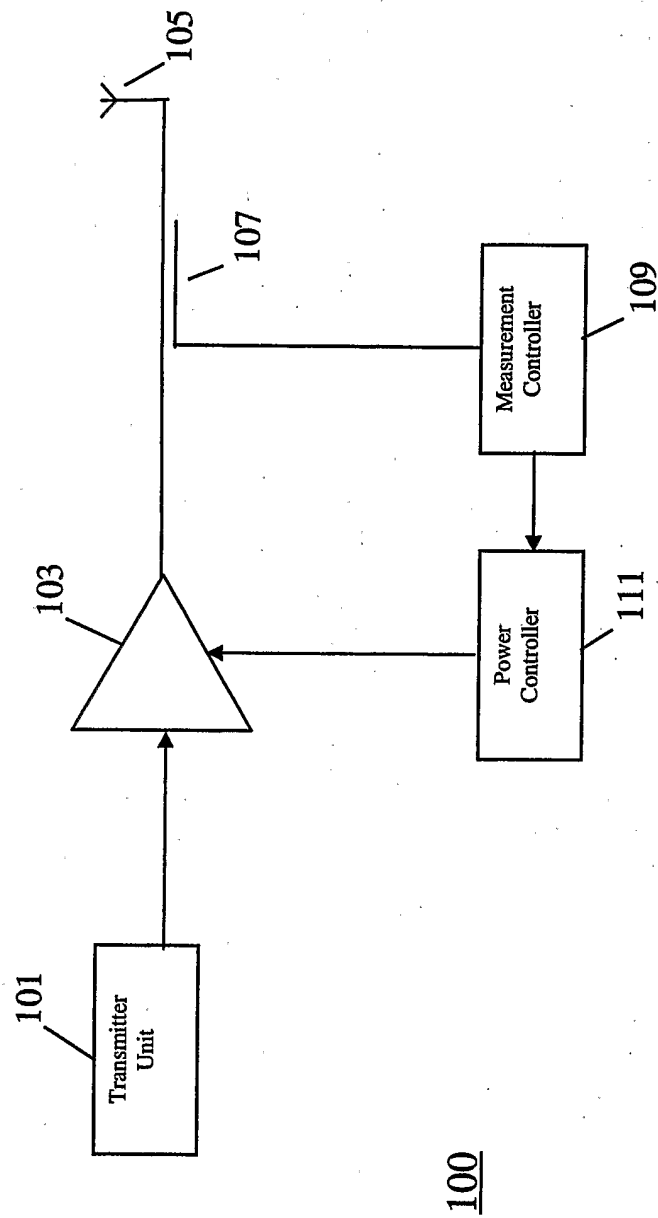


FIG. 1

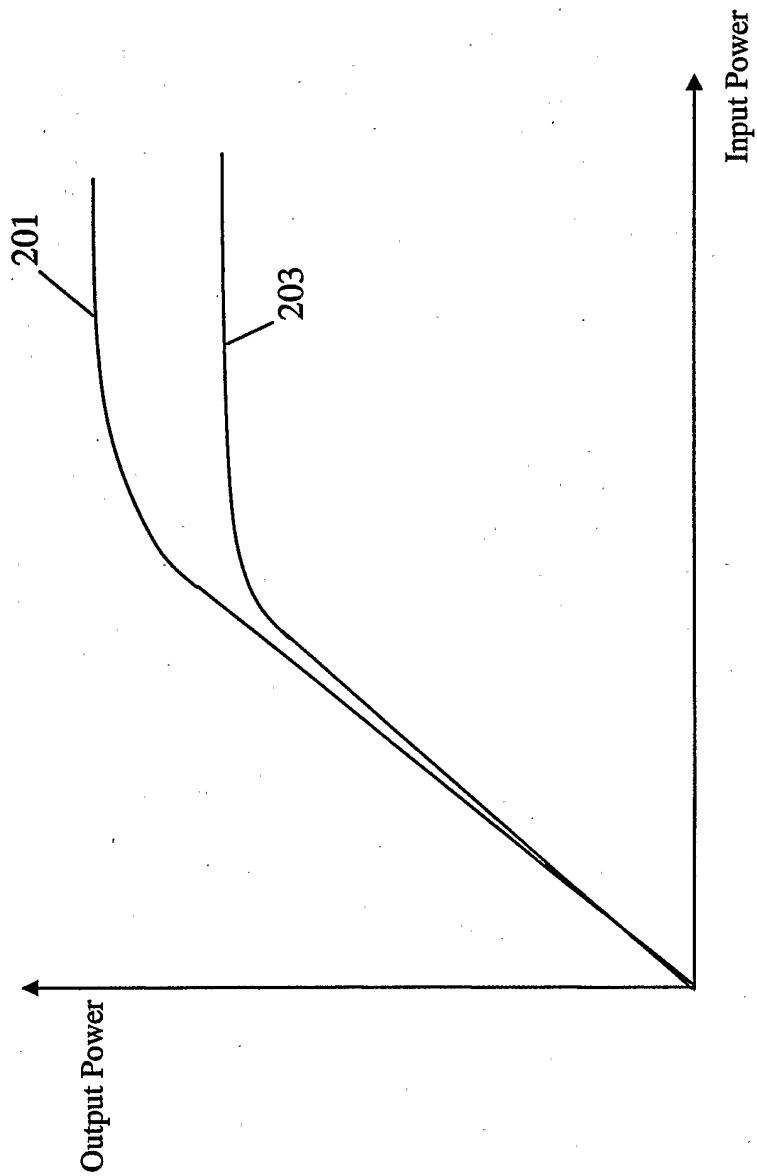


FIG. 2

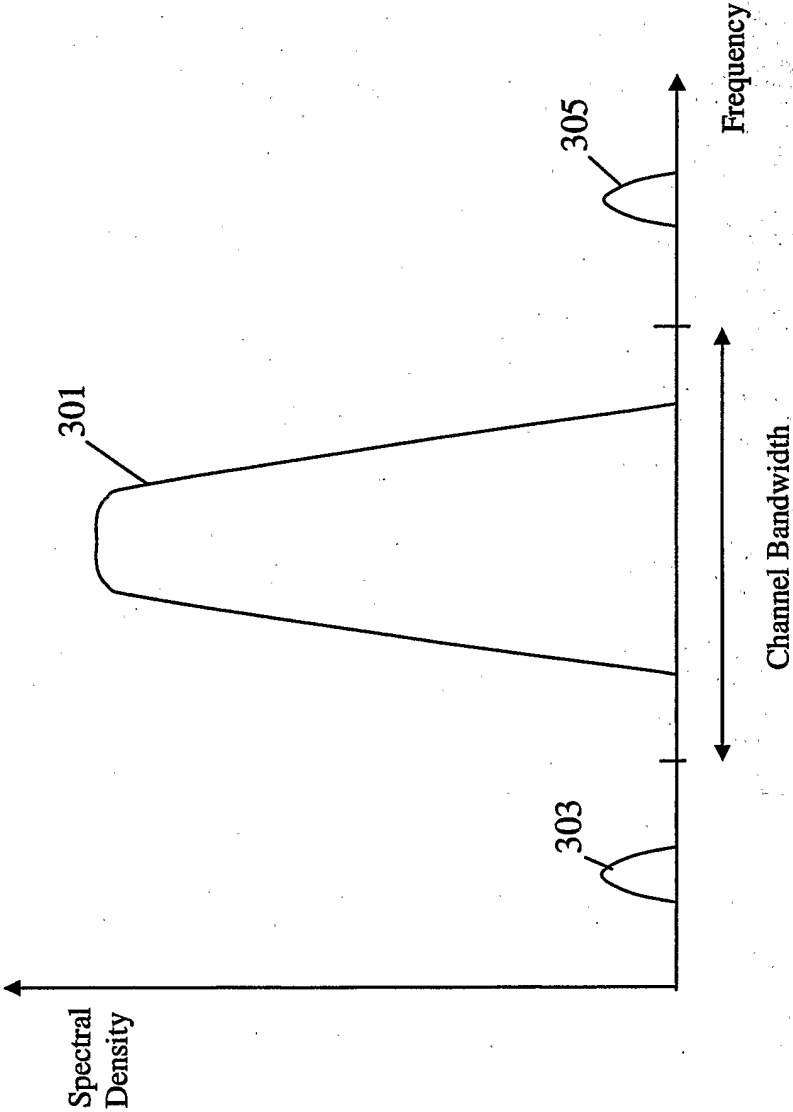


FIG. 3

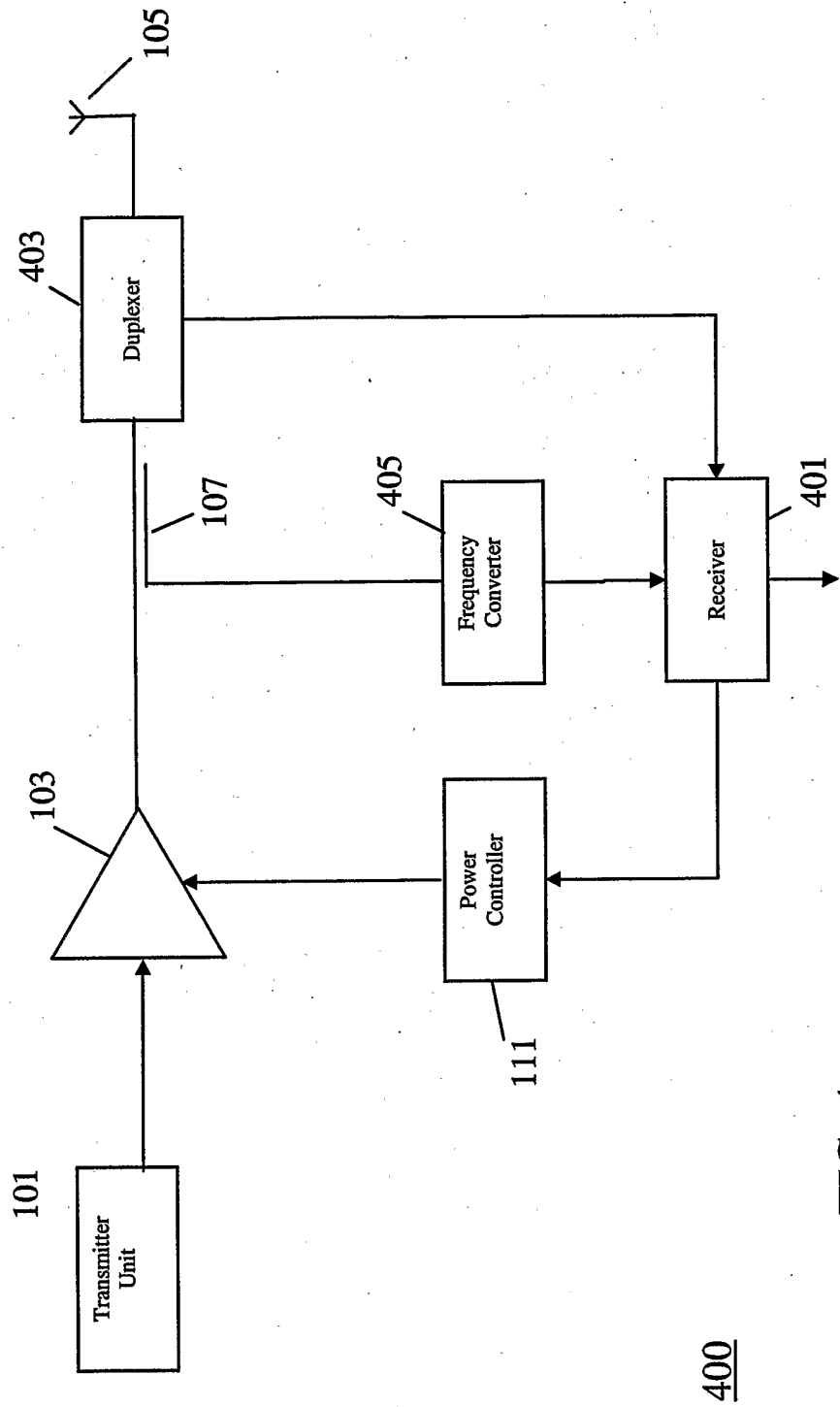


FIG. 4

FIG. 5

