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(54) **Title:** PROCESSING A SIGNAL IN STATION APPARATUS

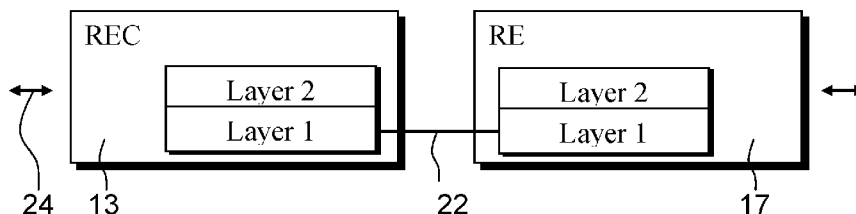


Fig. 2

(57) **Abstract:** The disclosure relates to processing of a signal in a station. A quantization algorithm can be applied for compression of the signal for transmission on an internal interface of the station. The algorithm comprises at least one adjustable parameter. Operation of the quantization algorithm is controlled by adjusting the at least one adjustable parameter according to a variable associated with the signal.

## DESCRIPTION

Title

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**Processing a signal in station apparatus**

10 This disclosure relates to processing of signals communicated within a station apparatus, and more particularly to processing where a signal is communicated on an interface between elements of a station apparatus.

15 A communication system can be seen as a facility that enables communication between two or more communicating apparatus such as base stations, user terminals, relay modes and/or other nodes. The communication may comprise, for example, communication of data signals for carrying communications such as voice, electronic mail (email), text message, multimedia and/or content data and so on. Non-limiting examples of services provided include two-way or multi-way calls, data communication or multimedia services and access to a data network system, such as the Internet. In a wireless communication system at least a part of communications between at least two stations occurs over wireless interfaces. Examples of wireless systems include public land mobile networks (PLMN), satellite based communication systems and different wireless local networks, for example wireless local area networks (WLAN). A user can access a communication system by means of an appropriate communication device or terminal. A communicating apparatus such as a base station or a user terminal device is provided with an appropriate signal receiving and transmitting apparatus for enabling the communications.

25 A communication system and associated devices typically operate in accordance with a given standard or specification which sets out what the various entities associated with the system are permitted to do and how that should be achieved. Communication protocols and/or parameters which shall be used for the connection are also typically defined. An example of the standardized architectures is known as the Global System for Mobile Communications (GSM) and another as long-term evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) radio-access technology. The LTE is being  
30 standardized by the 3rd Generation Partnership Project (3GPP).

A recent development of base station equipment has been related to introduction of a set of internal interfaces to enable a layered approach in terms of hardware architecture. An aim of these proposals is to introduce a standardized split between various base station elements. For instance, a split can be provided between a base band unit and a remote radio head (RRH) of a base station. The interface between the elements will handle the conversion of the base band signal to a desired radio carrier. Typically, when implementing a split at the base band level, signals transmitted on the interface are I and Q samples representing the complex base band signal. The samples are then converted by the radio element through I/Q mixing to a carrier frequency. Examples of layered interfaces include the common public radio interface (CPRI) and the open base station architecture initiative (OBSAI). A schematic illustration of a such configuration in accordance with CPRI specifications is shown in figure 2. Next generation interfaces for the split have also been discussed, these proposal being sometimes called open BaseBand Unit remote radio head (BBU RRH) interfaces (OBRI).

Transfer of data signals on a digital interface between the elements of a station apparatus, however, can require a considerable amount of bandwidth. An example of this is transfer of data in digital form to a digital to analogue unit of a remote radio unit. High system bandwidths and high resolution in the sample domain may require high bandwidth from the internal interface. Use of multiple antennas can also increase the bandwidth requirement as each antenna is represented by its own IQ sample stream.

Different solutions have been proposed to reduce the bandwidth requirement for the interface between the central unit and the RRH. Compression is one possibility to reduce the load. Various algorithms for compression of data to be transmitted utilizing quantization are known. A-law and  $\mu$ -law compression are among the most commonly used techniques for these purposes when digitalization and compression of data with wide dynamic range is needed. These methods are typically used in connection with voice applications. One solution aims to provide time domain correlation analysis and potentially also frequency domain analysis for compression of the signal carried over the interface. This is at the expense of increased signal-to-noise ratio through degradation of the error vector magnitude (EVM) created in the transmitter unit. The EVM is a measure of the observed difference between ideal symbols and measured symbols after impairments. These impairments may for instance occur in a transmitter module of a station. Performance requirements for a node are defined in relevant specifications.

The CPRI and OBSAI interfaces are open implementations, and it is up to vendors how to configure and utilize the transmission of data through the interface. One example is an I/Q interface configured to handle samples at the same resolution as what is offered by digital-to-analogue converters (DAC) in a remote radio head (RRH). Basically, in such configuration, the interface has to offer a throughput corresponding to the resolution and sample rate of the DACs in the RRH to accommodate the highest possible resolution. Centralized processing for multiple base stations at the same central unit (possibly combined with the possibility of having multiple antennae at the remote site) may set relative high requirements on the transfer rates between the central unit and the remote site. Even if this interface is considered as part of the backhaul network, increased bandwidth may cause increased cost for the network operator.

It is noted that the above discussed issues are not limited to any particular communication environment and station apparatus, but may occur in any appropriate station apparatus where internal communications are required.

Embodiments of the invention aim to address one or several of the above issues.

In accordance with an embodiment there is provided a method for processing a signal in a station, comprising applying a quantization algorithm for compression of the signal for transmission on an internal interface of the station, the algorithm comprising at least one adjustable parameter, and controlling the operation of the quantization algorithm by adjusting the at least one adjustable parameter according to a variable associated with the signal.

In accordance with another embodiment there is provided an apparatus for a station, comprising an interface for transmission of a signal to radio unit of the station, and a controller configured to apply a quantization algorithm for compression of the signal for the transmission, the algorithm comprising at least one adjustable parameter, wherein the controller is configured to adjust the at least one parameter of the quantization algorithm according to a variable associated with the signal.

In accordance with more specific embodiments the at least one parameter may comprise an indication of at least one of level of the signal, number of bits reserved for at least a part of the signal, number of quantization levels, a transition point between different resolution regimes, a transition point between different quantization methods, a positive/negative sign, and an amplitude range, and a phase range.

Indication of a level of signal may comprise the maximum level thereof. Different resolution regimes can comprise a high resolution regime and a low resolution regime.

The variable may comprise at least one of load, the type of the signal, and features associated with the signal.

5       At least one parameter of the quantization algorithm may be updated every transmission time interval or OFDM symbol.

10       I and Q samples representing a complex baseband signal may be compressed in certain embodiments for transmission over the interface. The interface may comprise an I/Q interface between a radio equipment control entity and a radio equipment entity of a base station. The interface may be provided between a central control unit and a remote radio unit of a base station.

Error vector magnitude performance may be optimized by means of the at least one parameter.

15       Data rate on the interface may be reduced in response to exceeding a threshold for error vector magnitude.

The at least one parameter may be communicated over the interface.

The apparatus may be comprised in a base station. Various means for implementing the apparatus may be provided. The means can be in hardware and/or software.

20       A computer program comprising program code means adapted to perform the herein described methods may also be provided. In accordance with further embodiments apparatus and/or computer program product that can be embodied on a computer readable medium for providing at least one of the above methods is provided.

Various other aspects and further embodiments are also described in the following detailed description of examples embodying the invention and in the attached claims.

25       The invention will now be described in further detail, by way of example only, with reference to the following examples and accompanying drawings, in which:

Figure 1 shows an example of a system and station apparatus wherein below described examples of the invention may be implemented;

Figure 2 shows an example of layered elements of a station apparatus;

Figure 3 is a flowchart in accordance with an embodiment; and

Figure 4 shows an example of a parameter relating to division of samples to different resolution regimes.

In the following certain exemplifying embodiments are explained with reference to a  
5 base station of a wireless communication system serving devices adapted for wireless communication. Therefore, before explaining in detail the exemplifying embodiments, certain general principles of a wireless system are briefly explained with reference to Figures 1 and 2 to assist in understanding the technology underlying the described examples.

In wireless or mobile communication systems access can be provided via a wireless  
10 access interface between mobile devices 20 and an appropriate access system. A communication device that a user can use for communications is often referred to as user equipment (UE) or terminal. A mobile device 20 may access wirelessly a communication system via a base station apparatus or site 10. A base station apparatus can be provided with radio transceiver equipment 12. In addition to the co-located radio equipment, the  
15 base station apparatus 10 can be provided with at least one remote radio head (RRH) 16 and 17. The remote radio units may each be provided with one or multiple antennae.

A base station apparatus is typically controlled by at least one appropriate controller so as to enable operation thereof and management of communication devices in communication therewith. The control apparatus can be interconnected with other control entities.  
20 In Figure 1 the controller is shown to be provided by block 13. All transceiver radio equipment 12, 16 and 17 are controlled by the same central control apparatus 13. An appropriate controller apparatus may comprise at least one memory, at least one data processing unit and an input/output interface. The controller is thus typically provided with at least one data processor 14 and appropriate memory function 15. It shall be understood that the  
25 control functions may be distributed between a plurality of controller units. The controller apparatus for a base station may be configured to execute an appropriate software code to provide the control functions.

In Figure 1 the base station apparatus 10 is shown to be connected to a data network 11 via an appropriate gateway 18. A gateway function between the access system  
30 and another network such as a packet data network may be provided by means of any appropriate gateway node, for example a packet data gateway and/or an access gateway. A communication system may thus be provided by one or more interconnect networks and

the elements thereof, and one or more gateway nodes may be provided for interconnecting various networks.

A non-limiting example of mobile architectures where the herein described principles may be applied is known as the Evolved Universal Terrestrial Radio Access Network (E-UTRAN). A non-limiting example of base station of a cellular system is what is termed as a NodeB or enhanced NodeB (eNB) in the vocabulary of the 3GPP specifications. The eNBs may provide E-UTRAN features such as user plane Radio Link Control/Medium Access Control/Physical layer protocol (RLC/MAC/PHY) and control plane Radio Resource Control (RRC) protocol terminations towards mobile communication devices.

Figure 2 shows a schematic view of a configuration in accordance with CPRI specifications where a split at the base band level between control unit 13 and remote radio unit 17 is provided. In Figure 2 the first mentioned element is labelled a radio equipment control (REC) and the latter element a radio equipment (RE). An example of data transfer on the interface 22 between the entities is transfer of data in digital form to a digital to analogue converter unit 19 of the remote radio unit 17, see Figure 1. The signals transmitted on the digital interface 22 between entities 13 and 17 can be I and Q samples representing the complex base band signal. The samples are then converted by the remote radio unit through I/Q mixing to an appropriate carrier frequency. The I/Q interface 22 can be configured to handle samples at the same resolution as what is offered by digital-to-analogue converters (DAC) in the remote radio head (RRH) 17.

The control apparatus 13 can be configured to provide control functions in association with control of transmissions on the interface 22, and generation, communication and interpretation of information regarding the control operations. For providing the desired operation, the control apparatus 13 comprises at least one memory 15, at least one data processing unit 14 and input/output interfaces. Via interface 24 the control apparatus 13 can receive signals to be transmitted. Via interface 22 the control apparatus can communicate with the radio unit(s). The control apparatus 13 can be configured to execute an appropriate software code to provide the control functions.

An appropriate mobile communication device 20 may be provided by any device capable of sending and receiving radio signals. Non-limiting examples include a mobile station (MS) such as a mobile phone or what is known as a 'smart phone', a portable computer provided with a wireless interface card or other wireless interface facility, personal data assistant (PDA) provided with wireless communication capabilities, or any combinations of these or the like. A mobile communication device may provide, for example, com-

munication of data for carrying communications such as voice, electronic mail (email), text message, multimedia, positioning data, other data, and so on. Users may thus be offered and provided numerous services via their communication devices. Non-limiting examples of these services include two-way or multi-way calls, data communication or multimedia services or simply an access to a data communications network system, such as the Internet.

In accordance with an embodiment shown by the flowchart of Figure 3 a bit-resolution quantization algorithm over an interface between a control unit and a radio unit is used at step 100 for compressing the signal to be transferred from a control unit to a radio unit. The algorithm comprises at least one adjustable parameter that can be varied at 102 depending on at least one variable associated with the input signal. The algorithm of this example is parameterized to accommodate variability of the input signal while at the same time being able to provide near-optimum performance in terms of degrading the error vector magnitude (EVM) of the transmitter unit.

The quantization algorithm may consist of two parts: (1) the quantization algorithm itself, and (2) parameterization of operation of the quantization unit. By means of this dynamic adjustment of the configuration of the quantization can be provided.

A non-limiting example for parameterization of operation of a quantization unit is to define a number of parameters which describe the configuration or operation of the quantization unit. For example, a quantization algorithm may operate with two methods, denoted "A" and "B" in here for simplicity. With the parameterization, one or more parameters can be defined for example such that transition point between different quantization methods is defined. For example, x% of the signaling states can be assigned to quantization method "A" while the remainder of the signaling states can be assigned to quantization method "B" by means of the adjustable parameter.

Further, a parameter y may be used for defining amplitude ranges assigned to each method. One example is to define that if the signal amplitude is lower than y% of the expected maximum amplitude of the signal, the signal is assigned to quantization method "A", otherwise the signal is assigned to quantization method "B". Instead of division by amplitude ranges, another division criterion may be used. For example, a division may be provided in a phase domain.

In accordance with an example parameterization can be based on sign operations. For example, if a symmetrical algorithm is provided a parameter in the form of one signal-

ing bit can be used to represent a sign. If a similar number of signaling states are assigned to positive and negative values, respectively, the operation can be adjusted by means of the sign bit. In accordance with another example, non-symmetrical operation can be provided e.g. if e.g. the x% of signaling states mentioned above is divided into positive and negative percentages.

In accordance with another embodiment an absolute value of a signal is represented by the parameter. This may be used, for instance, in case of polar representation.

In accordance with certain embodiments the quantization levels can be divided in N resolution regimes to provide optimal performance. In accordance with an embodiment the dynamic range is divided into two different regimes, for example high-resolution and low-resolution regimes, see Figure 4. In accordance with another embodiment high, medium, and low resolution regimes are provided.

A step-wise quantization algorithm can be used to obtain a near-optimum quantization performance. The step-wise algorithm can be a two-step linear compression algorithm or a combined two-step linear and exponential/logarithmic algorithm. Both approaches can provide an improved performance compared to simple linear quantization when considering the introduced EVM degradation. In a step-wise method two different mapping functions may be used, one for each resolution. The conversion/compression can be done within one conversion step/stage. From incoming sample point of view this means distribution of the sample to one of two (or N) regimes and mapping thereof to a corresponding output sample. In this embodiment the transition point between the regimes can be controlled by means of the parameterization.

A base station apparatus such as an eNB may have time-varying load. The load may depend, for example, on scheduling needs. A parameterization of the quantization scheme can be introduced to address variation in the load such that the at least one parameter of the algorithm changes according to the loading.

Further examples of the variable parameters for the algorithm can include the following:

- Maximum level of signal. This parameter may be derived statistically from the expected load of signal. The value of the parameter may be changed such that the lower the amount of user traffic the lower is the value of the maximum level of signal parameter.

• Number of bits reserved for the high-resolution part of the signal and/or the number of bits reserved for the low-resolution part of the signal. Division into low-resolution and high resolution parts enables use of fewer signaling states for maintaining a level of EVM. Use of fewer states can enable use of fewer bits, thereby lowering the requirement for signaling bandwidth.

• An indication of the number of quantization levels.

• Transition point in the amplitude domain where the algorithm should switch between high resolution and low resolution. This point combined with the number of bits can be used to define the actual curve shape of the quantization algorithm, as shown in Figure 4.

The parameterization of the quantization algorithm can be used to provide flexibility so that the compression algorithm can adjust to a large variety of configurations. The parameters can potentially be updated every transmission time interval (TTI) or every orthogonal frequency division multiplexing (OFDM) symbol. This may be particularly the case for a LTE based system where there may be differences per OFDM symbol due to differences in power reserved for reference symbols and data symbols. This may be especially predominant for situations with a relative low load. For such cases, the used parameters would then need to be transferred over the interface for the radio equipment of the remote unit of the base station architecture to be able to properly map the IQ samples.

The optimization may be provided for example based on an aim to keep the IQ interface rate constant (e.g. in a fixed transport implementation) but to adjust the parameters to optimize EVM performance. This can be advantageously applied due to the nature of dedicated fronthaul transport systems. Another possible aim is to reduce the speed of the IQ interface when the EVM performance is exceeded. For example, this can be used when variable bit rate can be tolerated and mapped to other gains over the transport interface.

The adjustment can be provided on dynamic, static or semi-static basis. The setting of the parameters can be based on input signal, for example based on a priori knowledge historical, statistical, or concurrent observations of the behavior of the input signal. The adjustment may be provided dynamically during the operation, periodically or for example only once per installation, for example when setting up the base station or when a modification thereof is made.

Apart from load, other variables may be responded to by setting of the adjustable parameter of the algorithm. For example, the setting may depend on the type of the sig-

nals (e.g. whether the signal is a high speed packet access (HSPA) signal, LTE signal, GSM signal, uplink or downlink signal) and/or depending on features that are associated with the signal (e.g. if multiple input multiple output (MIMO) is used, quadrature amplitude modulation (QAM) levels, etc.).

5           In accordance with an embodiment an apparatus for a station comprises control means for causing transmission of a signal to a radio unit of the station, and control means for applying a quantization algorithm for compression of the signal for the transmission. The control means are configured for adjustment of at least one adjustable parameter of the quantization algorithm according to a variable associated with the signal.

10           Although the embodiments are described in the context of LTE downlink, quantization algorithm(s) on complex baseband signals can be used for both link directions, as well as for other radio access technologies (for instance for WCDMA). The parameters used for optimizing the performance may need to be chosen differently for different radio access technologies and/or link directions.

15           An appropriately adapted computer program code product or products may be used for implementing the embodiments, when loaded or otherwise provided on an appropriate data processing apparatus, for example for causing determination of the variable associated with the input signal and the effect thereof on the at least one parameter of the quantization algorithm and/or running of any required algorithms such that a dynamic control on the interface is provided. The program code product for providing the operation  
20           may be stored on, provided and embodied by means of an appropriate carrier medium. An appropriate computer program can be embodied on a computer readable record medium. A possibility is to download the program code product via a data network. In general, the various embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Embodiments of the inventions may thus be practiced in various components such as integrated circuit modules. The design of integrated  
25           circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

30           It is noted that whilst embodiments have been described in relation to certain architectures, similar principles can be applied to other communication systems. For example, this may be the case in application where no fixed stations are provided but a communication system is provided by means of a plurality of user equipment, for example in adhoc networks. Also, the above principles can also be used in networks where relay nodes are

employed for relaying transmissions. Therefore, although certain embodiments were described above by way of example with reference to certain exemplifying architectures for wireless networks, technologies and standards, embodiments may be applied to any other suitable forms of communication systems than those illustrated and described herein. It is also noted that different combinations of different embodiments are possible. It is also noted herein that while the above describes exemplifying embodiments of the invention, there are several variations and modifications which may be made to the disclosed solution without departing from the spirit and scope of the present invention.

## Claims

1. A method for processing a signal in a station, comprising  
applying a quantization algorithm for compression of the signal for transmission on  
an internal interface of the station, the algorithm comprising at least one adjustable parameter, and

controlling the operation of the quantization algorithm by adjusting the at least one adjustable parameter according to a variable associated with the signal.

2. A method according to claim 1, wherein the at least one parameter comprises an indication of at least one of level of the signal, number of bits reserved for at least a part of the signal, number of quantization levels, a transition point between different resolution regimes, a transition point between different quantization methods, a positive/negative sign, an amplitude range, and a phase range.

3. A method according to claim 2, wherein the level of signal comprises the maximum level of the signal and the different resolution regimes comprise high resolution and low resolution.

4. A method according to any preceding claim, wherein the variable comprises at least one of load, the type of the signal, and features associated with the signal.

5. A method according to any preceding claims, comprising updating at least one parameter of the quantization algorithm every transmission time interval or OFDM symbol.

6. A method according to any preceding claims, comprising compression of I and Q samples representing a complex baseband signal.

7. A method according to claim 6, wherein the interface comprises an I/Q interface between a radio equipment control entity and a radio equipment entity of a base station.

8. A method according to any preceding claim wherein the interface is between a central control unit and a remote radio unit of a base station.

5 9. A method according to any preceding claims, comprising optimizing error vector magnitude performance by means of the at least one parameter.

10. A method according to claim 9, comprising maintaining a constant data rate on the interface.

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11. A method according to any of claims 1 to 8, comprising reducing data rate on the interface in response to exceeding a threshold for error vector magnitude.

12. A method according to any preceding claim wherein the algorithm comprises a two  
15 step linear compression algorithm.

13. A method according to any preceding claim wherein the algorithm comprises a combined two step linear and exponential / logarithmic compression algorithm.

20 14. A method according to any preceding claim, comprising sending the at least one parameter over the interface.

15. An apparatus for a station, comprising:  
an interface for transmission of a signal to a radio unit of the station, and

25 a controller configured to apply a quantization algorithm for compression of the signal for the transmission, the algorithm comprising at least one adjustable parameter, wherein the controller is configured to adjust the at least one parameter of the quantization algorithm according to a variable associated with the signal.

16. An apparatus according to claim 15, wherein the at least one parameter comprises an indication of at least one of level of the signal, number of bits reserved for at least a part of the signal, number of quantization levels, a transition point between different resolution regimes, a transition point between different quantization methods, a positive/negative sign, an amplitude range, and a phase range.

17. An apparatus according to claim 16, wherein the level of signal comprises the maximum level of the signal and the different resolution regimes comprise high resolution and low resolution.

18. An apparatus according to any of claims 15 to 17, wherein the variable comprises at least one of load, the type of the signal, and features associated with the signal.

19. An apparatus according to any of claims 15 to 18, configured to update at least one parameter of the quantization algorithm every transmission time interval or OFDM symbol.

20. An apparatus according to any of claims 15 to 18, configured to compress I and Q samples representing a complex baseband signal.

21. An apparatus according to claim 20, wherein the interface comprises an I/Q interface between a radio equipment control entity and a radio equipment entity of a base station.

22. An apparatus according to any of claims 15 to 21, wherein the interface is between a central control unit and a remote radio unit of a base station.

23. An apparatus according to any of claims 15 to 22, configured to reduce data rate on the interface in response to exceeding a threshold for error vector magnitude.

24. An apparatus for a station, comprising:  
control means for causing transmission of a signal to a radio unit of the station, and

control means for applying a quantization algorithm for compression of the signal for the transmission, the algorithm comprising at least one adjustable parameter, the control means being configured for adjustment of the at least one parameter of the quantization algorithm according to a variable associated with the signal.

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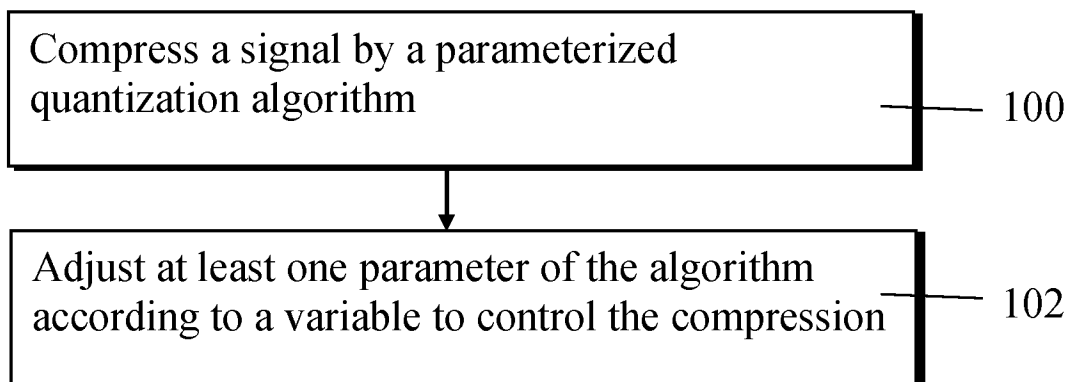
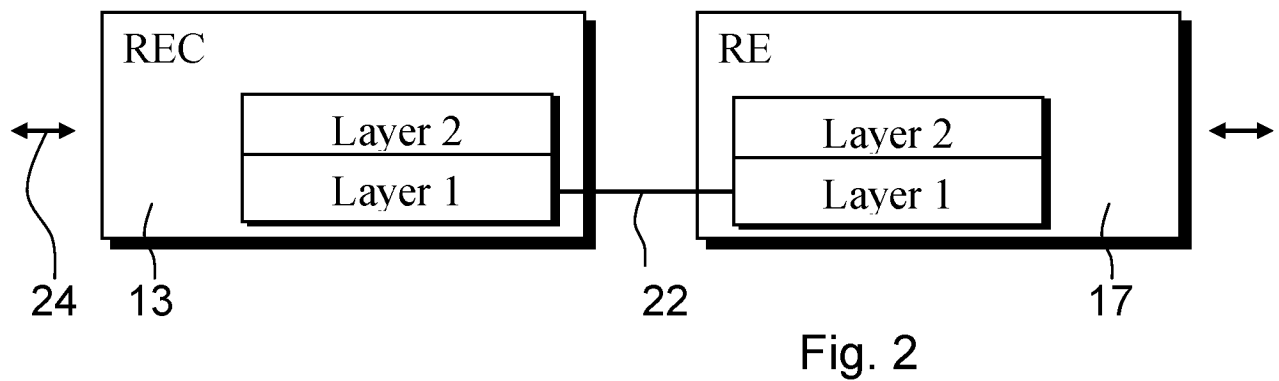
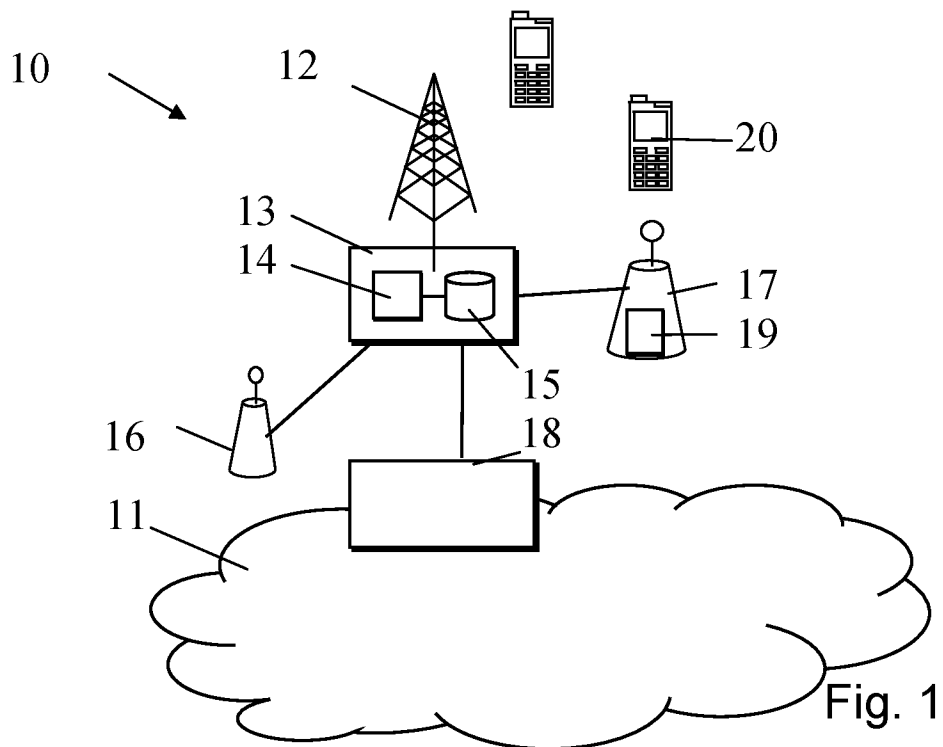
25. A station comprising the apparatus according to any of claim 15 to 24.

26. A communication system comprising the apparatus according to any of claim 15 to 24.

10

27. A computer program comprising code means adapted to perform the steps of any of claims 1 to 14 when the program is run on a processor.

15



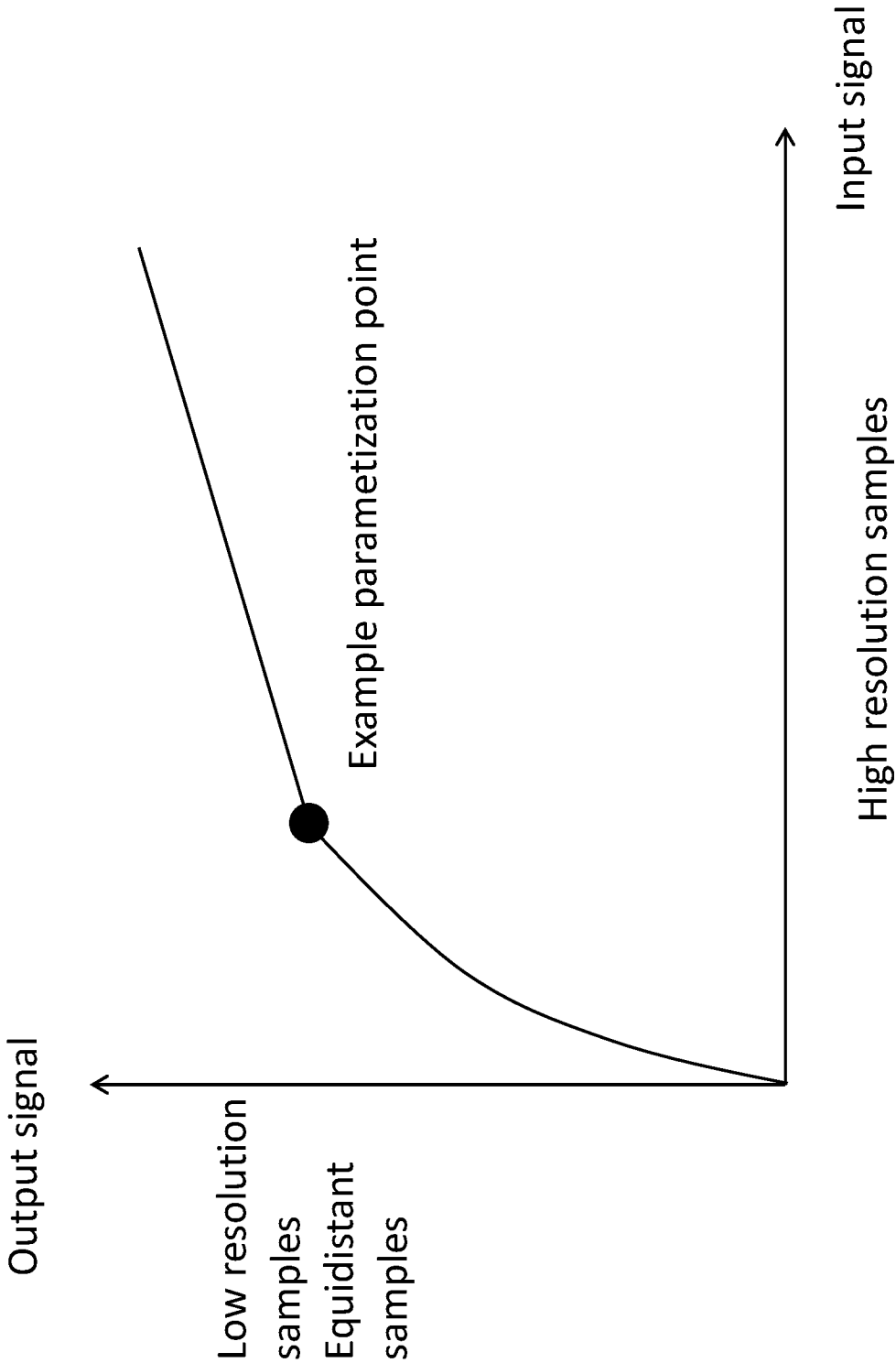


Fig. 4

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2012/051403

## A. CLASSIFICATION OF SUBJECT MATTER

INV. H03M7/30 G10L19/00 H04B14/04  
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)

H03M G10L H04B 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.   |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| X         | WO 2012/012248 A1 (QUALCOMM INC [US];<br>WILBORN THOMAS B [US]; BANISTER BRIAN C<br>[US]; YUN S) 26 January 2012 (2012-01-26)<br>the whole document                                                                 | 1-27                    |
| X         | US 2006/293884 A1 (GRILL BERNHARD [DE] ET<br>AL) 28 December 2006 (2006-12-28)<br><br>abstract<br>paragraph [0019] - paragraph [0021]<br>paragraph [0048] - paragraph [0052]<br>paragraph [0075] - paragraph [0135] | 1-5,<br>8-19,<br>22-27  |
| X         | EP 1 049 074 A1 (LUCENT TECHNOLOGIES INC<br>[US]) 2 November 2000 (2000-11-02)                                                                                                                                      | 1-4,<br>14-18,<br>24-27 |
| A         | the whole document                                                                                                                                                                                                  | 5-13,<br>19-23          |
|           | -----<br>-/-                                                                                                                                                                                                        |                         |



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

5 July 2012

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