



(51) International Patent Classification:
H04L 27/26 (2006.01)

(21) International Application Number:
PCT/IB2011/053334

(22) International Filing Date:
26 July 2011 (26.07.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/367,765 26 July 2010 (26.07.2010) US

(71) Applicant (for all designated States except US): **NOKIA CORPORATION** [FI/FI]; Keilalahdentie 4, FI-02150 Espoo (FI).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **REIKKINEN, Ville** [FI/FI]; Puistokatu 10 A 39, FI-90120 Oulu (FI). **VENTOLA, Mika** [FI/FI]; Kaurastie 4, FI-90800 Oulu (FI). **SIPILA, Teemu** [FI/FI]; Rantatie 36, FI-90460 Oulunsalo (FI).

(74) Common Representative: **NOKIA CORPORATION**; IPR Department, Ari Aarnio, Keilalahdentie 4, FI-02150 Espoo (FI).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: APPARATUS AND METHOD FOR CUBIC METRIC ESTIMATOR IN DUAL-CARRIER AND MULTI-CARRIER WIRELESS COMMUNICATION SYSTEM

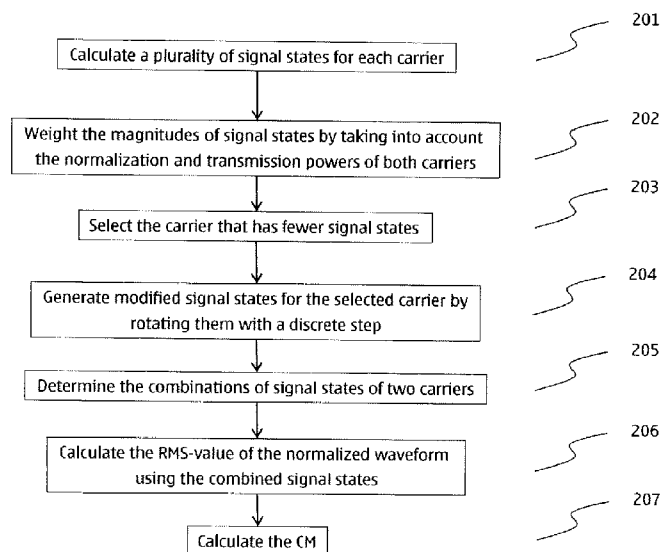


Figure 2

(57) Abstract: In accordance with an example embodiment of the present invention, a method is disclosed that comprises by using a processor, calculating a plurality of signal states for each of at least two carriers, selecting at least one carrier from the at least two carriers, generating modified signal states for each of the selected at least one carrier by rotating at least one of the respective plurality of signal states with a discrete frequency shift step, determining combinations of signal states of the at least two carriers based at least in part on the modified signal states of the selected at least one carrier, and calculating a cubic metric based on the determined combinations of signal states of the at least two carriers.

APPARATUS AND METHOD FOR CUBIC METRIC ESTIMATOR IN DUAL-CARRIER AND MULTI-CARRIER WIRELESS COMMUNICATION SYSTEM

5 TECHNICAL FIELD

The present application relates generally to an apparatus and a method for cubic metric estimator in dual-carrier and multi-carrier wireless communication system.

BACKGROUND

10 This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived, implemented or described. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by
15 inclusion in this section.

In wireless communication, different collections of communication protocols are available to provide different types of services and capabilities. High speed packet access (HSPA) is one of such collection of wireless communication protocols that extends and improves the performance of existing UMTS (universal mobile telecommunications system)
20 protocols and is specified by different releases of the standard by the 3rd generation partnership project (3GPP) in the area of mobile network technology. The other non-limiting example wireless communication protocols are long term evolution (LTE), global system for mobile (GSM) and worldwide interoperability for microwave access (WiMAX).

Current and future networking technologies continue to facilitate ease of
25 information transfer and convenience to users. In order to provide easier or faster information transfer and convenience, telecommunication industry service providers are developing improvements to existing networks. Carrier aggregation technology has drawn considerable attention in, e.g., HSPA and LTE.

In Release 8 (Rel-8) of HSPA standardization of 3GPP, dual-carrier HSDPA
30 (high speed downlink packet access) was specified by introducing dual-carrier operation in the downlink on adjacent carriers. In an example embodiment, dual-carrier HSPA may be used where a MAC (medium access control) scheduler may allocate two HSPA carriers in parallel and double the communication bandwidth. Besides the throughput gain from double

the bandwidth, some diversity and joint scheduling gains may also be expected. This can particularly improve the quality of service (QoS) for end users in poor environment conditions that cannot be gained from other techniques. Similar idea is under consideration in the enhanced LTE technology called LTE-Advanced. Via this technology LTE is expected to
5 improve end-user throughput, increase sector capacity, reduce user plane latency, and consequently offer superior user experience with full mobility.

In Release 9 studies of the HSPA track, a study item termed DC-HSUPA (dual-cell high speed uplink packet access) for uplink dual carrier UE (user equipment) operation has been launched. In DC-HSUPA, the UE may be assigned one or two uplink carriers for
10 data transmission if the UE is dual carrier capable. As compared to downlink dual-carrier operation, where the UE is required to receive the dual-carrier transmission transmitted by the Node B or base station, in the uplink the UE is power limited and thus it needs to share its transmission power among the carriers if it transmits on both carriers simultaneously.

Power amplifier (PA) of the transmitter is non-linear, which causes distortion
15 that degrades the error vector magnitude (EVM) and increases spurious emissions (SE). Signals that have higher peak to average ratio (PAR) will also have a higher linearity requirement for the PA. There are two possibilities to meet the higher linearity requirement: either the PA is designed to be more linear or the operating point of the existing PA has to be set so that the signals do not get distorted. As the PAs become more expensive from the cost
20 and power consumption point of view when the linearity of the PA is increased, it may be more desirable to use the existing PA designs. The distortion, and thus EVM and SE, of the PA may be controlled by adjusting its operating point. Typically, when PAR of the base band signal increases the operating point of the PA has to be adjusted towards more linear region in order to maintain EVM and adjacent channel leakage ratio (ACLR). This adjustment can
25 be done by increasing an output back-off of the PA.

An example of the increase of PAR is in an HSPA communication, when the HS-DPCCH (high speed dedicated physical control channel) and E-DPDCH (E-DCH dedicated physical data channel, wherein E-DCH stands for enhanced dedicated channel) channels are multiplexed into the Release 99 channels. For high power levels this may cause
30 the power amplifier to work in non-linear region, thus may increase ACLR and spectrum mask leakage. In order to tackle this problem and to enable to use PAs that have been designed for the Release 99, the standard allows the UE to reduce the maximum transmit power when HS-DPCCH and/or E-DCH are present.

The calculation of maximum power reduction (MPR) involves the cubic metric (CM). The CM value approximates the 3rd order non-linearity of PA and enables to generalize the amount of PA back-off allowed to fulfill the ACLR requirements.

The cubic metric may be computationally complex and it may need to be
5 calculated every time the channel gain factors change. For example, in HSPA, the calculation of CM for every transmission time interval (TTI) would be enough. However, because the HS-DPCCH transmission may change on every slot, CM may need to be determined for every slot. Furthermore, if the E-DPDCH scaling occurs, the cubic metric may need to be re-calculated within the current slot before the data is to be transmitted. A method that calculates
10 CM for single band or carrier scenario is described in the related application with US Patent Application Serial number 12/453433, titled "Apparatus, system, and method for calculating a non-linearity metric". This method utilizes the channel gain factors, determines the constellation points (i.e., the signal states to be transmitted) and calculates the cubic metric on the basis of the constellation points.

15

SUMMARY

Various aspects of examples of the invention are set out in the claims.

According to a first aspect of the present invention, a method may include by using a processor, calculating a plurality of signal states for each of at least two carriers,
20 selecting at least one carrier from the at least two carriers, generating modified signal states for each of the selected at least one carrier by rotating at least one of the respective plurality of signal states with a discrete frequency shift step, determining combinations of signal states of the at least two carriers based at least in part on the modified signal states of the selected at least one carrier, and calculating a cubic metric based on the determined combinations of
25 signal states of the at least two carriers.

According to a second aspect of the present invention, an apparatus may include at least one processor, and at least one memory including computer program code, wherein the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to calculate a plurality of signal states for each of at
30 least two carriers, select at least one carrier from the at least two carriers, generate modified signal states for each of the selected at least one carrier by rotating at least one of the respective plurality of signal states with a discrete frequency shift step, determine combinations of signal states of the at least two carriers based at least in part on the modified

signal states of the selected at least one carrier, and calculate a cubic metric based on the determined combinations of signal states of the at least two carriers.

According to a third aspect of the present invention, a computer program product comprising a computer-readable medium bearing computer program code embodied
5 therein for use with a computer, the computer program code may include code for calculating a plurality of signal states for each of at least two carriers, code for selecting at least one carrier from the at least two carriers, code for generating modified signal states for each of the selected at least one carrier by rotating at least one of the respective plurality of signal states with a discrete frequency shift step, code for determining combinations of signal states
10 of the at least two carriers based at least in part on the modified signal states of the selected at least one carrier, and code for calculating a cubic metric based on the determined combinations of signal states of the at least two carriers.

According to a fourth aspect of the present invention, an apparatus may include a means for calculating a plurality of signal states for each of at least two carriers, a means
15 for selecting at least one carrier from the at least two carriers, a means for generating modified signal states for each of the selected at least one carrier by rotating at least one of the respective plurality of signal states with a discrete frequency shift step, a means for determining combinations of signal states of the at least two carriers based at least in part on the modified signal states of the selected at least one carrier, and a means for calculating a
20 cubic metric based on the determined combinations of signal states of the at least two carriers.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of example embodiments of the present
25 invention, reference is now made to the following descriptions taken in connection with the accompanying drawings in which:

Figure 1 illustrates an example wireless system;

Figure 2 illustrates an overview of cubic metric calculation for dual-carrier high speed uplink packet access according to an example embodiment of the invention;

30 Figure 3 depicts an example how the combined signal states of two carriers can be generated according to an example embodiment of the invention; and

Figure 4 shows a simplified block diagram of an electronic apparatus in accordance with an example embodiment of the invention.

DETAILED DESCRIPTION

Figure 1 depicts an example wireless system 100. Wireless system 100 comprises a Node B or base station 101 and a plurality of user equipments (UEs) 103, 105 and 107. Although just one Node B and three UEs are shown in Figure 1, the wireless system 100 may comprise more Node Bs and more or less UEs. In one example embodiment, the Node B 101, possibly together with other Node Bs and one or more radio network controllers, comprises the UMTS (universal mobile telecommunications system) terrestrial radio access network (UTRAN). In the context of this disclosure, the Node B 101 communicates with the UEs 103, 105 and 107 via bidirectional communication channels or links 102, 104 and 106, respectively. While some of the UEs, for example, the UEs 105 and 107, may be conventional UEs that communicate with the Node B 101 in one carrier frequency or band for each of the downlink and uplink direction, at least one UE, for example, the UE 103, may be allocated dual or multiple carriers for at least its uplink communication channel 102. Therefore, in an example embodiment, the Node B 101 may allocate a communication carrier to each UE, e.g., UE 105 and 107. In an embodiment, the Node B 101 may allocate a plurality of communication carriers to a UE, e.g., UE 103. In such an embodiment, the increase in the number of allocated communication carriers may correlate with an increase in communication bandwidth. A throughput gain from the increase in the bandwidth allocated to a UE may be expected. In an example embodiment, the increased bandwidth, due to the plurality of communication carriers may allow for some diversity and joint scheduling gains.

In an example embodiment, multiple code channels may be multiplexed and transmitted on at least one of the allocated dual or multiple carriers of UE 103. The code channel can be, for example, in an HSPA system, dedicated physical control channel (DPCCH), high speed dedicated physical control channel (HS-DPCCH), E-DCH dedicated physical control channel (E-DPCCH), wherein E-DCH stands for enhanced dedicated channel, or E-DCH dedicated physical data channel (E-DPDCH). For uplink communication, the UE 103 generates in baseband an information signal to be transmitted for each of the code channels. The UE 103 also scales the signals by their respective gain factors (beta factors) according to certain scheduling information.

For single-carrier HSUPA (high speed uplink packet access), 3GPP TS 25.101 Chapter 6.2.2., incorporated by references herein, sets the requirements for the cubic metric

(CM). How the CM is actually computed or estimated is vendor dependent, but the methods have to be based directly or indirectly on the signal states, e.g., the constellation points, and beta values of the code channels.

In 3GPP TS25.101, cubic metric is given by

$$\text{CM} = \text{CEIL} \{ [20 * \log_{10} ((v_{\text{norm}})^3)_{\text{rms}}] - 20 * \log_{10} ((v_{\text{norm\_ref}})^3)_{\text{rms}} \} / k, \quad (1)$$

where $\text{CEIL}\{x, 0.22\}$ means rounding upwards to closest 0.22dB with 0.5 dB granularity, v_{norm} and $v_{\text{norm\_ref}}$ are the normalized voltage waveforms of the input signal and the reference signals, respectively, $(x)_{\text{rms}}$ denotes root mean square (RMS) value of x , and $20 * \log_{10} ((v_{\text{norm\_ref}})^3)_{\text{rms}}$ and k are constants. $(v_{\text{norm}})^3)_{\text{rms}}$ is calculated based on the signal states of code channels.

For UE 103, the introduction of dual or more carriers increases the computational complexity of cubic metric even further. In an example embodiment for dual carriers allocation, the two carriers are shifted in frequency (+2.5 MHz, -2.5 MHz), which means that the number of transmitted signal states becomes infinite, as the constellations of the first and the second carrier rotate in respect with each other.

In an example embodiment, the computation of the cubic metric takes into account the constellation points of two carriers, their rotation in respect with each other and the combined constellation points. In an example embodiment, a rotation with discrete step may be applied to the constellation points of one of the two carriers and to produce the combined constellation points, i.e., combined signal states. The cubic metric may be further calculated from the combined signal states as described in the related application with US Patent Application Serial number 12/453433, titled "Apparatus, system, and method for calculating a non-linearity metric". In an example embodiment, the rotation is preferably applied to the constellation points of the carrier that has a fewer number of constellation points. The accuracy of the approximation in respect to the computational complexity can be adjusted by selecting the rotation step correspondingly.

Figure 2 illustrates an overview of CM calculation for dual-carrier HSUPA according to an example embodiment of the invention. At 201, a plurality of possible computational signal states for each carrier are calculated. In one example embodiment, only part of all possible computational signal states, for example, one fourth of the signal states, for each carrier are calculated. The calculation may be prior to scrambling, spreading and root raised cosine (RRC) filtering operations of a UE, e.g., the UE 103 in Figure 1. Only part of

the signal states are useful because the rest of the signal states produce redundant information due to the symmetry of the constellation diagram. The number of the signal states depends on the number of active code channels.

At 202, the magnitudes of signal states are weighted by taking into account the normalization and the requested transmission powers of both carriers. In an example embodiment, this may be done basically in the following way: keep a carrier, for example, the first carrier, as a reference carrier, and weight the computational signal states of the second

carrier by the factor $u = \sqrt{\frac{P_2}{P_1}} \cdot \sqrt{\frac{\beta_{1,1}^2 + \beta_{1,2}^2 + \dots + \beta_{1,L_1}^2}{\beta_{2,1}^2 + \beta_{2,2}^2 + \dots + \beta_{2,L_2}^2}}$, where $\beta_{j,l}^2$ denotes the square of l th

beta factor on j th carrier and L_j is the number of active channels on j th carrier. P_1 and P_2

denote the requested transmission powers of the first and second carrier, respectively.

At 203, the carrier that has fewer signal states is selected. At 204, in order to approximate the effect of the frequency shift between the two carriers, the calculated signal states on the selected carrier are rotated with a discrete step, for example, with an angle of 5, 10 or 22.5 degree. In an example embodiment, only one fourth of signal states on the selected carrier are rotated. The adopted angle affects the accuracy of the CM estimation algorithm. By 204, modified signal states of the selected carrier are generated. At 205, all possible combinations between the modified signal states of the selected carrier and the signal states of the carrier having higher number of signal states are determined.

At 206, the RMS value of the normalized waveform, $(v\_norm^3)_{rms}$, is

calculated based on the combined signal states generated at 205. The CM then can be calculated as a function of $(v\_norm^3)_{rms}$, for example, according to the equation (1).

Figure 3 depicts an example how the combined signal states of two carriers can be generated according to an example embodiment of the invention. In Figure 3, one carrier is assumed to be the primary carrier and the other carrier is assumed to be the secondary carrier. In this example, the primary carrier has one code channel mapped to the quadrature branch (Q-branch) of the transmission path of a UE, e.g., the UE 103 in Figure 1, and two code channels mapped to inphase branch (I-branch) of the transmission path of the UE. The secondary carrier has two code channels, each of which is mapped to both Q-branch and I-branch. A binary phase shift keying (BPSK) modulation is applied to all code channels in this example.

Because a BPSK modulated code channel has two signal states, the primary carrier in the example of Figure 3 has totally 8 signal states, as shown at block 301. Similarly, the secondary carrier has totally 16 signal states, as shown at block 311. In an example embodiment, the primary carrier is selected for rotation of signal states since it has fewer
 5 number of signal states. In an example embodiment, only one fourth of signal states on the primary carrier, i.e., two signal states are used, as shown at block 302. In the example of Figure 3, a frequency shift step of 22.5 degree is adopted, which results in the modified signal states of the primary carrier as illustrated at block 303. The modified signal states of the primary carrier are combined with one fourth of the signal states of the secondary carrier,
 10 which are shown at block 312. Finally, the result of combination is described at block 321 and it can be used to calculate the RMS value of the waveform, thus, the cubic metric.

In an example embodiment of the invention, the number of combined signal states for dual-carrier system can be computed as $\frac{1}{4} \times N_1 \times \frac{1}{4} \times N_2 \times R$, where N_1 and N_2 are
 15 the number of signal states of the first and the second carrier, respectively. The value of N_1 and N_2 depend on the number of active code channels and the applied modulation on each code channel. R indicates how many “modified” or “rotated” signal states can be generated from each original signal state of a selected carrier. In an example embodiment, R is equal to 360/(discrete step), and the discrete step may be, for example, 5, 10 or 22.5 degree. In the example illustrated by Figure 3, the discrete step is 22.5 degree and R is equal to 16. Each
 20 state of the selected carrier, the primary carrier in the example of Figure 3, is multiplied by $e^{j2n\pi/16}$, where $n=0,1,\dots,15$. Therefore, 16 modified signal states are generated for each original state of the primary carrier. It can be noted that the smaller the discrete step, the more the number of combined signal states. It should be understood that the examples using the number of signal states and other concrete values are merely for illustrative purposes. Other
 25 values are also possible.

Reference is made to Figure 4 for illustrating a simplified block diagram of an electronic apparatus 400 in accordance with an example embodiment of the invention. In an example embodiment, the apparatus may be a mobile communication device which may be referred to as the UE 103. The apparatus 400 includes a processor 401 and a memory (MEM)
 30 402 coupled to the processor 401 that stores a program of computer instructions (PROG) 403. The apparatus 400 may further include a suitable transceiver (TRANS) 405 (having a

transmitter (TX) and a receiver (RX)) coupled to the processor 401. The TRANS 405 is for bidirectional wireless communications with other communication devices that are not shown in Figure 4.

As shown in Figure 4, the apparatus 400 may further include a signal states
5 determination and cubic metric computation unit 404. The signal states determination and cubic metric computation unit 404, together with the processor 401 and the PROG 403, is configured to perform the determination of combined signal states and computation of the cubic metric in a similar way as illustrated by Figure 2.

The PROG 403 is assumed to include program instructions that, when executed
10 by the associated processor, enable the electronic apparatus to operate in accordance with the example embodiments of this disclosure, as discussed herein.

In general, the various example embodiments of the apparatus 400 can include, but are not limited to, cellular phones, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities,
15 image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions.

The example embodiments of this disclosure may be implemented by computer
20 software executable by the processor 401 of the apparatus 400, or by hardware, or by a combination of software and hardware.

The MEM 402 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as
25 semiconductor-based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory, as non-limiting examples. The processor 401 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on
30 multi-core processor architecture, as non-limiting examples.

Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein may be allowing the cubic metric to be computed with reasonable

complexity for dual-carrier and multiple-carrier communication devices. This allows the device to determine the trade-off between the accuracy requirements and computational complexity.

Embodiments of the present invention may be implemented in software,
5 hardware, application logic or a combination of software, hardware and application logic. The software, application logic and/or hardware may reside on an apparatus such as a user equipment, a Node B/base station or other mobile communication devices. If desired, part of the software, application logic and/or hardware may reside on a user equipment 400, and part of the software, application logic and/or hardware may reside on other chipset or integrated
10 circuit. In an example embodiment, the application logic, software or an instruction set is maintained on any one of various conventional computer-readable media. In the context of this document, a “computer-readable medium” may be any media or means that can contain, store, communicate, propagate or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device. A computer-readable medium may
15 comprise a computer-readable storage medium that may be any media or means that can contain or store the instructions for use by or in connection with an instruction execution system, apparatus, or device.

Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the described
20 embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

It is also noted herein that while the above describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which may be made without departing from the scope of
25 the present invention as defined in the appended claims.

For example, while the example embodiments have been described above in the context of the HSUPA system for uplink transmission, it should be appreciated that the example embodiments of this invention are not limited for use with only this one particular type of wireless communication system, and that they may be used to advantage in other
30 wireless communication systems and in downlink transmission. Although two carriers are assumed in Figures 2 and 3 for illustration purpose, the example embodiments of this invention are also suitable for use with more than two carriers.

Further, the various names used for the described parameters are not intended to be limiting in any respect, as these parameters may be identified by any suitable names.

Further, the various names assigned to different channels (e.g., E-DPCCH, etc.) are not intended to be limiting in any respect, as these various channels may be identified by any

5 suitable names.

If desired, the different functions discussed herein may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined. As such, the foregoing description should be considered as merely illustrative of the principles, teachings and

10 example embodiments of this invention, and not in limitation thereof.

WHAT IS CLAIMED IS

1. A method, comprising:
by using a processor,
calculating a plurality of signal states for each of at least two carriers;
5 selecting at least one carrier from the at least two carriers;
generating modified signal states for each of the selected at least one carrier by rotating at
least one of the respective plurality of signal states with a discrete frequency shift step;
determining combinations of signal states of the at least two carriers based at least in
part on the modified signal states of the selected at least one carrier; and
10 calculating a cubic metric based on the determined combinations of signal states of
the at least two carriers.
2. The method of claim 1, wherein selecting at least one carrier further
comprises:
15 selecting the at least one carrier based at least in part on the number of the signal
states.
3. The method of claim 1, wherein selecting at least one carrier further comprises
selecting the at least one carrier with a fewer number of the signal states.
20
4. The method of claim 1, wherein generating modified signal states further
comprises:
rotating only part of the respective signal states of each of the selected at least one
carrier.
25
5. The method of claim 1, wherein generating modified signal states further
comprises:
rotating one fourth of the respective signal states of each of the selected at least one
carrier.
30

6. The method of claim 1, wherein generating modified signal states further comprises:

determining a plurality of multipliers based at least in part on the discrete frequency shift step; and multiplying at least one of the respective signal states by the plurality of multipliers.

7. An apparatus, comprising:

at least one processor;

and at least one memory including computer program code,

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to perform:

calculate a plurality of signal states for each of at least two carriers;

select at least one carrier from the at least two carriers;

generate modified signal states for each of the selected at least one carrier by rotating at least one of the respective plurality of signal states with a discrete frequency shift step;

determine combinations of signal states of the at least two carriers based at least in part on the modified signal states of the selected at least one carrier; and

calculate a cubic metric based on the determined combinations of signal states of the at least two carriers.

8. The apparatus of claim 7, wherein select at least one carrier further comprises: select the at least one carrier based at least in part on the number of the signal states.

9. The apparatus of claim 7, wherein select at least one carrier further comprises: select the at least one carrier with a fewer number of the signal states.

10. The apparatus of claim 7, wherein generate modified signal states further comprises:

rotate only part of the respective signal states of each of the selected at least one carrier.

11. The apparatus of claim 7, wherein generate modified signal states further comprises:

rotate one fourth of the respective signal states of each of the selected at least one carrier.

5

12. The apparatus of claim 7, wherein generate modified signal states further comprises:

determine a plurality of multipliers based at least in part on the discrete frequency shift step; and multiplying at least one of the respective signal states by the plurality of multipliers.

10

13. A computer program product comprising a computer-readable medium bearing computer program code embodied therein for use with a computer, the computer program code comprising:

15

code for calculating a plurality of signal states for each of at least two carriers; code for selecting at least one carrier from the at least two carriers; code for generating modified signal states for each of the selected at least one carrier by rotating at least one of the respective plurality of signal states with a discrete frequency shift step;

20

code for determining combinations of signal states of the at least two carriers based at least in part on the modified signal states of the selected at least one carrier; and code for calculating a cubic metric based on the determined combinations of signal states of the at least two carriers.

25

14. The computer program product of claim 13, wherein the computer program code for selecting at least one carrier further comprises:

code for selecting the at least one carrier based at least in part on the number of the signal states.

30

15. The computer program product of claim 13, wherein the computer program code for selecting at least one carrier further comprises:

code for selecting the at least one carrier with a fewer number of the signal states.

16. The computer program product of claim 13, wherein the computer program code for generating modified signal states further comprises:

code for rotating only part of the respective signal states of each of the selected at least one carrier.

5

17. The computer program product of claim 13, wherein the computer program code for generating modified signal states further comprises:

code for rotating one fourth of the respective signal states of each of the selected at least one carrier.

10

18. The computer program product of claim 13, wherein the computer program code for generating modified signal states further comprises:

code for determining a plurality of multipliers based at least in part on the discrete frequency shift step; and

15

code for multiplying at least one of the respective signal states by the plurality of multipliers.

19. The method of claim 1, wherein calculating the plurality of signal states for each of at least two carriers further comprises:

20

weighting the magnitudes of the plurality of signal states by taking into account the normalization and transmission powers of the at least two carriers.

20. The method of claim 1, wherein calculating the cubic metric further comprises:

25

calculating the RMS-value of a normalized waveform by using the combined signal states.

21. The apparatus of claim 7, wherein calculate the plurality of signal states for each of at least two carriers further comprises:

30

weight the magnitudes of the plurality of signal states by taking into account the normalization and transmission powers of the at least two carriers.

22. The apparatus of claim 7, wherein calculate the cubic metric further comprises:

calculate the RMS-value of a normalized waveform by using the combined signal states.

5

23. The computer program product of claim 13, wherein the code for calculating the plurality of signal states for each of at least two carriers further comprises:

code for weighting the magnitudes of the plurality of signal states by taking into account the normalization and transmission powers of the at least two carriers.

10

24. The computer program product of claim 13, wherein the code for calculating the cubic metric further comprises:

code for calculating the RMS-value of a normalized waveform by using the combined signal states.

15

20

25

30

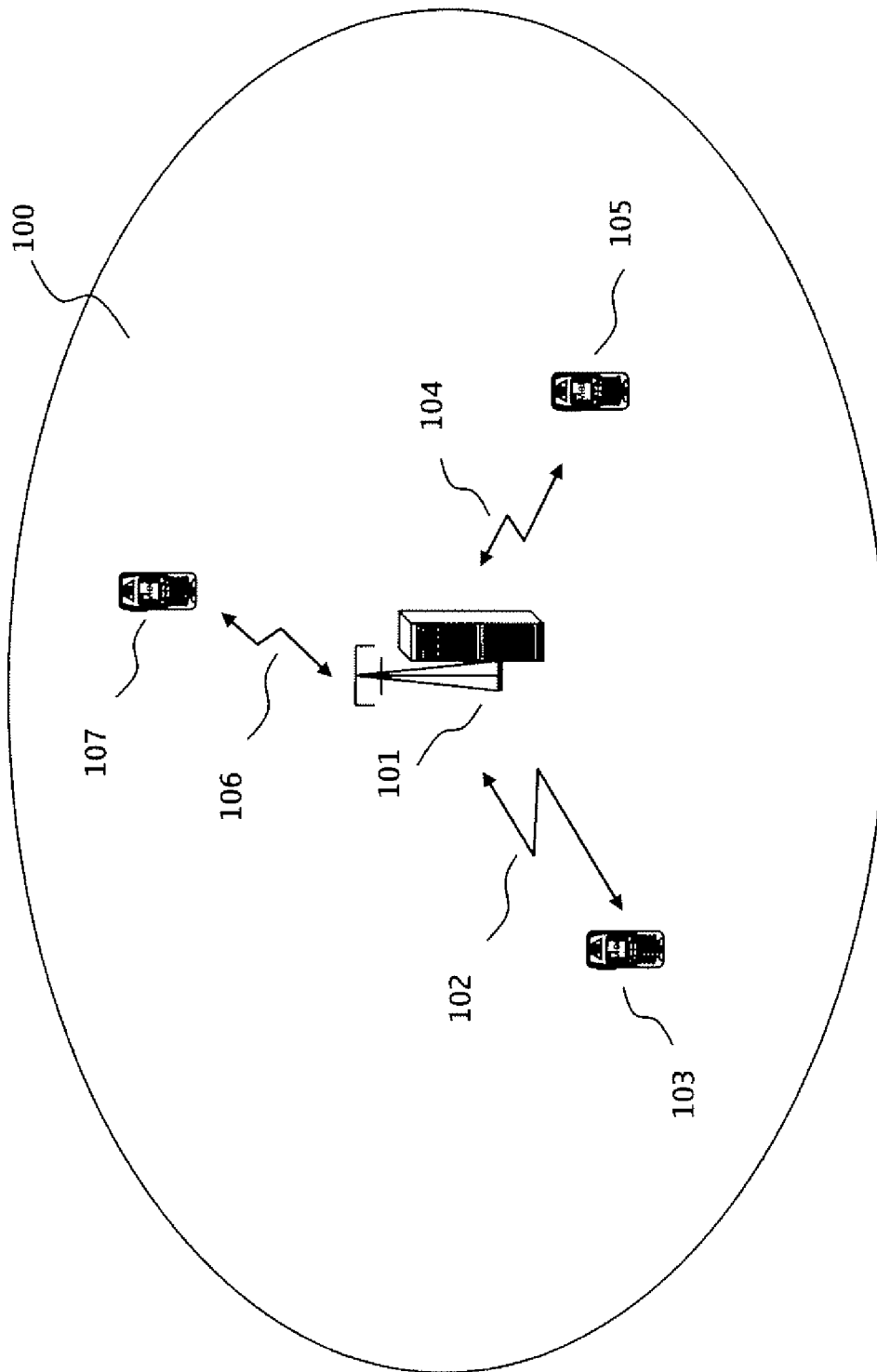


Figure 1

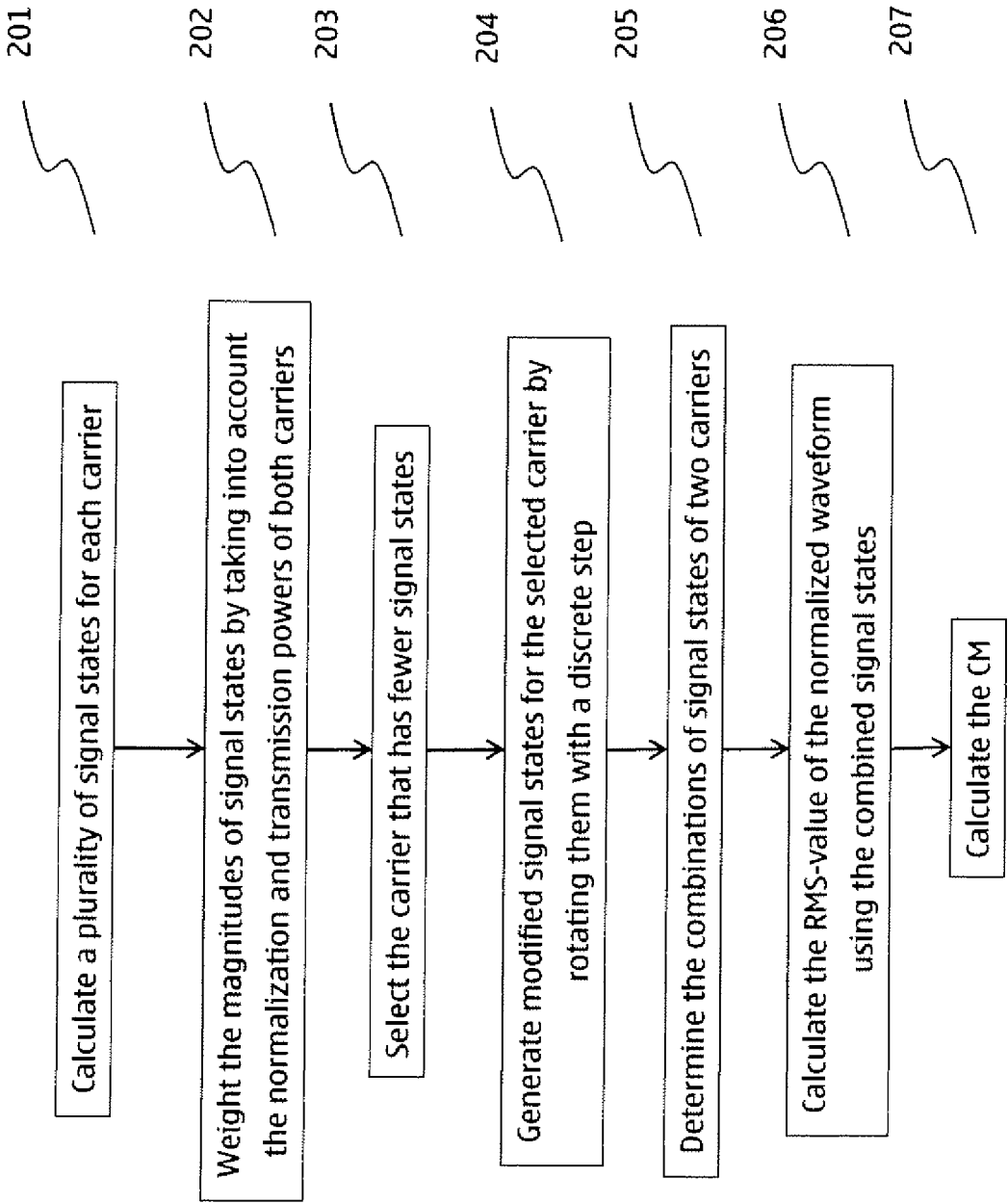


Figure 2

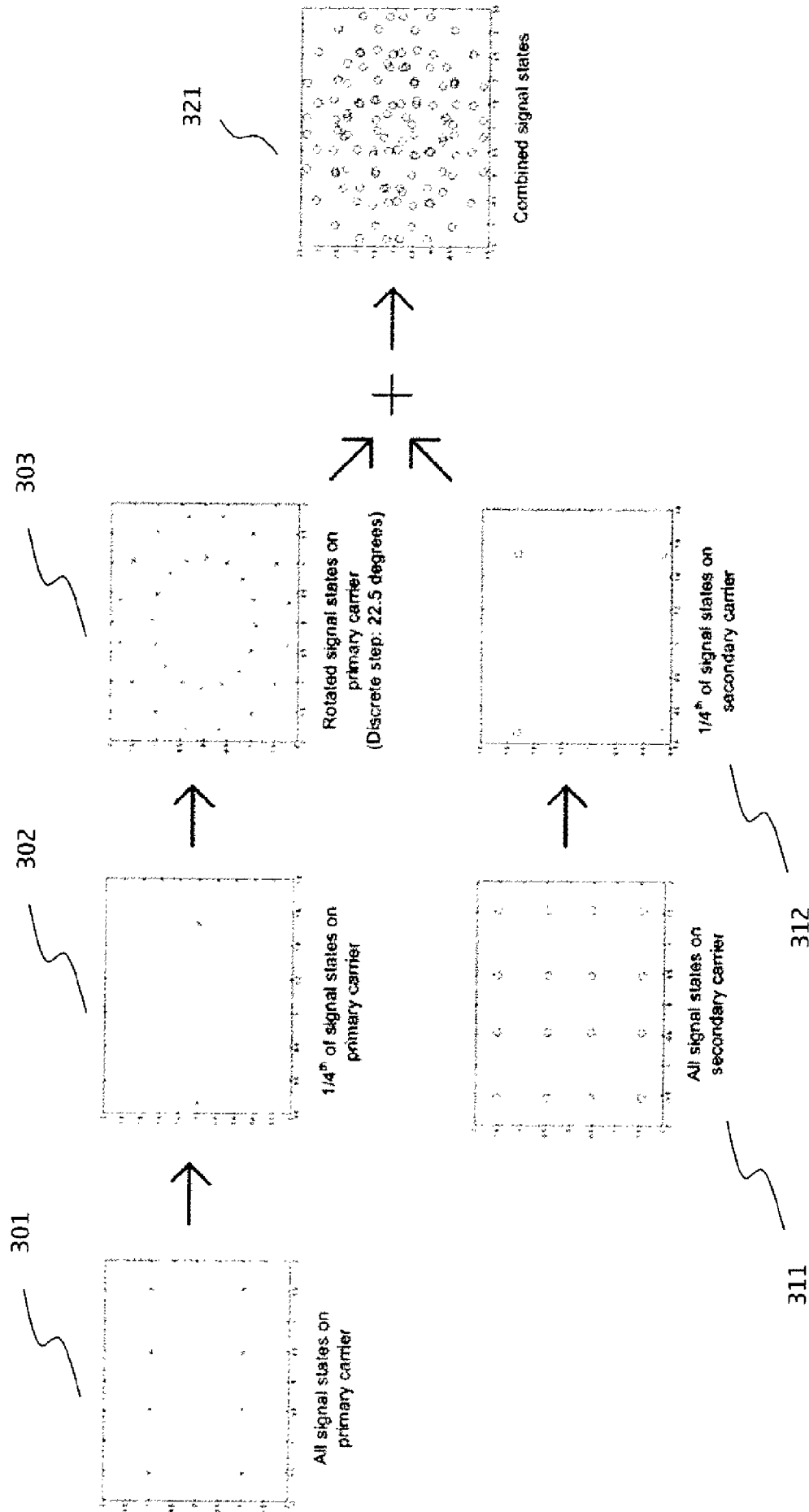


Figure 3

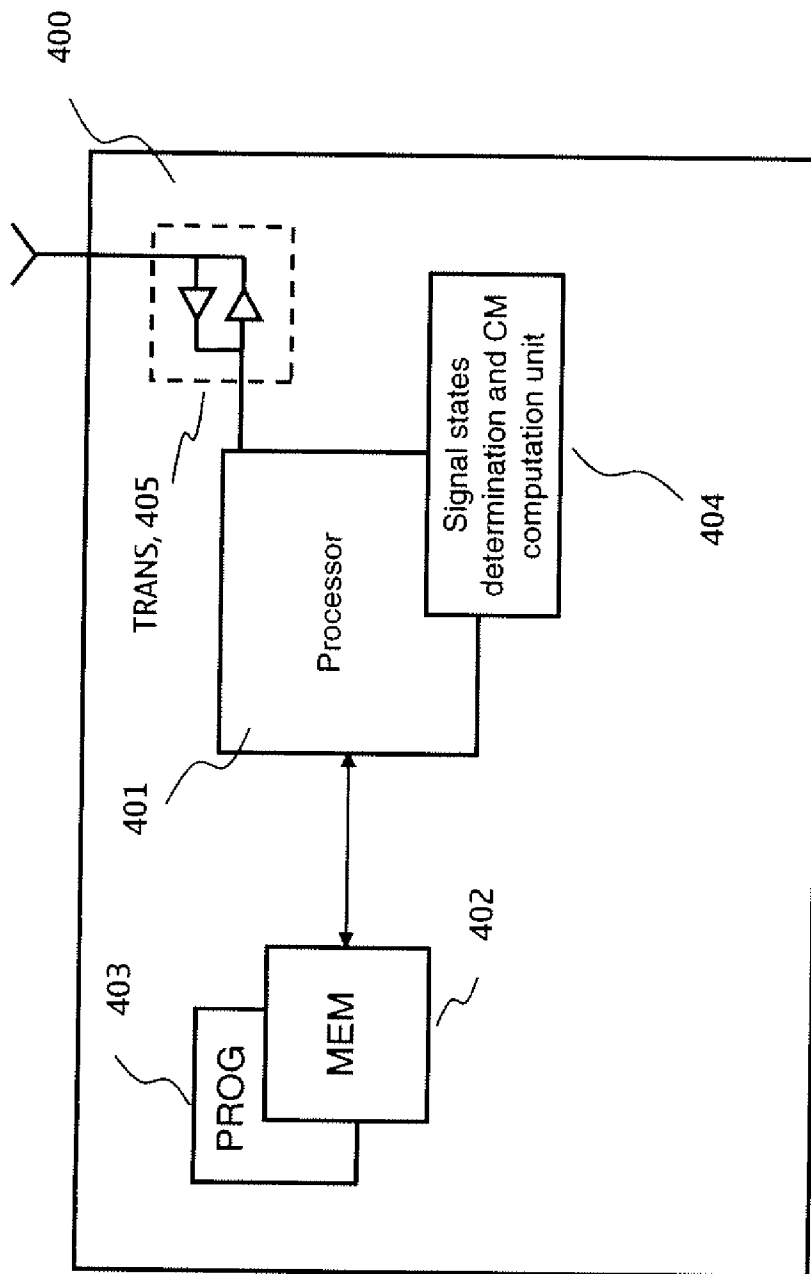


Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2011/053334

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: H04L

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20100034186 A1 (ZHOU YAN ET AL), 11 February 2010 (2010-02-11); paragraphs [0057], [0108] --	1, 4-7, 10-13, 16-24
A	WO 2010070425 A1 (NOKIA CORP ET AL), 24 June 2010 (2010-06-24); page 5, line 37 - page 6, line 15; page 18, line 19 - page 19, line 21 --	1-24
A	EP 1357718 A2 (SAMSUNG ELECTRONICS CO LTD), 29 October 2003 (2003-10-29); figures 1-9; See section 60 --	1-24
A	WO 03019791 A2 (NORTEL NETWORKS LTD), 6 March 2003 (2003-03-06); page 2, line 9 - page 7, line 16; figures 1,2 --	1-24

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“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

16-12-2011

Date of mailing of the international search report

16-12-2011

Name and mailing address of the ISA/SE

Patent- och registreringsverket
Box 5055
S-102 42 STOCKHOLM
Facsimile No. + 46 8 666 02 86

Authorized officer

Markus Stålö

Telephone No. + 46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2011/053334

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2008037739 A2 (ERICSSON TELEFON AB L M ET AL), 3 April 2008 (2008-04-03); page 14, line 24 - page 19, line 10; figures 10-13 --	1-24
A	"Multicarrier communication systems with low sensitivity to nonlinear amplification", Marc Deumal Herraiz, Thesis for the degree of Doctor of Philosophy, Enginyeria i Arquitectura La Salle Universitat Ramon Llull, Barcelona 2008; pages 57-58; figures 5.6; See Chapters 4.1 -- -----	1-24

Continuation of: second sheet

International Patent Classification (IPC)

H04L 27/26 (2006.01)

Download your patent documents at www.prv.se

The cited patent documents can be downloaded:

- From "Cited documents" found under our online services at www.prv.se (English version)
- From "Anförda dokument" found under "e-tjänster" at www.prv.se (Swedish version)

Use the application number as username. The password is **NDTOLIJARF**.

Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IB2011/053334

US	20100034186 A1	11/02/2010	TW	201012145 A	16/03/2010
			WO	2010017506 A1	11/02/2010
WO	2010070425 A1	24/06/2010	TW	201101897 A	01/01/2011
			US	20100153049 A1	17/06/2010
EP	1357718 A2	29/10/2003	AU	2003223129 B2	22/09/2005
			CA	2452277 A1	06/11/2003
			CN	1300963 C	14/02/2007
			CN	1522511 A	18/08/2004
			JP	2005524278 A	11/08/2005
			KR	100754721 B1	03/09/2007
			KR	20030084291 A	01/11/2003
			RU	2003137529 A	27/05/2005
			RU	2268547 C2	20/01/2006
			US	7376074 B2	20/05/2008
			US	20080049602 A1	28/02/2008
			US	20030202460 A1	30/10/2003
			WO	03092197 A1	06/11/2003
WO	03019791 A2	06/03/2003	BR	0212097 A	03/08/2004
			CN	1572060 A	26/01/2005
			CN	100375394 C	12/03/2008
			CN	1575549 A	02/02/2005
			EP	1419582 A1	19/05/2004
			EP	1428322 A2	16/06/2004
			HK	1073934 A1	06/02/2009
			JP	2005500784 A	06/01/2005
			JP	4174030 B2	29/10/2008
			KR	20100044260 A	29/04/2010
			WO	03019792 A1	06/03/2003
WO	2008037739 A2	03/04/2008	EP	2074779 A2	01/07/2009
			JP	2010505314 A	18/02/2010
			US	7848446 B2	07/12/2010
			US	20080075191 A1	27/03/2008