(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 September 2012 (20.09.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/125017 A1

(51) **International Patent Classification**:
H04B 17/00 (2006.01) ***H04L 27/26*** (2006.01)
H04J 11/00 (2006.01)

(21) **International Application Number**: PCT/MY2012/000045

(22) **International Filing Date**: 7 March 2012 (07.03.2012)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
PI 2011001167 15 March 2011 (15.03.2011) MY

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(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, QA, RO, RS, RU, RW, 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, RW, 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,

[Continued on next page]

(54) Title: A METHOD FOR ESTIMATING RSSI AND CINR AT A MOBILE STATION IN OFDMA/OFDM BASED SYSTEMS

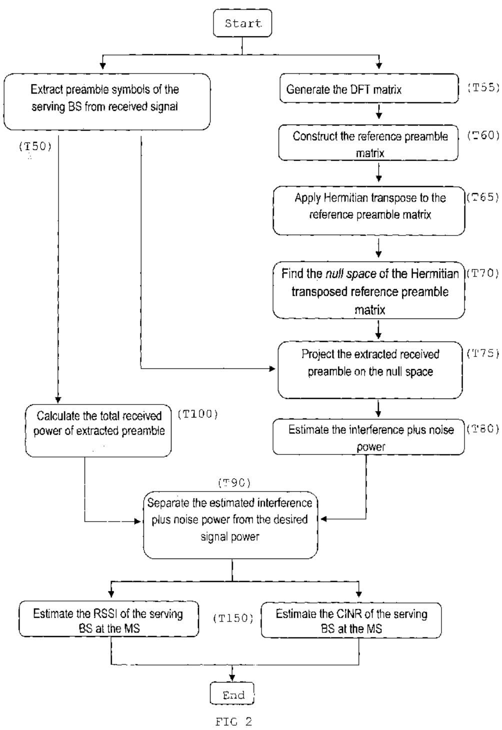

FIG 2

(57) Abstract: The present invention discloses a method for estimating the received signal strength indicator (RSSI) and the carrier-to-interference plus noise ratio (CINR) of a serving base station (BS) at a mobile station (MS) in OFDMA/OFDM-based communication systems. The steps of estimation are not dependent on the number of interfering base stations (BSs), their cell identifications (ID), associated preamble sequences or the CSI.

WO 2012/125017 A1

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))*

A METHOD FOR ESTIMATING RSSI and CINR at a Mobile Station IN OFDMA/OFDM BASED SYSTEMS

FIELD OF INVENTION

The present invention relates to wireless communication systems and specifically to methods for estimating received signal strength indicator (RSSI) and carrier-to-interference and noise ratio (CINR) at a mobile station (MS), and more specifically, to methods for estimating the RSSI and CINR in orthogonal frequency division multiple access (OFDMA) based systems.

BACKGROUND OF INVENTION

Beneficial services offered by the wireless communication systems have garnered the public attention and much has been written about them. The rapid demand for more enhanced technologies in communication systems has resulted to the creation of value-added features or integration of features which are capable of providing a higher level of efficiency and convenience. One of the primary challenges in efforts to improve the communication quality and to increase system capacity is to accurately estimate or gauge the received signal strength indicator (RSSI) and carrier-to-interference and noise ratio (CINR) at the mobile stations (MSs) within the wireless communication networks.

Accurate estimation of the RSSI and CINR is crucial, since inaccurate estimates may affect the network performance. . For instance, in the event that a CINR reported to the serving base station (BS) is above than the actual CINR, the network throughput may decrease due to frame re-transmission, while reporting a CINR that is below the actual one may lead to scheduling data rates below the supportable data rate. In any case, none of these circumstances would be preferred by users of the communication systems.

The RSSI provides a simple indication of how strong the signal is at the receiver. If the received signal strength is higher than a predetermined threshold value, the link is considered to be good. Estimation of the RSSI Is simple and computationally less complex, as it does not require processing and demodulation of received samples. Suitably, RSSI estimates provide reasonably reliable channel strength assessments. On the contrary, the CINR measurements provide more accurate and reliable estimates but at the expense of computational complexity and additional delay.

At present, there are varieties of methods developed over recent years primarily to accommodate the performance drawbacks associated with the estimation of the CINR and RSSI of a received signal at an MS. For instance, United States Patent Application No US 20090092178 teaches a method for estimation of RSSI and CINR, in which the number of interferer base stations (BSs) and their cell identifications (IDs) as well as associated preamble sequences are assumed to be known. Based on this information, the received signal is cross-correlated with a shift-one replica of itself to isolate the noise and interference. This method assumes *a priori* knowledge of the number of interfering BSs, their cell identifications and associated preamble sequences, the information that may not be available in practice.

While the known in the art systems providing such enhanced features are expedient for users of wireless networks, a great majority of the methods are rather inadequate at some degree, be it in the operational perspective or overall estimation performance.

As discussed above, developing a system and method that is practically suitable to accommodate the drawbacks in estimation of RSSI and CINR with respect to wireless communication networks has been difficult.

Recognizing the aforementioned shortcomings, the present invention has been accomplished to significantly improve the conventional methods and systems.

It is a primary object of the present invention to provide a method for accurately estimating the RSSI and CINR of a serving BS at an MS in OFDMA-based wireless communication systems, devoid of using any knowledge about the number of interfering BSs, their cell identifications, associated preamble sequences or the channel state information (CSI).

It is yet a primary object of the present invention to provide a method for accurately estimating the RSSI and CINR of a serving BS at an MS for any number of interfering BSs and with low computational requirements.

It is another object of the present invention to provide a method for accurately estimating the co-channel interference plus noise at an MS regardless the number of interfering BSs.

Further objects and advantages of the present invention will become apparent in the following description.

SUMMARY OF INVENTION

There is disclosed a method for estimating signal strength of a serving base station (BS) at a mobile station (MS), in an OFDMA-based wireless communication system comprising the steps of: receiving signal at the mobile station (MS); extracting preamble symbols of said serving base station (BS) (T50) from the received signal ; generating (T55) the discrete Fourier transform (DFT) matrix; constructing (T60) the reference preamble matrix; performing Hermitian transpose to said reference preamble matrix (T65); obtaining the null space of the Hermitian transposed reference preamble matrix (T70) and storing said null space for access whenever required; projecting the extracted received preamble symbols onto the null space of the Hermitian transposed reference preamble matrix (T75); estimating the power of the co-channel interference plus noise (T80); calculating the total power of extracted received preamble (T100); separating the power of the interference plus noise from the power of the desired signal of the serving base station (BS) (T90); and estimating (T150) the CINR and RSSI of the serving BS at the MS.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

FIG 1 shows a block diagram of a communication network;

FIG 2 shows an overall flowchart for the method in accordance with a preferred embodiment of the present invention;

FIG 3 shows a structure of the preamble subcarriers for segment 0;

FIG 4 shows a schematic diagram for estimation of RSSI and CINR at a mobile station in accordance with a preferred embodiment of the present invention;

FIG 5 shows the RSSI estimation at a mobile station in accordance with a preferred embodiment of the present invention;

FIG 6 shows the CINR estimation at a mobile station in accordance with a preferred embodiment of the present invention.

DETAILED DESCTRIPTION

In line with the above summary, the following description of a number of specific and alternative embodiments is provided to understand the inventive features of the present invention. It shall be apparent to one skilled in the art, however that this invention may be practiced without such specific details. Some of the details may not be described at length so as not to obscure the invention.

The present invention discloses a method to accurately estimate the received signal strength indicator (RSSI) and for estimating the carrier to interference and noise ratio (CINR) of a serving base station (BS) at a mobile station (MS) in OFDMA/OFDM-based wireless communication systems.

FIG 1 shows a block diagram of a typical communication network, whereby the components involved are base stations (BSs) and a mobile station (MS). In a communication link as shown in FIG 1, there is at least one serving BS and a receiving MS, whereby the performance of the link is subjected to co-channel interference from N1 interfering BSs. In view of OFDMA-based systems, the total number of sub carriers is subdivided into sub-channels where each mobile station (MS) is allocated one or more sub-channels, whereby examples of OFDMA-based systems are IEEE 802.16e standard of Worldwide Interoperability for Microwave Access (WiMAX), long term evolution (LTE) and wireless broadband (WiBro).

It should be noted that the present invention operability is not restricted to specific permutations in the respective OFDMA-based systems but it can be used with any permutations such as, but not limiting to, PUSC, FUSC and AMC.

FIG 2 shows an overall flowchart depicting the steps involved with respect to the method in accordance with a preferred embodiment of the present invention.

The first step in accordance with the preferred embodiment of the present invention is to extract preamble symbols (T50) of the serving BS from the received signal at a MS. At the same time, the discrete Fourier transform (DFT) matrix is generated (T55) for one time preferably at the beginning of transmission, with number of row equals to the length of the reference preamble and number of columns equals to the length of the cyclic prefix (CP).

The method then proceeds with constructing (T60) the reference preamble matrix also for one time, preferably at the beginning of transmission. Subsequently, a Hermitian transpose is performed (T65) on the reference preamble matrix for one time, preferably at the beginning of transmission. The next step is to find or obtain the null space (T70) of the Hermitian transposed reference preamble matrix for one time at the beginning of the transmission and thus storing the obtained null space in a memory device, such that it can be used every time a new preamble symbol is received. Then, the extracted received preamble is projected (T75) onto the null space, so as to separate the interference plus noise from the desired signal of the serving BS.

The next step is to estimate the co-channel interference plus noise power (T80) without taking into consideration the number of interfering BSs, prior to calculating (T100) the total power of the extracted received preamble. Following this, the method then proceeds to separate (T90) the estimated interference plus noise power from the desired signal power. Finally, the estimation of CINR and RSSI are carried out at the MS (T150).

An example of OFDMA-based systems which can be used with the method of the present invention is, WiMAX.

It should be noted, and for the purpose of better elucidation with respect to the method of the present invention, in the case of WiMAX, several initial aspects are taken into consideration with respect to estimating the RSSI and CINR. In WiMAX, a frame consists of downlink (DL) and uplink (UP) subframes. Each DL subframe starts with a preamble symbol followed by a number of OFDMA symbols that are configured to carry data and pilot signals. The preamble symbol contains predetermined information that is known to both the transmitter and receiver prior to the transmission of the communication signal. The preamble symbols can be processed by a receiver to maintain synchronization with a transmitter, perform channel estimation, determine frequency offset to be corrected and implement other signal processing functions. For the present invention, the preamble symbols play a major role in estimating the RSSI and CINR of the signal received at MS.

Furthermore for mobile WiMAX, the DL transmission can be divided into a three segment structure, as suitably shown in FIG 3. The structure includes a preamble which is configured to begin the transmission. Further, the preamble subcarriers are divided into three carrier-sets, whereby each carrier set carries the preamble defined for the segment of the same numbering. Accordingly, each segment modulates each third sub-carrier. The subcarriers are modulated using BPSK modulation with a specific Pseudo-Noise (PN) code and each subcarrier is boosted with a factor 2✓2. It should be noted that in the case of segment 0, the DC carrier is not modulated at all and the appropriate PN is discarded thus the carrier shall always be zeroed.

For the preamble symbol there is provided guard band subcarriers on the left side and the right side of the spectrum. FIG 3 shows an example of the preamble segment 0 for the case when the FFT size is 1024.

The operational view of estimating RSSI and CINR at a MS in an OFDMA-based wireless communication system will be described herein with reference to FIG 4, FIG 5 and FIG 6.

Referring to FIG 4, a received signal (S100) at a MS is analog-to-digital (A/D) converted and filtered. The output signal from the A/D converter is then provided as an input to a cyclic prefix (CP) (S200) removal and serial-to-parallel converter, where the CP is removed and the signal is serial-to-parallel (S/P) converted. The obtained parallel signal is then applied to fast Fourier transform (FFT) block (S300) in order to transform the time domain input signal into frequency domain signal. The output signal from FFT is demultiplexed (S400) and the preamble signal is extracted (S500). Finally, the power of the extracted preamble is calculated (S600).

Next step is to obtain a reference preamble matrix, whereby in order to attain this, the reference preamble of the serving BS is diagonalized (S700) and the discrete Fourier transform (DFT) matrix is generated with number of rows equals to the length of the reference preamble and number of column equals to the length of cyclic prefix (CP). The reference preamble matrix is obtained by multiplying the diagonalized frequency domain reference preamble of the serving BS by the generated DFT matrix. The reference preamble matrix is then Hermitian transposed (S800 and provided as input to a *null space* transformation block (S900) where the *null space* (with orthonormal basis vectors) of the input matrix is calculated and stored in memory to be used every time a new preamble is received.

In the next step, the co-channel interference plus noise (S1000) is completely separated from the desired signal of the serving BS by way of projecting (dot product multiplication) the received preamble (S500) onto the *null space* of the Hermitian transposed reference preamble matrix (S900). This step is based on the assumption that the received signals of the serving BS and interfering BSs are uncorrelated and mutually uncorrelated, which implies that the interference plus noise signal and desired signal of the serving BS are mutually uncorrelated, so that they can be totally separated from each other. Estimation of the co-channel interference plus noise power is then carried out taking into consideration one received preamble or by averaging over a number of received preambles.

The RSSI of a serving BS is estimated at an MS by subtracting the estimated power of the interference plus noise from the total power of the received preamble (extracted preamble power). Accordingly, the estimate of RSSI can be obtained from one received preamble or by averaging over a number of received preambles.

Finally, the CINR of a serving BS is estimated at an MS by subtracting the estimated power of the interference plus noise from the total power of the received preamble and dividing the result by the estimated power of the interference plus noise. Accordingly, the estimate of the

CINR can be obtained from one received preamble or by averaging over a number of received preambles.

While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the invention.

CLAIMS

1. A method for estimating the received signal strength indicator (RSSI) and the carrier-to-interference plus noise ratio (CINR) of a serving base station (BS) at a mobile station (MS), in a wireless communication system comprising the steps of:

receiving signal at the mobile station (MS);

extracting preamble symbols of said serving base station (BS) (T50) from the received signal at a mobile station (MS);

generating (T55) the discrete Fourier transform (DFT) matrix;

constructing (T60) the reference preamble matrix;

performing Hermitian transpose to said reference preamble matrix (T65);

obtaining the *null space* of the Hermitian transposed reference preamble matrix (T70) and storing said *null space* for access whenever required (T75);

projecting the extracted received preamble symbols onto the *null space* of the Hermitian transposed reference preamble matrix;

estimating the co-channel interference plus noise;

determining the power of the co-channel interference plus noise;

calculating the total power of the extracted received preamble (T100);
separating the interference plus noise from the desired signal of the serving base station (BS) (T90); and
estimating (T150) the RSSI at a mobile station (MS).

2. The method as claimed in Claim 1 for estimating received signal strength indicator (RSSI).

3. The method as claimed in Claim 1 for estimating carrier-to-interference and noise ratio (CINR).

4. The method as claimed in Claim 1 wherein the step of constructing the reference preamble matrix further comprises the step of multiplying the diagonalized frequency domain reference preamble of the serving base station (BS) by a discrete Fourier transform (DFT) matrix.

5. The method as claimed in Claim 2 wherein the step of estimating the RSSI can be based on one received preamble or average over a number of received preambles.

6. The method as claimed in Claim 3 wherein the step of estimating CINR can be based on one received preamble or average over a number of received preambles.

7. The method as claimed in Claim 1 wherein the system is OFDM-based communication systems.

8. The method as claimed in Claim 1 wherein the steps of generating (T55) the discrete Fourier transform (DFT) matrix; constructing (T60) the reference preamble matrix; performing Hermitian transpose to said reference preamble matrix (T65) and obtaining the *null space* of the Hermitian transposed reference preamble matrix (T70) are performed preferably at the beginning of transmission.

9. The method as claimed in Claim 1 wherein the method is not restricted for a specific permutation, and can be used with other types of communication systems such as long term evolution (LTE) and wireless broadband (WiBro).

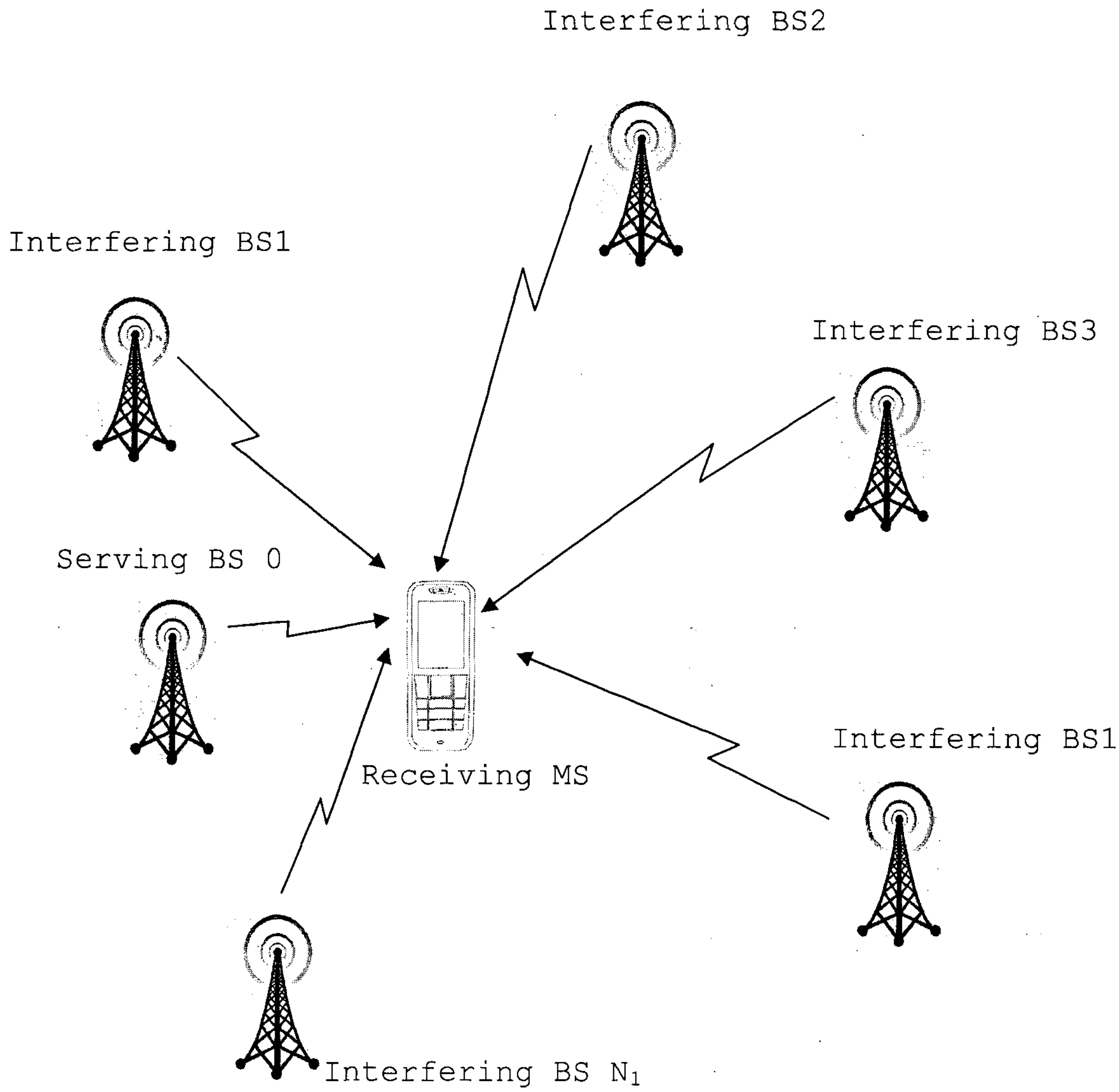
Interfering BS2
Interfering BS1
Interfering BS3
Serving BS 0
Receiving MS
Interfering BS1
Interfering BS N_1

FIG 1

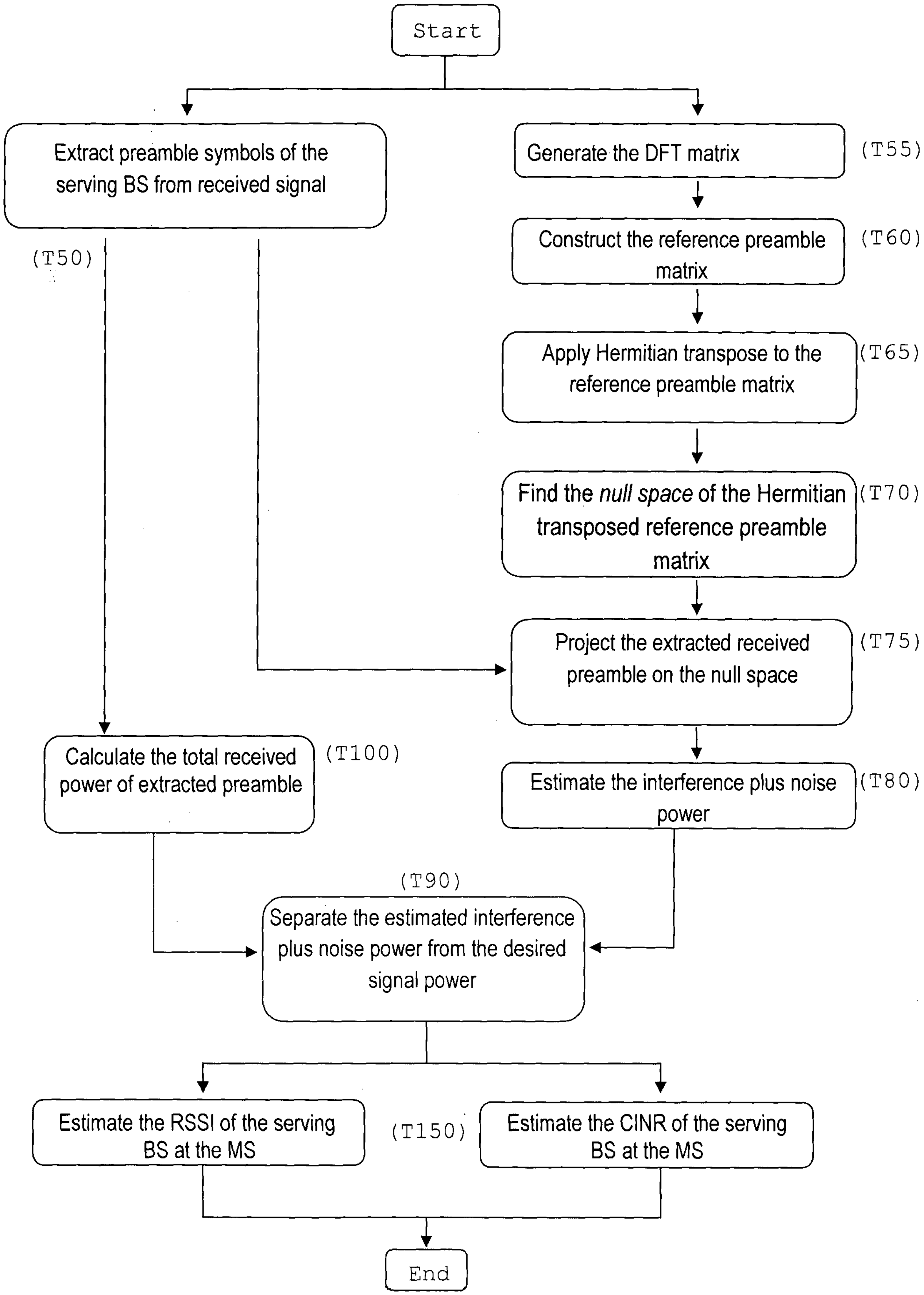
Start
Extract preamble symbols of the serving BS from received signal
(T50)
Generate the DFT matrix
(T55)
Construct the reference preamble matrix
(T60)
Apply Hermitian transpose to the reference preamble matrix
(T65)
Find the null space of the Hermitian transposed reference preamble matrix
(T70)
Project the extracted received preamble on the null space
(T75)
Calculate the total received power of extracted preamble
(T100)
Estimate the interference plus noise power
(T80)
(T90)
Separate the estimated interference plus noise power from the desired signal power
Estimate the RSSI of the serving BS at the MS
(T150)
Estimate the CINR of the serving BS at the MS
End

FIG 2

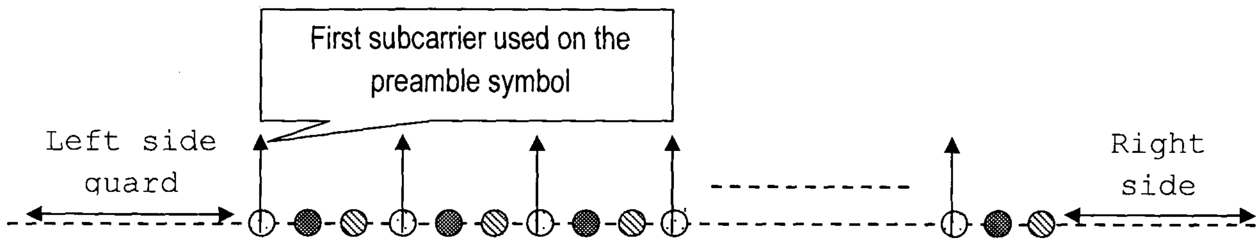
First subcarrier used on the preamble symbol
Left side guard
Right side

FIG 3

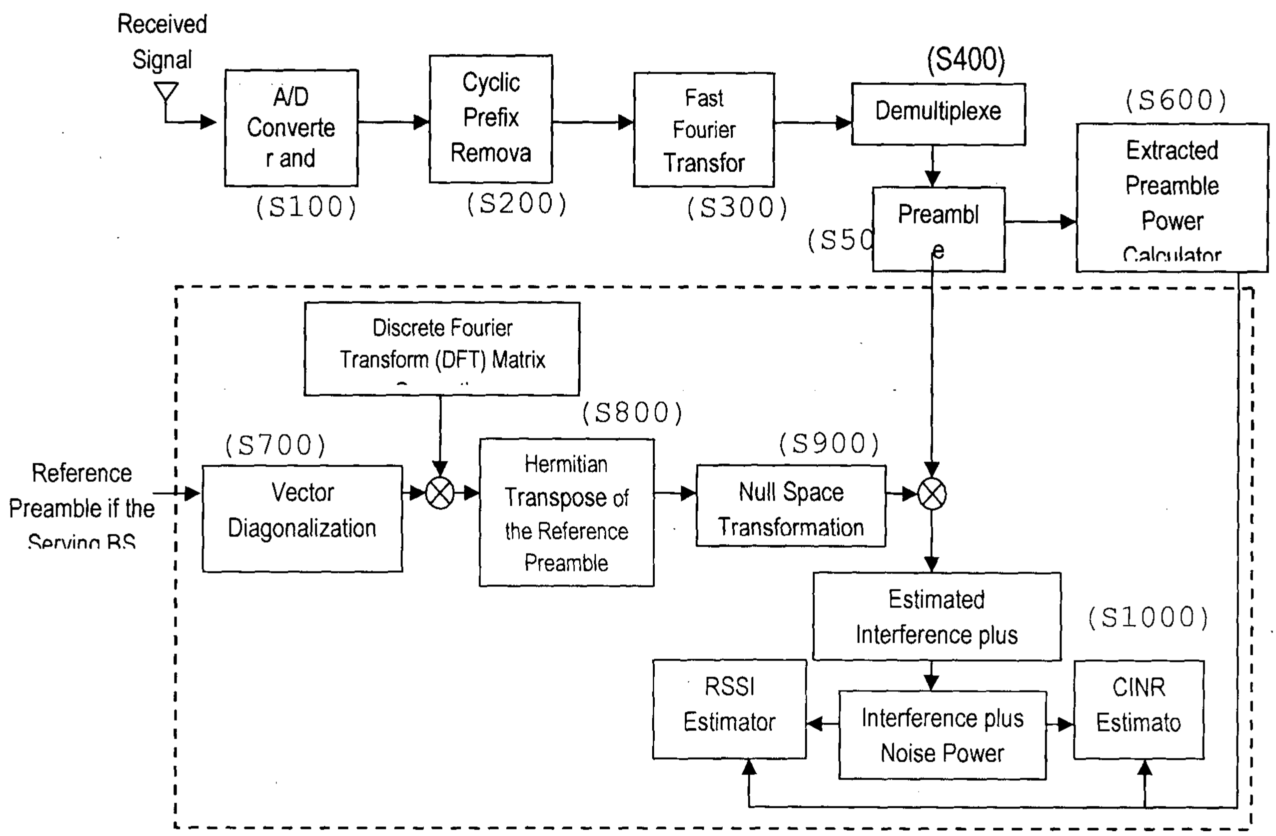
Received Signal
A/D Converte r and
(S100)
Cyclic Prefix Remova
(S200)
Fast Fourier Transfor
(S300)
(S400)
Demultiplexe
(S600)
Extracted Preamble Power
Preambl e
Discrete Fourier Transform (DFT) Matrix
(S800)
(S700)
(S900)
Reference Preamble if the
Vector Diagonalization
Hermitian Transpose of the Reference Preamble
Null Space Transformation
Estimated Interference plus
(S1000)
RSSI Estimator
Interference plus Noise Power
CINR Estimato

FIG 4

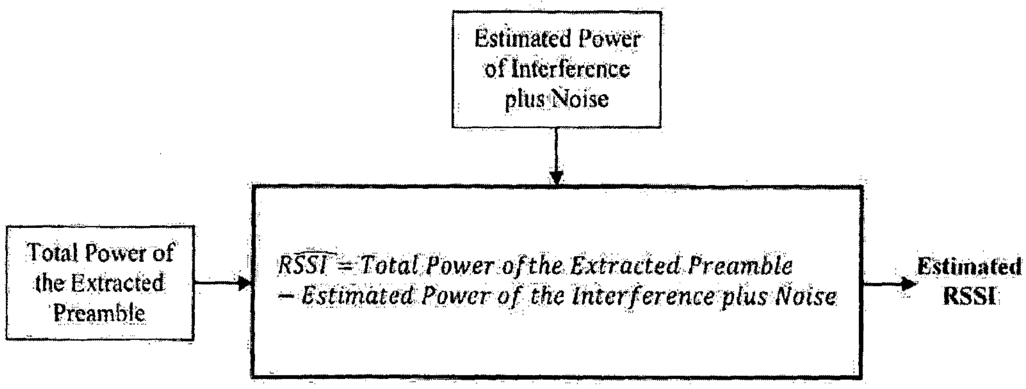
Estimated Power of Interference plus Noise
Total Power of the Extracted Preamble
$\widehat{RSSI}$ = Total Power of the Extracted Preamble − Estimated Power of the Interference plus Noise
Estimated RSSI

FIG 5

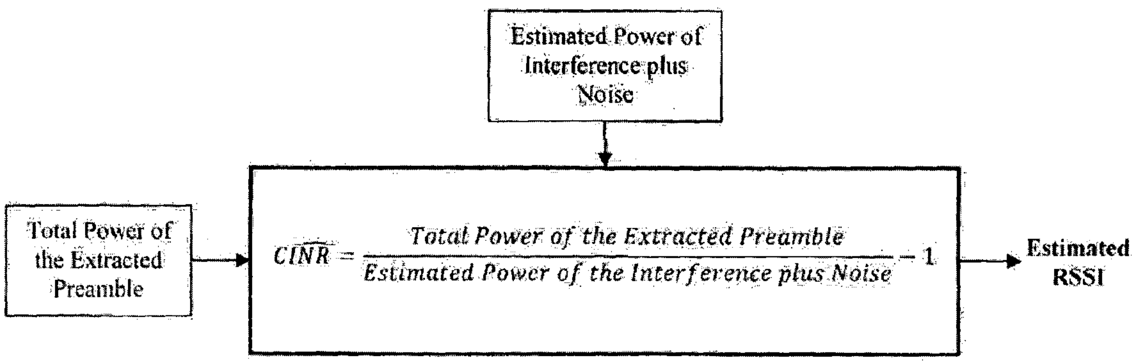
Estimated Power of Interference plus Noise
Total Power of the Extracted Preamble
$\widehat{CINR} = \frac{Total\ Power\ of\ the\ Extracted\ Preamble}{Estimated\ Power\ of\ the\ Interference\ plus\ Noise} - 1$
Estimated RSSI

FIG 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/MY2012/000045

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H04B 17/00 (2006.01) ***H04J 11/00*** (2006.01) ***H04L 27/26*** (2006.01)

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)

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)

EPODOC, WPI, INSPEC, Google Scholar, Google Patents: with wireless, mobile, cellular, RSSI, signal strength, CINR, estimate, calculate, preamble, serving, base station, DFT, Hermitian, and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/0092178 A1 (SAYANA et al.) 09 April 2009 Abstract; paragraphs [0026]-[0071]; Figs. 3-4.	
A	US 2007/0217495 A1 (HAN et al.) 20 September 2007 Abstract; paragraphs [0033]-[0068]; Figs. 4-6.	
A	US 2008/0299983 A1 (KWAK et al.) 04 December 2008 Whole document	

[X] Further documents are listed in the continuation of Box C [X] 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	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 06 June 2012	Date of mailing of the international search report 7 June 2012
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **DR. THAYAPARAN THANABALASINGHAM** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2238

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/0036064 A1 (SONG et al.) 15 February 2007 Whole document	
A	US 2011/0009125 A1 (SHIN et al.) 13 January 2011 Whole document	

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	2009092178	US	7912113	WO	2009046001		
US	2007217495	KR	20070090520				
US	2008299983	CN	101346962	EP	1966964	KR	20070072225
		WO	2007078084				
US	2007036064	KR	20070018663				
US	2011009125	CN	102474900	EP	2452537	KR	20110005362
		WO	2011005048				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX