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(54) Title: METHOD AND APPARATUS FOR ESTIMATING SIGNAL TO INTERFERENCE PLUS NOISE RATIO FOR A RANDOM ACCESS CHANNEL OF A WIRELESS NETWORK

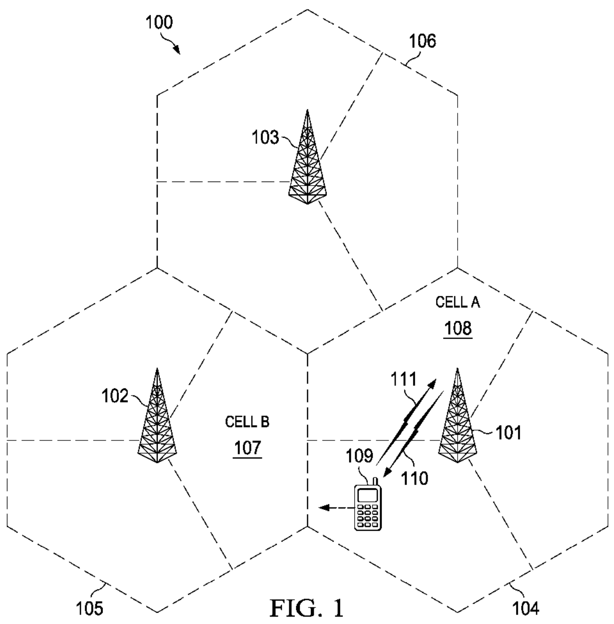

FIG. 1

(57) Abstract: In described examples, a wireless device (101) includes a preamble detector configured to identify preambles transmitted via a random access channel of a wireless network (100). The preamble detector includes a noise floor estimator. The noise floor estimator is configured to estimate, for a given preamble root sequence identified by the preamble detector, a noise floor value as mean energy of received signal samples, excluding detected preamble samples on the given preamble root sequence, below a noise floor threshold assigned to the given preamble root sequence. The noise floor estimator is configured to compute the noise floor threshold as a product of: average energy of the received signal samples less total signal energy contained in each cyclic prefix window in which a preamble is detected using the given preamble root sequence; and a predetermined normalized relative noise floor threshold based on a target false preamble detection rate.

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METHOD AND APPARATUS FOR ESTIMATING SIGNAL TO INTERFERENCE PLUS NOISE RATIO FOR A RANDOM ACCESS CHANNEL OF A WIRELESS NETWORK

[0001] This relates in general to wireless networks, and in particular to a method and apparatus for estimating signal to interference plus noise ratio for a random access channel of a wireless network.

BACKGROUND

[0002] In some wireless networks, such as long term evolution (LTE) networks, user equipment (UE) obtains uplink synchronization by transmitting a preamble to a base station (or evolved Node B, eNB) via a physical random access channel (PRACH). The preambles used in the PRACH are constant-amplitude Zadoff-Chu (ZC) sequences of a prime length, such that the cyclic auto-correlation of the ZC sequence is an ideal delta function and the cyclic cross-correlation of two ZC sequences with different root sequence indices is a constant of magnitude $\frac{1}{\sqrt{N_{ZC}}}$, where N_{ZC} is the ZC sequence length. At the base station, when a preamble is detected in the PRACH, its associated signal to interference plus noise ratio (SINR) can be estimated. The estimated preamble SINR can be used for the transmit power control (TPC) of the following first scheduled transmission on the uplink shared channel (ULSCH). As the preamble SINR estimate is primarily used for transmission on the ULSCH, the estimate should reflect the channel condition on the ULSCH even through the estimation is performed on the PRACH.

SUMMARY

[0003] A method and apparatus for determining noise floor and signal to interference plus noise ratio (SINR) for the physical random access channel (PRACH) of a wireless network are disclosed herein. In described examples, a wireless device includes a preamble detector configured to identify preambles transmitted via a random access channel of a wireless network. The preamble detector includes a noise floor estimator. The noise floor estimator is configured to estimate, for a given preamble root sequence identified by the preamble detector, a noise floor value as mean energy of received signal samples, excluding detected preamble samples on the given preamble root sequence, below a noise floor threshold assigned to the given preamble root sequence. The noise floor estimator is configured to compute the noise floor threshold as a product of: average energy of the received signal samples less total signal energy contained in each cyclic prefix window in which a preamble is detected using the given preamble root sequence; and a predetermined normalized relative noise floor threshold based on a target false preamble detection rate.

[0004] In further described examples, a method includes receiving signals transmitted via a random access channel of a wireless network. Preambles are detected in the received signals. For a given preamble root sequence with any preamble detected, a noise floor value is estimated as mean energy of received signal samples, excluding detected preamble samples on the given preamble root sequence, below a noise floor threshold assigned to the given preamble root sequence. The noise floor threshold is computed as a product of: average energy of the received signal samples less total signal energy contained in each cyclic prefix window in which a preamble is detected using the given preamble root sequence; and a predetermined normalized relative noise floor threshold based on a target false preamble detection rate.

[0005] In more described examples, apparatus for implementing a wireless base station includes a preamble detector configured to identify preambles transmitted via a random access channel of a wireless network. The preamble detector includes a noise floor estimator. The noise floor estimator is configured to estimate, for a given preamble root sequence identified by the preamble detector, a noise floor value as mean energy of received signal samples, excluding detected preamble samples on the given preamble root sequence, below a noise floor threshold assigned to the given preamble root sequence. The noise floor estimator is configured to compute the noise floor threshold as a product of: average energy of the received signal samples less total signal energy contained in each cyclic prefix window in which a preamble is detected using the given preamble root sequence; and a predetermined normalized relative noise floor threshold based on a target false preamble detection rate. The noise floor estimator is configured to adjust the noise floor value for the given preamble root sequence based on interference energy of all preambles detected using a preamble root sequence other than the given preamble root sequence, for the purpose of SINR estimation for each detected preamble.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a block diagram of a wireless network of various embodiments.

[0007] FIG. 2 is a block diagram of a preamble detector for use in a base station of a wireless network of various embodiments.

[0008] FIG. 3 is a diagram of received signal power samples for a root sequence of various embodiments.

[0009] FIG. 4 is a flow diagram of a method of determining signal to noise and interference ratio (SINR) in a wireless device of various embodiments.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0010] In conventional preamble detection methods, a noise floor estimate is used for computing a preamble detection threshold based on a target false preamble detection rate (i.e., target false alarm rate). Unfortunately, if multiple root sequences are configured at a base station, due to the constant cross correlation between different root sequences, the preambles received using a first root sequence contribute to the noise floor estimate of a different root sequence. Accordingly, the noise floor estimate for a root sequence can include interference from the preambles received for different root sequences. In addition to this cross-correlation interference, when multiple preambles are received for a given root sequence, the noise floor estimate for the given root sequence also increases. This is due to the fact that the total received power for a root sequence is used for computing the noise floor estimate for preamble detection, which includes the power of all received preambles for the given root sequence.

[0011] Embodiments of the present disclosure provide an improved noise floor estimate for use in signal to interference plus noise ratio (SINR) determination. Embodiments generate the improved noise floor estimate by excluding preamble signal energy from the signal energy applied to compute the noise floor estimate. Applying the improved noise floor estimate, embodiments can compute an SINR value for use with the uplink shared channel (ULSCH) that is more accurate than conventional systems.

[0012] FIG. 1 is a block diagram of a wireless network 100 of various embodiments. The example wireless network includes base stations 101, 102 and 103. In practice, embodiments of the network 100 may include any number of base stations. Each of base stations 101, 102 and 103 is operable over corresponding coverage areas 104, 105 and 106. Each base station's coverage area is further divided into cells. In the illustrated network, each base station's coverage area is divided into three cells. Handset or other user equipment (UE) 109 is shown in Cell A 108. Cell A 108 is within coverage area 104 of base station 101. Base station 101 transmits to and receives transmissions from UE 109. As UE 109 moves out of Cell A 108 and into Cell B

107, UE 109 may be handed over to base station 102. Because UE 109 is synchronized with base station 101, UE 109 can employ non-synchronized random access to initiate handover to base station 102.

[0013] Non-synchronized UE 109 also employs non-synchronous random access to request allocation of up-link 111 time or frequency or code resources. If UE 109 has data ready for transmission (such as traffic data, measurements reports, and tracking area updates), UE 109 can transmit a random access signal on up-link 111. The random access signal notifies base station 101 that UE 109 requires up-link resources to transmit the UE's data. Base station 101 responds by transmitting to UE 109 (via down-link 110) a message containing the parameters of the resources allocated for UE 109 up-link transmission along with a possible timing error correction.

[0014] After receiving the resource allocation and a possible timing advance message transmitted on down-link 110 by base station 101, UE 109 optionally adjusts its transmit timing and transmits the data on up-link 111 employing the allotted resources during the prescribed time interval.

[0015] Various embodiments of the network 100 operate in compliance with the long term evolution (LTE) networking standards. Accordingly, UE 109 obtains uplink synchronization by transmitting a preamble to base station 101 via a physical random access channel (PRACH). The preamble includes Zadoff-Chu (ZC) sequences of prime length. Such sequences possess ideal periodic autocorrelation and optimum periodic cross-correlation. The preamble can be a root ZC sequence or a cyclic shifted version of a root ZC sequence.

[0016] The base stations 101, 102 and 103 include preamble detectors that identify preambles transmitted by a UE, compute SINR for the PRACH, and determine transmit power to be applied by the UE on the Uplink Shared Channel based on the SINR computed for the PRACH. The preamble detectors included in the base stations 101, 102 and 103 provide PRACH noise and PRACH SINR values that are more accurate than those provided by convention base stations. Accordingly, the base stations 101, 102 and 103 can determine the transmit power to be applied by the UE on the ULSCH more accurately than conventional base stations.

[0017] FIG. 2 is a block diagram of a preamble detector 200 of various embodiments for use in a base station of the wireless network 100. In preamble detector 200, radio frequency signal is received via antennas 202A and 202B. The received signals are digitized, and cyclic prefix (CP) removers 204a and 204b remove the cyclic prefixes from the received signals. After cyclic prefix removal, the signals are converted to frequency domain by frequency domain transformers 206a and 206b. A discrete Fourier transform (whose size is either the entire preamble length or its constituent sequence length) may be performed, depending on whether coherent or non-coherent accumulation is used. Subcarrier demappers 208a and 208b extract the subcarriers used by preambles in the frequency domain. In the frequency domain embodiments, one preamble detector can be used for detecting all signatures based on one root preamble sequence.

[0018] The received signal is correlated with all available root preamble sequences to detect UE preamble transmissions. Each available root preamble sequence includes a corresponding root preamble frequency response 210A-210N and 220A-220N. Complex conjugators 212A-212N and 222A-222N compute complex conjugates of the root preamble frequency responses 210A-210N and 220A-220N. Multipliers 214A-214N and 224A-224N multiply subcarrier by subcarrier the demapped subcarriers with the complex conjugates of the root preamble sequences to perform the correlation.

[0019] PRACH preamble detection in the preamble detector 200 uses power sample based processing that compares each power sample with a preamble detection threshold. The base station declares corresponding detected signatures and estimates associated UE delays for any power samples exceeding the detection threshold. Embodiments of the preamble detector 200 generalize sample-based preamble detection using a sliding window of data of CP duration. Instead of each power sample, the received preamble energy within the sliding window is compared with a preamble detection threshold defined as:

$$T_{\det} = \frac{T_r}{N_{rx} R_{seq}} \gamma_n$$

where $T_{\det}$ is the absolute preamble detection threshold, $\frac{T_r}{N_{rx} R_{seq}}$ is the predetermined relative preamble detection threshold based on a predefined false alarm probability when no preamble is transmitted, N_{rx} is the number of receive antennas, R_{seq} is the number of sequence repetitions, and γ_n is the noise floor estimate.

[0020] The sample based approach can be viewed as a special case of the sliding window based approach with a sliding window of one sample. In embodiments disclosed herein, the window can be the result of a windowing filter, such as a unit impulse window filter, a rectangular window filter, a triangular window filter, a Hamming window filter, a Hann window filter, a cosine window filter, a Lanczos window filter, a Bartlett window filter, a Gauss window filter, a Bartlett-Hann window filter, a Blackman window filter, or a Kaiser window filter. Filter taps of the window filter may be computed adaptively.

[0021] The preamble detector 200 up-samples the preamble by zero padding the correlations at zero padders 216A-216N and 226A-226N in the frequency domain, such that signal length is a power of 2. The inverse frequency transformers 218 and 228 convert the frequency domain signals to time domain signals. Signal power converters 219 and 229 compute the square of the absolute value of the time-domain signal. Summer 230 sums the resultant power signals.

[0022] The noise floor estimator 232, peak searcher 234, and SINR estimator 338 operate on time domain signals. The preamble detection threshold $T_{\det}$ is derived assuming a predefined false alarm probability when no preamble is transmitted. With sliding window based preamble detection, the preamble detection threshold is a straightforward extension of the single sample case with a sliding window length W_{CP} of $W_{CP} > L$ samples, where L is the preamble upsampling ratio.

[0023] The noise floor estimator 232 may generate two different noise floor estimates based on the time domain power samples provided by the summer 230. A first noise floor estimate γ_n is generated for use in preamble detection, and a second noise floor estimate $\hat{\gamma}_n$ (which is different from γ_n) is generated for use in SINR computation after preamble detection. For computation of noise floor γ_n, the noise floor estimator computes a noise floor threshold as:

$$T_n = \frac{F_Z^{-1}(1-P_{fa})}{N_{rx}R_{seq}} \cdot \frac{1}{N_{IDFT}} \sum_{i=1}^{N_{IDFT}} z(i)$$

where P_{fa} is a predefined PRACH false alarm rate, N_{IDFT} is the size of the inverse transform performed at the transformers 218 and 228, $z(i)$ are power samples generated by summer 230, and $F_Z(z) = 1 - e^{-z} \sum_{k=0}^{N_{rx}R_{seq}-1} \frac{1}{k!} z^k$ is the cumulative distribution function (CDF) for central chi-square distribution with additive white Gaussian noise input. The quantity $\frac{F_z^{-1}(1-P_{fa})}{N_{rx}R_{seq}}$ is the predetermined normalized relative noise floor threshold based on a predefined false alarm rate.

[0024] Applying the noise floor threshold T_n, the noise floor estimator computes the noise floor γ_n as average power below the noise floor threshold T_n:

$$\gamma_n = \frac{1}{N_s} \sum_{\substack{i=1,\\ z(i)<T_n}}^{N_{IDFT}} z(i)$$

where N_s is the number of samples $z(i)$ summed.

[0025] The preamble detector 200 may include a combination of dedicated circuitry and a processor executing instructions to provide the functionality disclosed herein. For example, CP removers 204a and 204b, frequency domain transformers 206a and 206b, and subcarrier demappers 208a and 208b may be implemented by dedicated hardware circuitry. Functionality downstream of the subcarrier demappers 208a and 208b may be implemented via a processor (e.g., a digital signal processor) executing instructions, retrieved from a storage device by the processor, so that such execution causes the processor to perform the operations disclosed herein. The noise floor estimator 232 and SINR estimator 238 may implemented by the processor executing instructions stored in a computer-readable medium, such as a memory.

[0026] Unfortunately, because multiple root sequences are configured at the preamble detector 200, due to the constant cross correlation between different root sequences, the preambles received at one root sequence contribute to the noise floor estimate γ_n at another root sequence. Accordingly, the noise floor estimate γ_n for a root sequence can include interference from the preambles received at a different root sequence. In addition to this cross-correlation interference, when multiple preambles are received at a given root sequence, the noise floor estimate at the given root sequence also increases due to the increase in total received power of the multiple preambles. The increased noise floor detrimentally impacts SINR.

[0027] To alleviate the impact of preamble energy on noise floor and SINR computation, the noise floor estimator 232 computes the second noise floor estimate $\hat{\gamma}_n$ after preamble detection. Noise floor estimate $\hat{\gamma}_n$ excludes preamble signal energy from the noise floor computation, which provides a more accurate noise floor value and ultimately a more accurate SINR value.

[0028] FIG. 3 is a diagram of signal power samples generated for a root sequence by the summer 230 of various embodiments. In FIG. 3, two preamble search windows corresponding to two preambles using two cyclic shifts of one ZC root sequence are shown as a matter of convenience.

In practice, the preamble detector 200 may apply any number of preamble search windows contingent on specific cell configuration. A preamble detection threshold computed as described herein is shown, and example noise floor threshold values applied to compute γ_n and $\hat{\gamma}_n$ are shown. In FIG. 3, a single preamble exceeding the preamble detection threshold is shown in window 302. Window 302 is a sliding preamble detection window of length W_{CP} (i.e., cyclic prefix length).

[0029] For each preamble identified by the preamble detector 200, the noise floor estimator 232 computes the total sample power E_{CP} within the window W_{CP} containing the detected preamble. The window may start at a position at which maximum total power is contained within the window, or the window may start at the maximum detected sample position, depending on the employed preamble detection method. Sample power E_{CP} for each identified preamble is excluded from the sample power of a root sequence applied to compute the noise floor $\hat{\gamma}_n$. For a given root sequence, the noise floor estimator 232 excludes the total preamble power E_{CP} for preambles detected for the given root sequence, and excludes cross-correlation interference power derived from E_{CP} for preambles detected for other root sequences.

[0030] FIG. 4 is a flow diagram of a method 400 of determining noise floor and SINR in the preamble detector 200 of various embodiments. Although depicted sequentially as a matter of convenience, at least some of the actions shown can be performed in a different order and/or performed in parallel. Additionally, some embodiments may perform only some of the actions shown. At least some of the operations of the method 400 may be performed by a processor executing instructions retrieved from a non-transitory computer readable storage medium.

[0031] In block 402, the preamble detector 200 is operating as a component of a base station (such as base station 101 in the network 100). The preamble detector 200 is receiving wireless signals transmitted by user equipment, and detecting preambles transmitted by the user equipment at each of multiple root sequences.

[0032] In block 404, for each root sequence, the noise floor estimator 232 computes the power E_{CP} for each preamble detected (i.e., sum of sample powers within window W_{CP}), and computes the average received sample power for each root sequence excluding E_{CP} for each preamble detected for the root sequence. Thus, the noise floor estimator 232 computes the power for each root sequence excluding preamble samples from the power computation.

[0033] In block 406, for each root sequence, the noise floor estimator 232 computes a second noise floor threshold as a product of: (a) a predetermined normalized relative noise floor threshold that is based on a target false preamble detection rate, and (b) the average received sample power excluding E_{CP} values computed for preambles detected at the root sequence.

[0034] In block 408, the noise floor estimator 232 computes, for each root sequence, noise floor estimate $\hat{\gamma}_n$ as mean power of received samples, excluding E_{CP} values computed for preambles detected at the root sequence, below the second noise floor threshold.

[0035] In block 410, the noise floor estimator 232, for each root sequence, computes the total interference energy of the preambles detected at each other root sequence. The noise floor estimator 232 computes the interference energy, for each root sequence, as a sum of energy of all preambles detected for the root sequence (E_{CP}) less the noise energy within the window W_{CP} corresponding to each preamble detected for the root sequence.

[0036] In block 412, the noise floor estimator 232, for each root sequence, computes cross-correlation interference power for each other root sequence. The noise floor estimator 232 computes the cross correlation interference power for a root sequence by dividing the total interference energy for the root sequence by the number of power samples for the root sequence.

[0037] In block 414, the noise floor estimator 232 adjusts the noise floor estimate $\hat{\gamma}_n$ for each root sequence by subtracting (from the noise floor estimate $\hat{\gamma}_n$) the cross-correlation interference power calculated for each other root sequence. The cross-correlation interference power may be normalized by dividing the cross-correlation interference power by the number of receive antennas N_{rx} and the number of sequence repetitions R_{seq}.

[0038] In block 416, the SINR estimator 238 generates an SINR estimate based on the noise floor estimate $\hat{\gamma}_n$ provided by the noise floor estimator 232 in block 412. The base station may apply the SINR estimate to generate, and transmit to the user equipment, a power control value for use by the user equipment in ULSCH transmissions.

[0039] Modifications are possible in the described embodiments, and other embodiments are possible, within the scope of the claims.

CLAIMS

What is claimed is:

1. A wireless device, comprising:

a preamble detector configured to identify a plurality of preambles transmitted via a random access channel of a wireless network, the preamble detector including a noise floor estimator configured to:

estimate, for a given preamble root sequence identified by the preamble detector, a noise floor value as mean energy of received signal samples, excluding detected preamble samples on the given preamble root sequence, below a noise floor threshold assigned to the given preamble root sequence; and

compute the noise floor threshold as a product of: average energy of the received signal samples less total signal energy contained in each cyclic prefix window in which a preamble is detected using the given preamble root sequence; and a predetermined normalized relative noise floor threshold based on a target false preamble detection rate.

2. The wireless device of claim 1, wherein a plurality of preambles are detected using a same preamble root sequence.

3. The wireless device of claim 1, wherein the noise floor estimator is configured to: determine total interference energy of all preambles detected using a preamble root sequence other than the given preamble root sequence; and adjust the noise floor value for the given preamble root sequence based on the interference energy.

4. The wireless device of claim 3, wherein the noise floor estimator is configured to determine the total interference energy as a sum of signal energy contained in a cyclic prefix window in which a preamble is detected using a preamble root sequence other than the given preamble root sequence less noise energy contained within the cyclic prefix window in which a preamble is detected using a preamble root sequence other than the given preamble root sequence.

5. The wireless device of claim 3, wherein the noise floor estimator is configured to determine total cross-correlation interference energy as a ratio of the total interference energy to the number of power samples for each preamble root sequence.

6. The wireless device of claim 5, wherein the noise floor estimator is configured to adjust the noise floor value for the given preamble root sequence by excluding from the noise floor value the cross-correlation interference energy.

7. The wireless device of claim 1, further comprising a signal to interference-plus-noise ratio (SINR) estimator configured to determine SINR for a preamble detected by the preamble detector, the SINR calculated based on the noise floor value calculated by the noise floor estimator, wherein the noise floor value excludes all preamble signal energy.

8. The wireless device of claim 7, further comprising a transmitter configured to apply the SINR in a transmission to a wireless device that transmitted the preamble detected by the preamble detector.

9. A method, comprising:

receiving signals transmitted via a random access channel of a wireless network;

detecting preambles in the received signals;

estimating, for a given preamble root sequence identified by the detecting, a noise floor value as mean energy of received signal samples, excluding detected preamble samples on the give preamble root sequence, below a noise floor threshold assigned to the given preamble root sequence;

computing the noise floor threshold as a product of: average energy of the received signal samples less total signal energy contained in each cyclic prefix window in which a preamble is detected using the given preamble root sequence; and a predetermined normalized relative noise floor threshold based on a target false preamble detection rate.

10. The method of claim 9, further comprising:

determining total interference energy of all preambles detected using a preamble root sequence other than the given preamble root sequence; and

adjusting the noise floor value for the given preamble root sequence based on the interference energy.

11. The method of claim 10, further comprising determining the total interference energy as a sum of signal energy contained in a cyclic prefix window in which a preamble is detected using a preamble root sequence other than the given preamble root sequence less noise energy contained within the cyclic prefix window in which a preamble is detected using a preamble root sequence other than the given preamble root sequence.

12. The method of claim 10, further comprising determining total cross-correlation interference energy as a ratio of the total interference energy to the number of power samples for each preamble root sequence.

13. The method of claim 12, further comprising adjusting the noise floor value for the given preamble root sequence by excluding from the noise floor value the cross-correlation interference energy.

14. The method of claim 9, further comprising estimating a signal to interference-plus-noise ratio (SINR) for a detected preamble, the SINR calculated based on the noise floor value, wherein the noise floor value excludes all preamble signal energy.

15. The method of claim 14, further comprising applying the SINR in a transmission to a wireless device that transmitted the detected preamble.

16. The method of claim 9, wherein a plurality of preambles are detected using the given preamble root sequence, and a cyclic prefix window corresponds to each of the preambles.

17. Apparatus for implementing a wireless base station, comprising:

a preamble detector configured to identify a plurality of preambles transmitted via a random access channel of a wireless network, the preamble detector including a noise floor estimator configured to:

estimate, for a given preamble root sequence identified by the preamble detector, a noise floor value as mean energy of received signal samples, excluding detected preamble samples on the give preamble root sequence, below a noise floor threshold assigned to the given preamble root sequence;

compute the noise floor threshold as a product of: average energy of the received signal samples less total signal energy contained in each cyclic prefix window in which a preamble is detected using the given preamble root sequence; and a predetermined normalized relative noise floor threshold based on a target false preamble detection rate; and

adjust the noise floor value for the given preamble root sequence based on interference energy of all preambles detected using a preamble root sequence other than the given preamble root sequence.

18. The apparatus of claim 17, wherein the noise floor estimator is configured to determine the total interference energy as a sum of signal energy contained in a cyclic prefix window in

which a preamble is detected using a preamble root sequence other than the given preamble root sequence less noise energy contained within the cyclic prefix window in which a preamble is detected using a preamble root sequence other than the given preamble root sequence.

19. The apparatus of claim 18, wherein the noise floor estimator is configured to: determine total cross-correlation interference energy as a ratio of the total interference energy to the number of power samples for each preamble root sequence; and adjust the noise floor value for the given preamble root sequence by excluding from the noise floor value the cross-correlation interference energy.

20. The apparatus of claim 17, further comprising a signal to interference-plus-noise ratio (SINR) estimator configured to determine SINR for a preamble detected by the preamble detector, the SINR calculated based on the noise floor value calculated by the noise floor estimator, wherein the noise floor value excludes preamble signal energy.

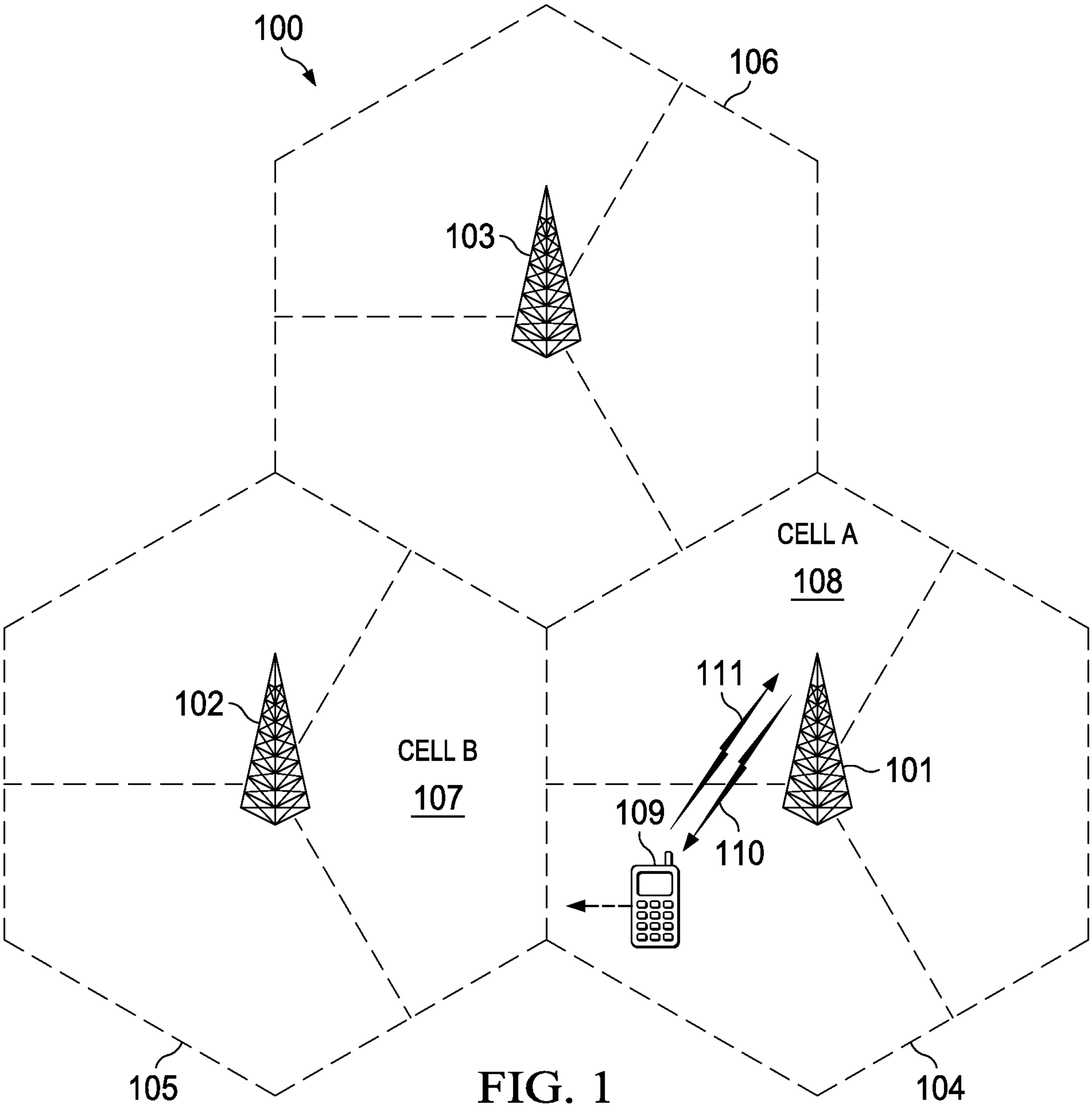
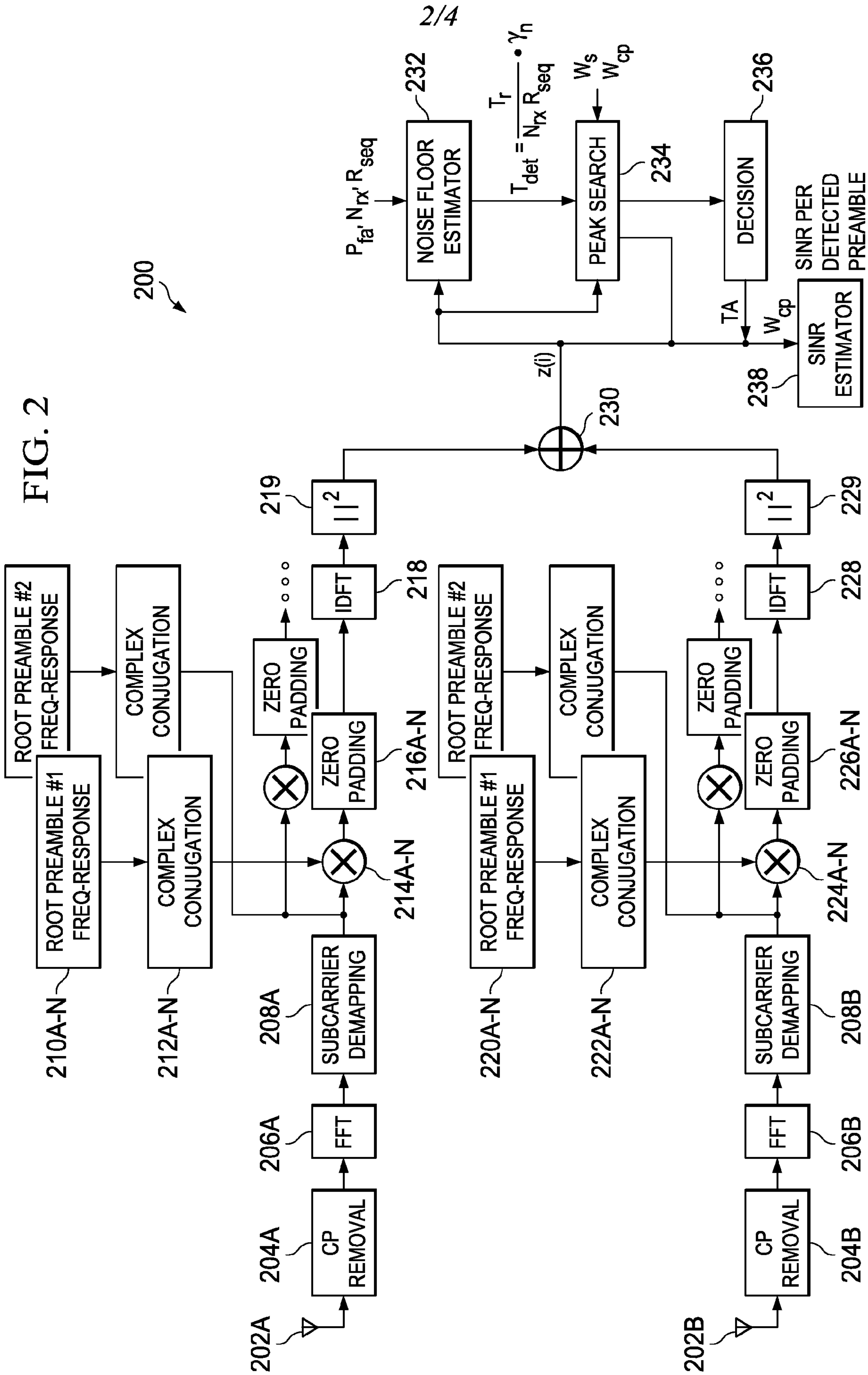


FIG. 1

FIG. 2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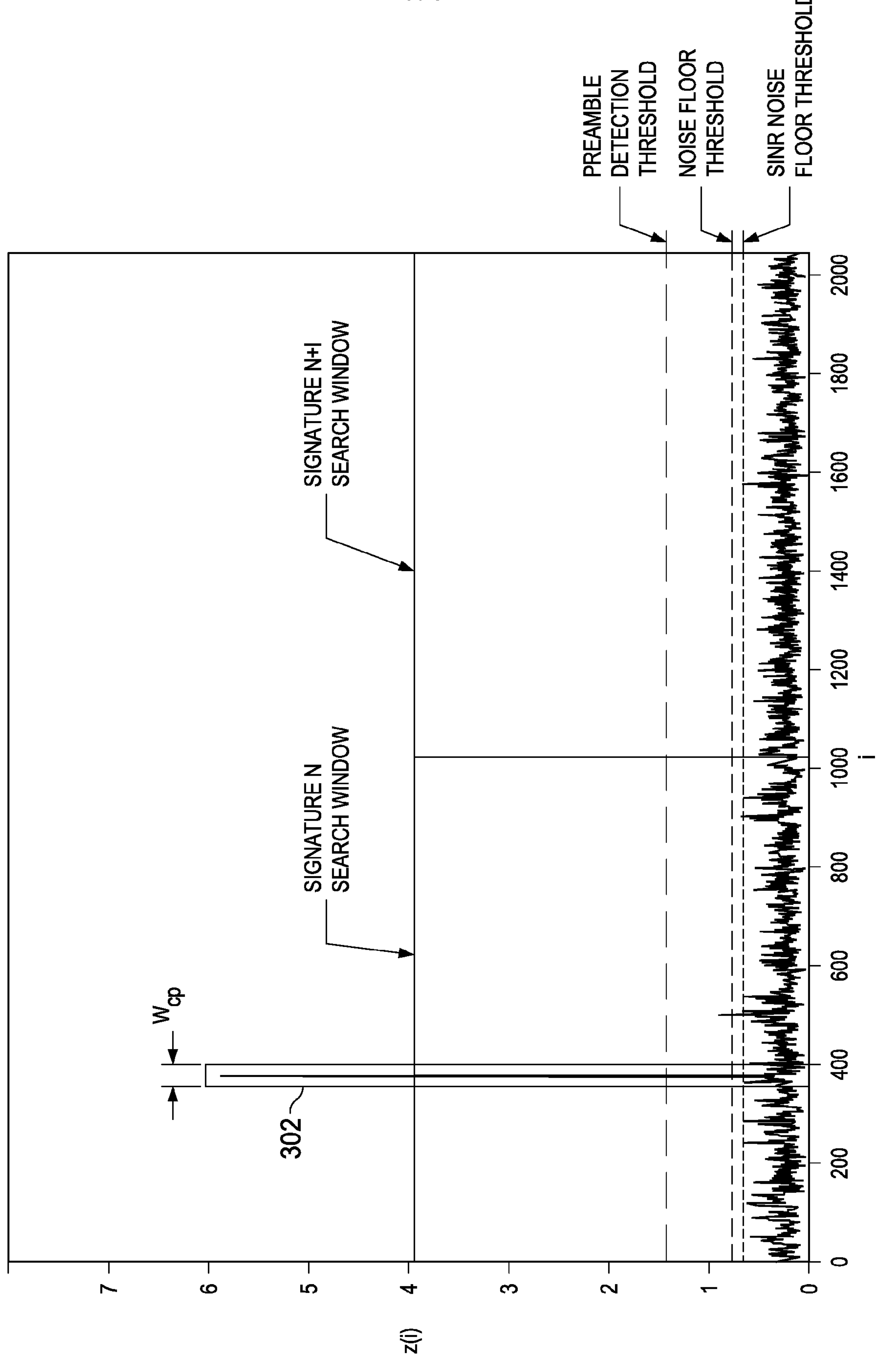
ROOT PREAMBLE #2 FREQ-RESPONSE
222A-N
COMPLEX CONJUGATION
COMPLEX CONJUGATION
224A-N
ZERO PADDING
ZERO PADDING
226A-N
IDFT
228
| |2
229
230
z(i)
P_{fa}, N_{rx}, R_{seq}
NOISE FLOOR ESTIMATOR
232
$T_{det} = \frac{T_r}{N_{rx} R_{seq}} \bullet \gamma_n$
W_s
W_{cp}
PEAK SEARCH
234
DECISION
236
TA
W_{cp}
SINR ESTIMATOR
238
SINR PER DETECTED PREAMBLE

FIG. 3


PREAMBLE DETECTION THRESHOLD
NOISE FLOOR THRESHOLD
SINR NOISE FLOOR THRESHOLD
SIGNATURE N+I SEARCH WINDOW
SIGNATURE N SEARCH WINDOW
W_{cp}
302
x 10^{-11}
z(i)
i
0
1
2
3
4
5
6
7
0
200
400
600
800
1000
1200
1400
1600
1800
2000

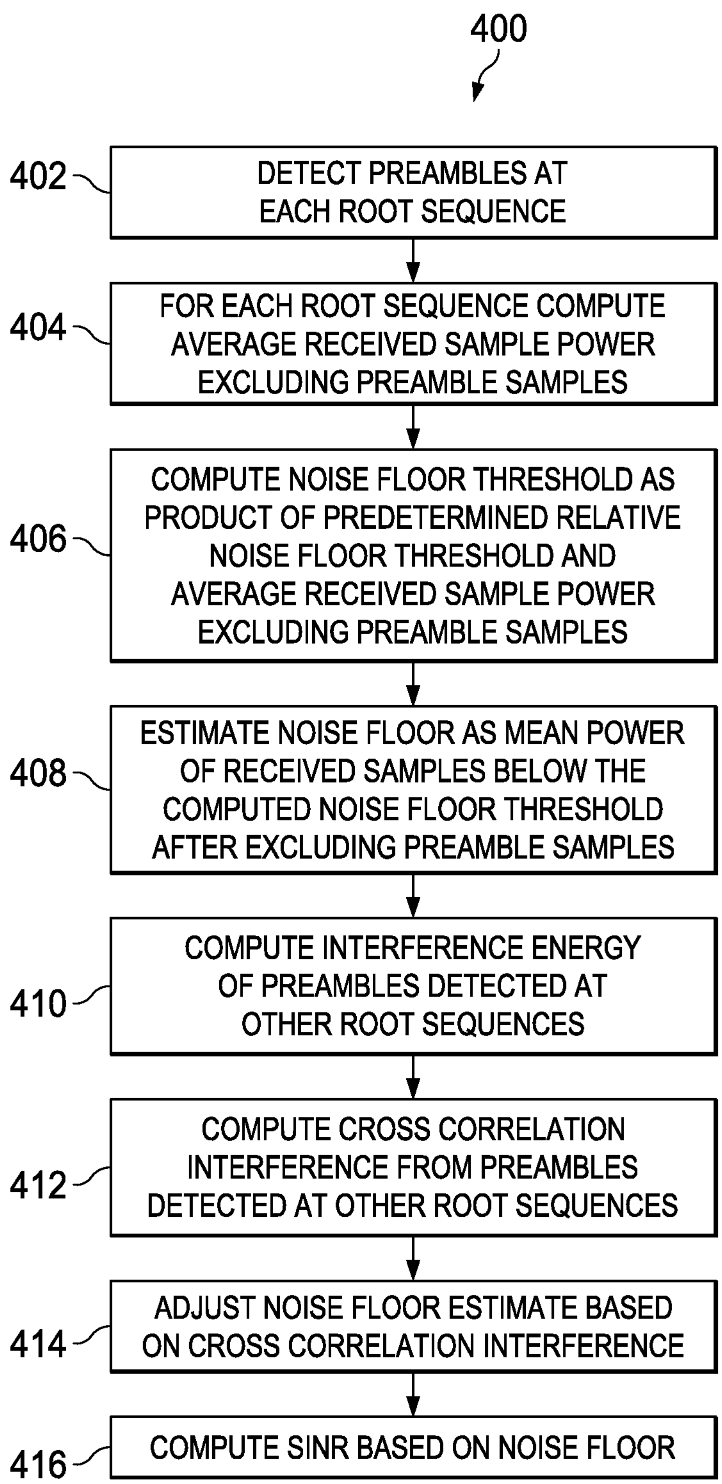

400
402
DETECT PREAMBLES AT EACH ROOT SEQUENCE
404
FOR EACH ROOT SEQUENCE COMPUTE AVERAGE RECEIVED SAMPLE POWER EXCLUDING PREAMBLE SAMPLES
406
COMPUTE NOISE FLOOR THRESHOLD AS PRODUCT OF PREDETERMINED RELATIVE NOISE FLOOR THRESHOLD AND AVERAGE RECEIVED SAMPLE POWER EXCLUDING PREAMBLE SAMPLES
408
ESTIMATE NOISE FLOOR AS MEAN POWER OF RECEIVED SAMPLES BELOW THE COMPUTED NOISE FLOOR THRESHOLD AFTER EXCLUDING PREAMBLE SAMPLES
410
COMPUTE INTERFERENCE ENERGY OF PREAMBLES DETECTED AT OTHER ROOT SEQUENCES
412
COMPUTE CROSS CORRELATION INTERFERENCE FROM PREAMBLES DETECTED AT OTHER ROOT SEQUENCES
414
ADJUST NOISE FLOOR ESTIMATE BASED ON CROSS CORRELATION INTERFERENCE
416
COMPUTE SINR BASED ON NOISE FLOOR

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2014/047667

A. CLASSIFICATION OF SUBJECT MATTER

***H04L 25/08** (2006.01)*
***H04L 27/38** (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)

H04L 25/00-25/40, 27/36-27/38, h04w 74/08, H04K 1/10

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)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/057584 A2 (TELECIS WIRELESS, INC. et al.) 15.05.2008, [0006]-[0009], [0065]-[0069], claims 1-12, fig. 1-5, 8	1-4, 9-11, 17
A		5-8, 12-16, 18-20
A	WO 2009/109854 A2 (NOKIA CORPORATION et al.) 11.09.2009	1-20
A	WO 2011/022404 A2 (QUALCOMM INCORPORATED et al.) 24.02.2011	1-20

☐ 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 document 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

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2014 (10.10.2014)	30 October 2014 (30.10.2014)

Name and mailing address of the ISA/RU:	Authorized officer
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